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Economic evaluation of mining projects under conditions of uncertainty for prices and operating costs

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ABSTRACT: Evidence suggests that mining projects include risk and this kind of business is complex and includes unpredictable costs and also in many cases, such as exploration evaluation, uncertainty of the mining engineering and economic uncertainty are affective. In this paper we use two scenarios for economic evaluation of project. First scenario investigates certainty of prices and operating costs and second scenario uncertainty of prices and costs. It is concluded that the mine evaluation suggests greater net present value when uncertainty is considered for both price and operating costs. The purpose of this study is investigated decision making in certain and uncertain situations. For investigate this subject binominal tree by DiverGen software and for calculating of present value of the project Excel software were used .results show that binominal tree is better device for decision making in uncertain situations.

KEYWORDS: Economic uncertainty, Metal price, Operating costs, Net present value, Binomial tree technique, Sensitivity analysis

1 INTRODUCTION

Economic evaluation is a way of systematically analyzing all the costs and benefits associated with a proposal and assessing its overall benefits. The analysis can incorporate monetary, quantitative and qualitative factors. Economic evaluation can assist in better quantification of the benefits and a more balanced assessment of the relative merit of options. Evaluation provides vital information to decision makers at various levels within government. The use of economic evaluation is encouraged in all relevant areas of public sector activity including policy proposals, program evaluation and regulatory review. an economic evaluation of a proposal should always explain who will be affected and to what degree, whether it is an agency, sections of the community, industry or individuals.(Marilyn chilvers, 2009). One of the most important assumptions to be made in any economic evaluation is that of prices. commodity prices can be found in special publications or websites. For example in Iran the “umetal website and” reports daily, monthly and yearly price surveys for metallic and non-metallic commodities.

Mining projects are complex businesses that demand a constant assessment of risk. This is because the value of a mine project is influenced by many underlying economic and physical uncertainties, such as metal prices, ore grades, costs, schedules and environmental issues. Therefore, evaluating and estimating a mine project without mentioning the risk for future losses (or opportunities) will lead to invalid results. consequently, man- agers and stockholders of a mine company make an indiscreet decision based on invalid information(dehghani & ataee-pour, 2012) the main sources of uncertainty

arising at the beginning of a mine project can be categorized into three groups: exploration uncertainties, engineering uncertainties and economic uncertain ties. Exploration uncertainties will occur in the duration of resource evaluation stages such as geologic uncertainty, data collection, interpretation, modeling, deposit classification, reporting and so forth. engineering uncertainties include bench heights determination, planned grade control, minimum stopping widths, choice of stopping method, dilution factors, geotechnical and hydrological parameters, mining recovery factors and metallurgical recovery. This type of uncertainty will affect the ultimate pit (stope) limit and scheduling period. economic uncertainty: economic if outcomes will occur with a probability that cannot even be estimated, the decision maker faces uncertainty. this meaning to uncertainty is attributed to frankknight, and is sometimes referred to as knighting uncertainty. the decision maker can apply game theory even in such a circumstance, e.g. the choice of a dominant strategy(economics.about.com)

In the mining industry, metal prices are normally modeled as the average price for the last three years, especially for those commodities whose price is listed on open markets, such as precious and base metals. even though the use of a single commodity price makes the comparison between companies easy, it prevents the use of excessively optimistic prices. it may be misleading when evaluating mining projects. For example, an overestimated metal price may result in a favorable rate of return for a project, which is otherwise doubtful. Conversely, an underestimated metal price may result in an unfavorable return for the project, which is otherwise profitable. Cost is another source of uncertainty when evaluating a mine project. The economic evaluation component of the feasibility study is based on the information that provides an answer to the question, 'what is it going to cost?'. Since the estimation of capital and operating costs is an important requirement for open pit mine evaluation, uncertainty in costs arises due to the lack of engineering or economic information at the beginning of the mine project. simply put, current mining companies do not know with absolute certainty how much they will be able to spend tomorrow, let alone next month or next year .numerous research works have been carried out for price uncertainty (Brenan and Schwartz (1985); trigeorgis (1993); Moyne et al. (1996); Kelly (1998); moel and tufano (2002); monkhouse and Yeats (2005); abdel sabour and poulin (2006); samis et al. (2006); shafiee et al. (2009)). but there is no notice- able research on operating cost uncertainty. Indeed, the operating costs are determined as a certain parameter in the previous research works, mostly. While, some parameters such as market variations, government policy changes, novel technology, management adjustments and so forth may change the operating cost, unpredictably. Thereupon, for determining the real and correct project value, it is necessary to consider the operating costs uncertainty. The purpose of this study is investigated decision making in certain and uncertain situations.

