Evaluating investment projects in mining industry by combining discount method and real option valuation

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Modern specialised literature and business practice differentiate an increasing number of methods for evaluating investment projects, but the majority of authors adopted the general division onto non-discount (classical, traditional) methods, discount methods, and methods for preliminary project evaluation. Evaluation results are the basis for making positive or negative investment decisions.This paper provides an overview of the dynamic methods for evaluating investment projects in mining industry as well as the examples of their application in practice.

Key words: *Methods, investment projects, economic evaluation, mining*

Introduction

It is well-known that mining investment projects involve substantial investments, long period of time, sequential type of investment decisions and complex mosaic of numerous unknown factors that affect the value of the project. Apart from that, mining projects are typically followed by a number of geological, technological, technical, economic, environmental , social and financial risks. It is very difficult to accurately and with certainty foresee the significance of any of those risks to the project realisation in advance, as well as how reliable the implementation of specific project activities and the project itself would be. All risks of the mining project represent unknown factors that determine the value of the project. Therefore, it can be concluded that the project value, as a function of random variables, is a random variable itself.

Evaluation of capital investments into mining investment projects is a specific measurement method of the benefit and cost ratio within a predetermined project duration. Each evaluation method shall explain and support the acceptability or unacceptability of the investment project.

One of the reconstructions or supporting reconstruction phases of the mine is the equipment replacement, usually of a greater capacity and in a technical - technological sense more efficient. Replacement of the equipment is done in all situations where the lifetime of the mine is longer than the period required to perform depreciation of the equipment. As is well known, every piece of equipment, particularly mining equipment is physically worn and rendered obsolete over time, due to the specific operating conditions. Despite regular maintenance, which increases the equipment value, the cost of investment (capital) maintenance shall reduce its capacity, therefore causing the unit price to be increased. Having said that, each of the following major maintenance or repair operations, as well as routine maintenance, are becoming more and more expensive, with the delays getting longer.

In order to prevent negative processes, it is necessary to timely replace depreciated mining equipment on the basis of detailed techno-economic analyses to determine its optimal lifetime .

Certainly one of the key criteria in making investment decisions on replacing mining equipment is the economic efficiency criterion of equipment replacement, for which purpose the traditional dynamic methods are used. There are three basic methods in dynamic evaluation of the investment effectiveness: PB - Pay Back, Net Present Value - NPV and Internal Rate of Return - IRR. However , the fact is that the NPV method ignores the evaluation of important unknown factors, as well as the ability of flexible managerial response. By neglecting the managerial response ability to react and change the course of the project during its life cycle, the project value is undervalued, even to a significant extent, in some cases. For that reason, it often happens that the project does not appear promising when the NPV is viewed, but the managers still manage to launch the project due to strategic reasons. In other words, there is a contradiction between the evaluation of the project based on NPV results and evaluation of the project based on managerial intuition . In order to relativise such contradiction, a step-back procedure is often applied, with the NPV method results being adjusted to make NPV acceptable on paper. It is certain that such practice has no rational or conceptual basis and certainly underestimates the credibility of all techno-economic and financial analyses in the process of making important investment decisions.

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Referring to to decisions regarding the costly and long-term mining projects, which can even affect the fate of the mining company, such as the opening of new mines, it is necessary to conduct a rigorous and logically-consistent techno-economic and financial analysis. In other words, for a competent investment decision, it is necessary to apply a quantitative analysis enabling the incorporation and rationalization of managerial intuition. The concept allowing such action is the Real Options Analysis. The following chapters contain a general presentation of these methods and their specific application. The economic efficiency evaluation of replacement of mining equipment is provided for specific conditions of Bogutovo Selo open-pit mine in Ugljevik, Republic of Srpska, Bosnia and Herzegovina, while the combined NPV method and Real Options Method was used in techno-economic evaluation of the investment project for Radljevo deposit in the Kolubara coal basin in Serbia.

Dynamic Methods

As discussed above in the dynamic assessment of investment efficiency, there are three basic methods in general: PB - Pay Back, NPV - Net Present Value and IRR - Internal Rate of Return. All analyses are dependent on estimation of cost and benefit and on the dynamic plan of spending and cash inflow, so that the same principle is used regardless of whether the decision relates to the repair or replacement of equipment, mine production increase or any other investment activity.