2 METHODOLOGY

We start methodology by introducing techniques in economic evaluation and also elements of cash flow for calculating. Finally we focus on binominal tree, one the most applied prediction method which can predicts price easier and closer to the exact price. Economic evaluation model are different but choosing an applied model help us to deduct or recognize other effects like inflation and unpredictable matters. According to these reasons binominal tree is a good choice for pricing. At the onset we have to realize that a relationship exists between operating costs and grades.

A mine exploiting a very rich deposit can afford higher operating costs. The mine can afford to use more expensive methods to extract rich parts of the deposit. So, if we look in our economic evaluation for analogous data from operating mines we should be careful to select not only similar deposit types but also deposits with similar grades. Perhaps it's a good idea to use cutoff calculations like marginal stripping ratio and so on. but these kinds of calculation are temporarily and their results are not so reliable(wellmer, dalheimer, & Wagner, 2008)

2.1 ECONOMIC EVALUATION TECHNIQUES

Economic evaluation is a systematic means of analyzing all the costs and benefits of options for meeting an objective(s), then selecting the best option. in essence, economic evaluation shows: whether the benefits of a proposal or change exceed its costs. Which option has the highest net benefit or which option is the most cost effective if benefits are equivalent the distribution of costs and benefits across stakeholders. Clearly, the results of an economic evaluation will not be the only factor taken into account when making a decision, but they provide important information on the effects of each possible decision. Different types of evaluation can be applied to proposals. These range from financial evaluations to those that include broader impacts on the community, such as economic and social evaluations.

Mine projects are different from exploration projects which usually have the definition of mineralization or mineral deposits as their objective .the evaluations should:

a) Provide a base on which economic decisions are made,

b) Identify and quantify risk, and

c) Establish project priority.

At least four aspects of the environment in which the project is evaluated may be identified — technical, financial, social and political. a number of values and indices that can be used in financial evaluation:

b) Payback period,

c) Net present value (NPV) at a predetermined discount rate and,

d) Internal rate of return (irr).

Another value measurement that could be used is the present value ratio (pvr).

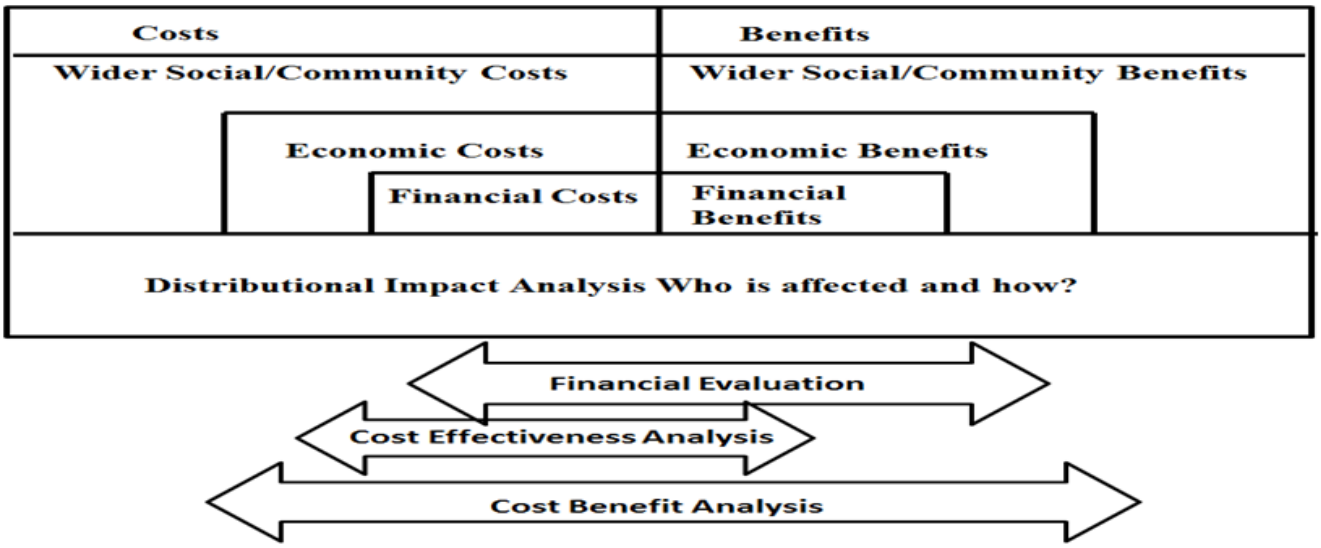

Fig. 1.Economic evaluation techniques

2.2 ELEMENTS OF CASH FLOW CALCULATIONS

In cash flow calculations only true flows of money (of cash) of a project are considered. to better imagine what cash flow is, we imagine the mine as a "box" (fig. 2) and ask ourselves, what money flows in and what money flows out of this "box". The money that flows in are the revenues which we calculated it. The money that flows out are first the operating costs (wages that have to be paid to the employees of the mine, money for energy, explosives etc.) further money that flows out are interest for loans and taxes and royalties t. the difference between money inflows and outflows is the cash flow. one distinguishes between gross cash flow, i.e. the difference between revenues and operating costs before interest, taxes and royalties (cf) and the net cash flow (nc) the same difference after interest, taxes and royalties.(wellmer, dalheimer, & wagner, 1989) operating cost: operating costs are calculated directly from material consumption, salaries and wages, services, availability of machinery etc.(wellmer et al., 2008) operating costs: identified by function — mining, treatment, engineering, administration, etc.; or by resource — labour, supplies, equipment, services, overheads etc.(Allen, 2012)

Hence depreciations and periods of depreciation are of no direct importance. Depreciation is an accounting measure to calculate tax deductions. Periods of depreciation only have an indirect influence via tax charges; the latter are genuine annual payments and therefore are included in cash flows (see fig.2). However, if no taxes are paid as used to be the case in the Australian gold mining industry or if tax holidays are granted for the first years of operation of a project to encourage mining investments as is the custom in some developing countries, then depreciation for the purpose of cash flow calculations is altogether irrelevant.

annual cash flow = capital expenditure + revenue — operating costs — taxes — increases in working capital + loans — loan repayment — interest.