Pay Pack Period Method - Investment Return

This method determines the time for which the project provides the return of the funds invested, i.e. a year of the project lifetime in which the cumulative net inflow becomes positive. The first step is to set up a plan with equal periods of time, with the total number of such time periods should be equal to the project lifetime [1].

The basis for this type of analysis is represented by the comparison of maintenance costs, i.e. total operating costs of new equipment in relation to the depreciated equipment, or equipment nearing the end of its depreciation period. On the basis of such findings a time projection is made in order to reach total investment effects.

The following example represents the calculation in the purchase of new equipment with a value of EUR 2.0 million. The first step is to evaluate the effect of the investment by evaluating the capacities and cost per year for the new equipment. Thereafter, by multiplying the annual capacity to the difference in the cost of old and new equipment, a change of estimated benefit from investment is calculated. The next step is to calculate the refunds over time, usually over a number of years. In the event that the production varies per year, or changes of estimated benefit from investment, the average for all years is used. The table below displays the manner in which such calculation is performed.

Tab.1. NPV calculations.

Year	Equipment capacity [10^3 t]	Previous expenses [€/t]	New expenses [€/t]	Estimated benefit from investment	
				[€/t]	[10^3€]
0	0	0.25	0.05	0.20	0
1	2.000	0.25	0.05	0,20	400
2	2.000	0.25	0.05	0,20	400
3	1.900	0.25	0.06	0,19	361
4	1.800	0.25	0.06	0,19	342
5	1.750	0.25	0.07	0,18	315
6	1.700	0.25	0.07	0,18	306
7	1.600	0.25	0.09	0,16	256
8	1.600	0.25	0.08	0,17	272
9	1.500	0.25	0.10	0,15	225
10	1.450	0.25	0.10	0,15	217
Total	17.280				3 114

Source: Author's calculations

The above table demonstrates that the average capacity of the new equipment in the ten-year period is 17,280 x 103t, and the average change from the investment is EUR 310. Since 2 million euros were spent in this investment, Payback period is calculated by dividing the investment amount by the annual average investment return. In this case: 2.000.000/311.400 = 6,42 years.

In the event that there are more alternative projects, the best one is considered to be the one which is characterised by the shortest return period, on the basis of the number of years. As shown in the example, it is a relatively simple and easy to understand criterion, which is often used in practice, particularly for smaller projects, but can also be used with larger projects, in which case it represents the first criterion onto which more complex indicators are upgraded. The Analysis of return covers a short period, which is its main weakness. With increased investment and longer time period, it is necessary to consider the volume of investment and the time value of money. For such reason a Net Present Value or NPV analysis is used.

Project Net Present Value – NPV

Modern business investment policy requires to ensure appropriate minimum acceptable rate of return, in order to to ensure investments. To perform such calculation, it is necessary to start from the conception of the discounted present value. Discounted present value is defined as the difference between current and future inflows and outflows of the project, based on the fact that it is better to have, for example a euro today, than a euro in the future. Another way to interpret is that with the interest or discount rate of 10 %, a year from now 1 euro is worth only 0.909 euros, meaning 90.9 euro cents become a net present value of one euro in a year.

In order to calculate the present value, it is necessary to determine the discount factors on a yearly basis, which is calculated by the following formula [2]:

$$F = \frac{1}{\left(1 + \frac{R}{100}\right)^{n}}$$

where: F - discount factor,
R - discount rate,
n - number of years.

The project is acceptable if its current value is greater than or at least equal to zero. Thus, the net present value of the project is the ability of the project to repay the investment. Financial interpretation is as follows: When an investor decides whether to invest or not, he has to decide whether it is more profitable to deposit the funds in the bank and provide a certain safe return to the bank, or to invest them in the planned project. The decision will be in favour of investing in the project only if the project provides the yield higher than the interest that can be safely counted if the funds were in the bank. On such basis, the discount rate should be at least equal to the interest rate which can be provided in reliable banking institutions with great certainty, increased by the risk factors of the investment. Tab. 2 gives the example with only two cases, with a discount rate of 10 % and 12 %.