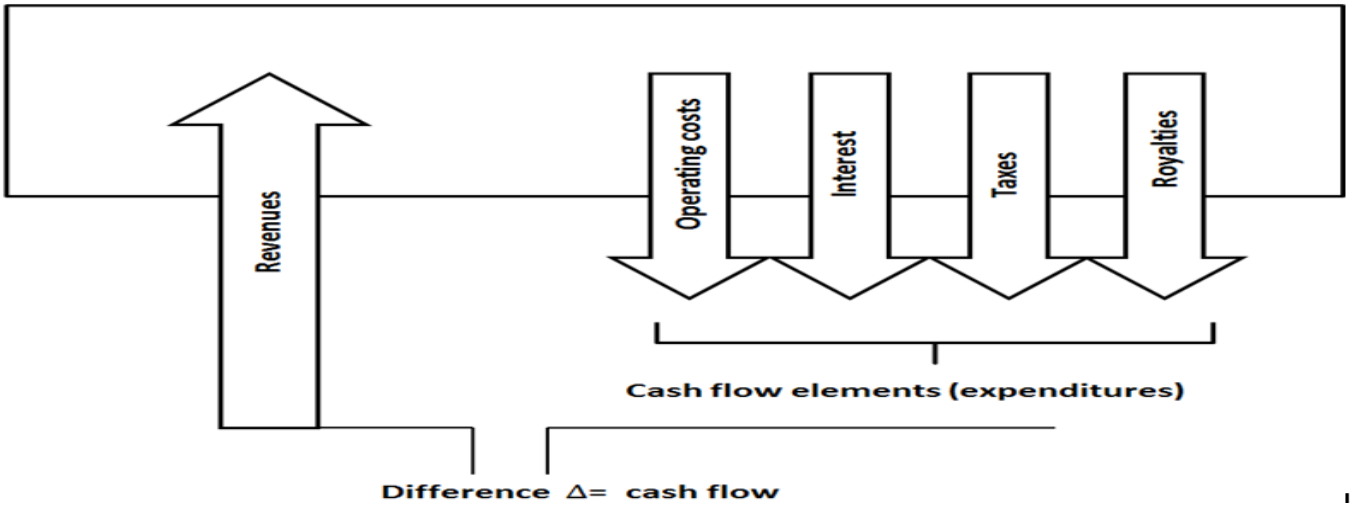

Fig. 2mine in operation

2.3 BINOMINAL TREE

Binominal tree is a flexible and vigorous method which use specified structure to show all aspect of price by model (Chashemi& Ghasemi, 1391).

A graphical representation of possible intrinsic values that an option may take at different nodes or time periods. The value of the option depends on the underlying stock or bond, and the value of the option at any node depends on the probability that the price of the underlying asset will either decrease or increase at any given node. Binomial trees are useful tools when pricing options and embedded options, but there is a fundamental flaw with the model. The problem lies in the possible values the underlying asset can take in one period time. In this model, the underlying asset can only be worth exactly one of two possible values, which is not realistic, as assets can be worth any number of values within any given range (www.investopedia.com).

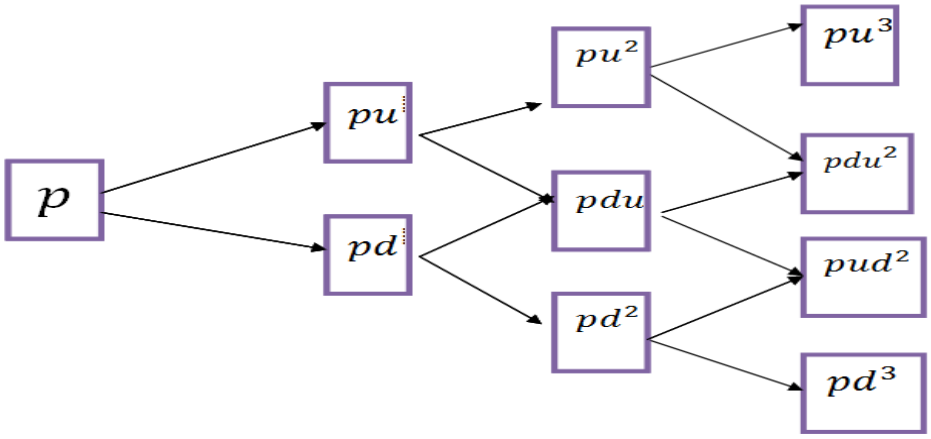

Fig. 3 Binomial tree

Each of these branches and ways in binominal tree may transfer from one group to another group which binominal tree shows the direction of and probability of the relationship. Higher branches express PR probability and multiplier of U, while lower branches show probability of (1-PR) and multiplier of D. By these factors probability shows with the following formula:

$$u = e^{\sigma\sqrt{\delta t}} \qquad \text{eq. 1}$$

$$d = \frac{1}{u} = e^{-\sigma\sqrt{\delta t}} \qquad \text{eq. 2}$$

$$p_r = \frac{(1+r_f)-d}{u-d} \qquad \text{eq.3}$$

The basic inputs are the volatility of the metal price or operating cost(s), the risk-free rate (rf) and stepping time (dt). In this paper, two different scenarios were studied.

Scenario 1: NPV computation under certain metal price and operating cost situation

Scenario 2: NPV computation under uncertain metal price and certain operating cost situation

In this scenario the project NPV was calculated using the traditional DCF technique. For this purpose, at the first step, the free cash flow (FCF) was determined using the following formula:

$$fcf_{n,k} = \{([(p_n - c_n)Q_n] - FC_n - D_n)(1 - tax) +\}D_n \quad \text{eq. 4}$$

where FCFn is the free cash flow to the firm at time n, Pn is the mineral commodity price at time n, Cn is the variable cost at time n, Qn is the production rate at time n, FCn is the fixed cost at time n, Dn is the deprecation at time n, Tax is the corporative tax and n is the time period. There are many methods for estimating the future metal price and operating cost such as using the average of the previous metal price and operating cost data and regression analysis. After calculating FCF we can estimate NPV by the following formula:

$$NPV = -P_0 + \sum_{n=1}^{N} \frac{FCF_n}{(1+i)^n} \qquad \text{eq. 5}$$

Where i is the discount rate for the mining project.

In the second Scenario

Both of sale price and operating costs are in the uncertainty situation so we use binominal tree for commodity and operating costs. Then free cash flow will be calculated and finally we achieve project value.

3 NUMERICAL EXAMPLE

Chadormaloo is a company which established in 27 KHordad (June) of 1371 and registered in Registry of Companies of Yazd. And then according to Resolution of the extraordinary general meeting in 16 aban of 1377 the company moved to Tehran and registered in Registry of Companies and non-business institutes of Tehran. Company legal personality in August in 76 of the state was changed to private and accepted as corporate company in Tehran stock exchange in 1382.(www.chadermaloo.com).

Briefly the basic activity of the company is exploration and exploitation of mines and iron ore and product concentrate and Production of pellets, seed production of iron ore and steel production. 50 percent of Iranian concentrate of iron ore is allocated to Chadermaloo. And also 56 percent of pellets market is allocated by the same company notice that ChaderMaloo's tax breaks extended because the company located in deprived area.

Although Chadermaloo's mine produce several products like pellets, iron ore and etc.but here we investigate iron ore.

Scenario 1: NPV computation under certain metal price and operating cost situation

Table 1 shows calculated factors like iron ore price and operating cost and other basic factors in 1392.

In this scenario we assume that basic factors only under the effect of interest rate of return will modify. In the paper the amount of interest rate of return is 23 percent and also because of tax break of the company the tax is zero. And also estimated depreciation is 1075200 million Rials.

Table 1. Input data parameters

Input data	Amount	Unit
Metal price	1680000	RLS/T
Primary cost	12000000	MRLS
Operating cost	740000	RLS/T
Iron production	16	MT
Fix cost	1684946	MRLS
Deprecation	1075200	MRLS
tax	0	0
Discount rate	25	%

Now according to these data present value of the project by calculated amount is 356844220 million rials.

Scenario 2: NPV computation under uncertain metal price and certain operating cost situation

In this scenario both of price and cost are determine in uncertain situation so we should calculate a single tree for each of them. And by DerivaGem Software and also according to information below, binominal tree will be calculated.

Table 2. Binomial tree

In put	Volatility (σ)	Up (u)	Down (d)	Risk free rate	probability
price	%40	1/4918	0/6703	%25	0/7471
cost	%37	1/4477	0/6907	%25	0/7837