If a column with a discount rate of 10 % is taken as reference, it is clear that the discount factor in the fifth year equals 0,621. By multiplying discount factor and cash flow in a year, a net present value is received for that year. The next step is to add the net present values per year and subtract them from the total value of the investment.

Tab. 2. NPV calculations.

Year	Cash flow	Discount rate	Present value	Discount rate	Present value
	[euro]	[10 %]	[euro x 10^3]	[12 %]	[euro x 10^3]
1	2	3	4	5	6
	(2 000)	1.000	(2 000)	1.000	(2 000)
1	400	0,909	363,60	0,893	357,20
2	400	0,826	330,40	0,797	363,06
3	361	0,751	271,11	0,712	257,03
4	342	0,683	233,59	0,636	217,51
5	315	0,621	195,62	0,567	178,60
6	306	0,564	172,58	0,507	155,14
7	256	0,513	131,33	0,452	115,71
8	272	0,467	127,02	0,404	109,89
9	225	0,424	95,40	0,361	81,23
10	217	0,386	83,76	0,322	69,87
Total			2004.41		1905,24

Source: Author's calculations

If the sum of the present values is positive, the project is acceptable, otherwise the project is rejected. When the net present value is approximately zero, the discount rate is defined as the internal rate of return. In this case, it refers to the example with a discount rate of 10 %, for the payback period of 10 years. In the case of a 12 % discount rate, the sum of the net present values is lower than the total investment of EUR 94.760, which means that the project is unacceptable.

Basically, the concept of present value means that, for a project, each inflow or outflow per a year, is discounted by the factors of a predetermined rate of return and reduced onto present value. Such rate should be set so that it could represent the volume of investments, the value of money over the period of time, as well as the level of business risk within the project being considered. The project is approved if the present value is greater than zero, and rejected if it is equal to zero or less than zero. Thus, it is very important to choose the rate of return with this approach.

Internal Rate of Return (IRR)

Internal rate of return is, by definition, the rate that brings the present value of the project to zero. This means that, to calculate IRR, it is necessary to find the discount rate that will equate the present value of the expected costs and the present value of expected benefits. If the net present value is positive, it is clear that this rate will be higher than the discount rate. The calculation of the internal rate of return is a complex procedure, performed by using a iterative procedure. i.e . the method of "trial and error", by increasing and decreasing the value of the discount rate until it reaches the rate with which the net present value equals zero, and can be expressed by the following formula [2]:

$$IRR = I_2 + \frac{PV(I_2 - I_1)}{PV + NV}$$

Where: IRR - Internal Rate of Return,

I_1 - the lower the rate at which the NPV remains positive, but is close to zero,

I_2 - the higher the rate at which the NPV is already negative, but is close to zero,

PV - positive value of NPV at lower discount rate,

NV - negative NPV at a higher rate (using the absolute value).

When the data in the table above are entered in the above formula, the following is obtained:

$$IRR = 12 + \frac{4410(12-10)}{4410+94760} = 12{,}08\%$$

It is important to note that PV and NV should be very close to 0, and I_1 i I_2 are very close to each other. Otherwise, the calculated rate will not be accurate. In order to better understand the methods described above, an example of techno-economic analysis of the operation of mining equipment in the actual working conditions in the Ugljevik mine, Republic of Srpska, Bosnia and Herzegovina.

Techno-economic analysis of the operation of mining machinery in open pit mine Bogutovo Selo, Ugljevik

Techno-economic analysis of the mining machinery operation in the open pit mine Bogutovo Selo was conducted for the period of eight years (2005 - 2012), with the results of such analyses presented in the following tables. Mean values of the cost per derived moto hour (€/moto hour) and the cost of the actual masses for the specified period (€/m^3 of solid mass), as well as the equipment amortization level, have been provided. It should be noted that the operating expenses do not include the cost of electric power, nor the labour costs with regards to the operation and maintenance of mining equipment, since they are specified as a total within the mines own balance. A comparative analysis of operational costs per various types of equipment and their degree of depreciation is shown. Based on these findings , calculations were performed using discounted methods.