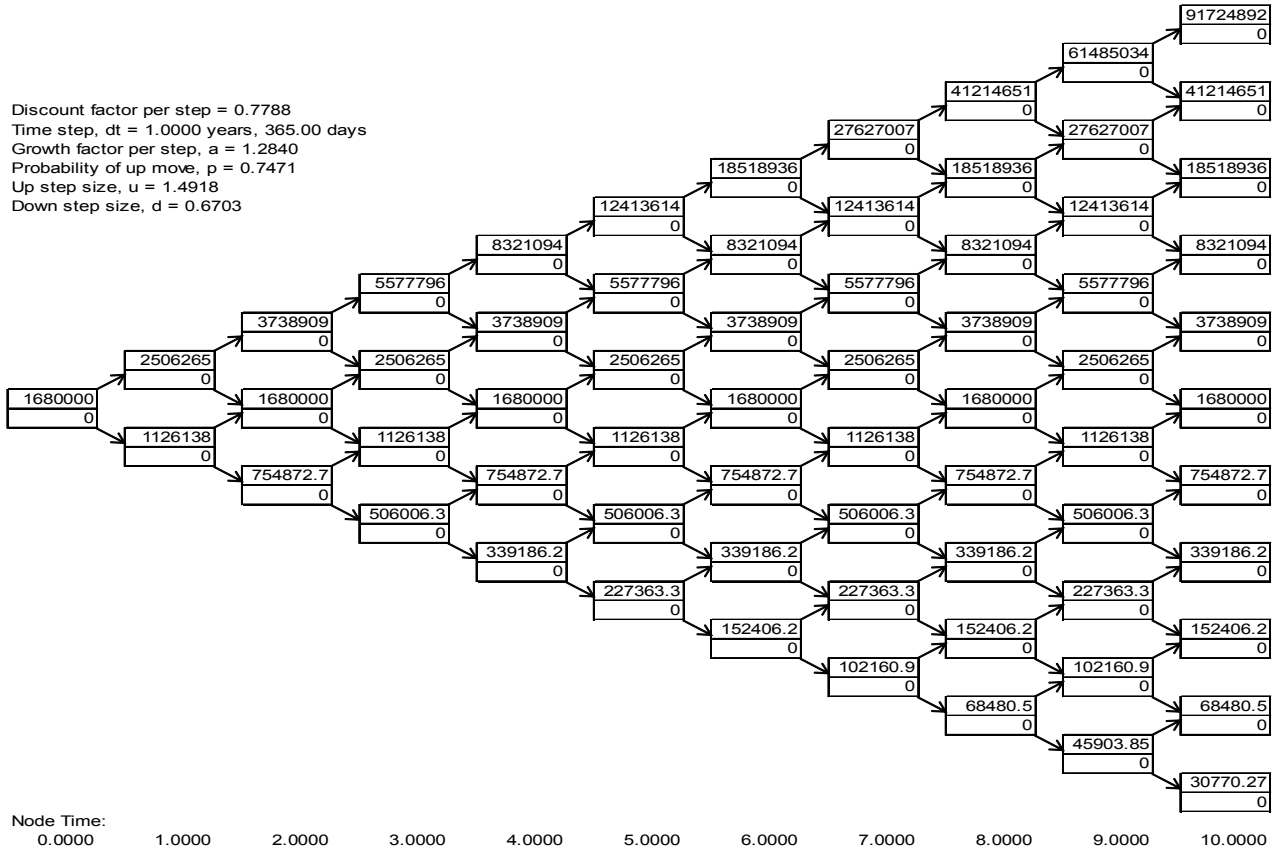

Fig. 4 Binomial tree for price metal

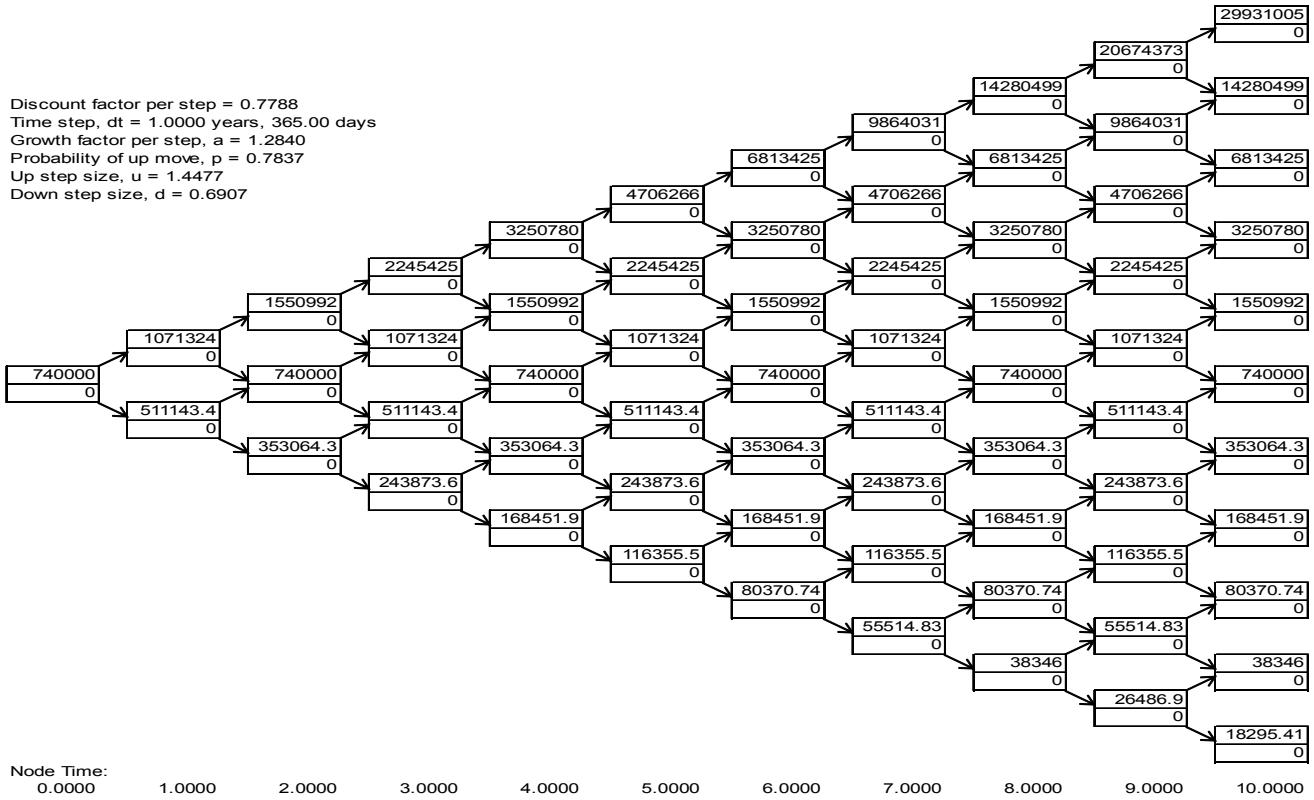

Fig. 5 Binomial tree for cost

Now according to above figures (4&3) fundamental parameter is calculated. by formula (4&5) present value of the project is 42882716. So present value of the project in uncertainty situation is more than prices and costs.

Table 3. The project cash flow

	1392	**1393**	**1394**	**1395**	**1396**	**1397**	**1398**	**1399**	**1400**	**1401**	**1402**
Iron ore price (RLS/T)	1860000	1872430	1925400	2102320	2287750	2314689	2435870	2542334	2746012	2833451	2937226
Operating cost (RLS/T)	740000	839596	967361	1032520	1125497	1254937	1378772	1453927	1593442	1700873	1875481
Fixed cost (MRLS)	1684946	1859349	1974636	2135726	2287450	2376280	2593672	2781425	2853436	2956746	3129746
Deprecation (MRLS)	1075200	1075200	1075200	1075200	1075200	1075200	1075200	1075200	1075200	1075200	1075200
Iron ore production (MRLS)	16	16	16	16	16	16	16	16	16	16	16

4 SENSITIVITY ANALYSIS

In this section a sensitivity analysis was carried out using the input data. For this purpose, the NPV of each scenario was computed by changing the input data. Each kind of input data was changed while other kinds of input data were constant. The NPV, obtained previously, was assumed as the base NPV for comparison. Now are results same? Sensitivity analysis which calculated by Excel Software shows in the table4.

Table 4. Sensitivity analysis

Input data	Scenario	Change (%)	Calculated NPV (MRLS)
Iron ore price	1	+%10	46659823
	2	+%10	55286215
	1	-%10	27003016
	2	-%10	30479218
Operating cost	1	+%10	32502242
	2	+%10	36745101
	1	-%10	41160597
	2	-%10	49020332
Risk free rate (rf)	1	%20 -- %25	50911941
	2	%20--%25	60341269

5 CONCLUSION

Present value of Chadermaloo was investigated in 2 different scenarios. First scenario in the certain situation for price and operating costs and second scenario in uncertain situation for price and operating costs, the results explained below: The present value of the project in uncertain situation is more than present value of the project in certain situation. In sensitivity analysis present value of the project in uncertain situation is more than the present value of the project in certain situation even the basic factors of the model changed. So binomial tree is an appropriate approach for uncertainty situations. Thus when we want to make a decision in uncertain situation binominal tree give us reliable approach of the future.

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