The criterion that was used in determining the benefit from investing into excavators and lorries was the annual capacity multiplied by the difference between the operation cost of depreciated and new equipment, while the benefit from investing into other equipment was calculated as a product of operational hours and difference in operating costs. Time projection was made in the next step in order to reach the total effect of the investment. The analysis was performed by agreeing on the total number of twelve-year periods, with two different discount rates of 8 % and 12 % [3, 4].

Tab.3. Excavator operation cost.

EXCAVATOR TYPES	Basic operation cost [€/moto hr]	Operation cost [€/ m^3] of solid mass	Depreciation level [%]
H-241	78	0,32	100
RH-120	84	0,22	100
PC 3000	60	0,12	20
EKG 8i	52	0,20	100

Source: Author's calculations

Tab. 4. Operation cost.

Truck Types	Basic operation cost [€/moto hr]	Operation cost [€/ m^3 of solid mass]	Depreciation level [%]
Wabco	83	1,15	100
FK-100	63	0,98	100
CAT 777	57	0,77	100
FK-85	68	1,37	100
Belaz-75145	84	0,96	90
Belaz-75135	69	0,77	60
Belaz-75575	52	0.68	10

Source: Author's calculations

Tab. 5. Auxiliary machinery operation cost.

Mining machinery types	Basic operation cost [€/moto hr]	Depreciation level [%]
Bulldozer CAT D8R	35	90
Bulldozer TD-25G	36	100
Bulldozer D155AX	30	20
Wheel dozer TD 824C	31	100
Wheel dozer TD 824G	24	60
Grader CAT 16 H	28	80
Grader 825 A	24	30
Loader ULT 220	28	100
Loader CAT 980G, CAT 966G	22	60

Source: Author's calculations

Tables 6 and 7 contain the results of three methods of investment efficiency evaluation: PB - Pay Back period method, NPV - Net Present Value method and IRR - Internal Rate of Return method.

Tab. 6. Investment analysis for front loaders and trucks.

Machinery		Front loaders and bucket capacities $V_{k=}$ 12-14 m^3	Dump truck capacities 110-120 t
Annual equipment capacity	m^3 of solid mass	16.000.000	400.000
Changes in returns on investment in 12 years	€	3.888.000	1.287.000
Net present present value return from investment [€]	Discount rate 8 %	2.555.525	845.000
	Discount rate 12 %	2.143.223	709.000
New machine price	€	2.500.000	700.000
NPV analysis [€]	Discount rate 8 %	55.525	845.000
	Discount rate 12 %	-356.777	709.000
Pay back analysis (PB)	Year	8	7
Internal Return Rate (IRR)	%	12.5 %	15.2 %
NPV analysis for 8% discount rate. Investment return	Year	12	9

Source: Author's calculations

Tab. 7. Investment analysis for Bulldozers and graders.

Machinery		Bulldozers	Graders
Moto hours for 12 year period	Moto hours	30.000	26.000
Change in return on investment	€	458.376	683.472
Net present present value return from investment [€]	Discount rate 8 %	304.235	455.992
	Discount rate 12 %	256.000	384.689
New machine price	€	263.338	391.031
NPV analysis [€]	Discount rate 8 %	40.894	64.961
	Discount rate 12 %	-7.124	-6.342
Pay back analysis (PB)	Year	7	7
Internal Return Rate (IRR)	%	15.4	15.6
NPV analysis for 8% discount rate. Investment return	Year	9	9

Source: Author's calculations

Based on the results of the analyses it can be concluded that, on the basis of the Pay Back method, the funds invested in new equipment are to be returned within 7 -8 years. When the time projection of money is entered into the analysis (NPV analysis), so that the annual profit of the investment is discounted by a pre-set rate of return factors, in this case being 8 %, the investment in the purchase of new front loaders, is payable within 12 years with 12.5 % internal rate of return, and 9 years for the purchase of dump trucks and auxiliary equipment (bulldozers, graders) with an internal rate of return of about 15 %.

Real Options Analysis in the evaluation of mining investment projects

The realistic option is the discretion right of the management to make a decision or undertake a certain action in the future on the basis of additional information regarding the important unknowns in the project. During the investment period of the mining project, the management can abandon the project if it is evident that any of the unknowns may influence the project in such manner so that the overall assessment of the project becomes negative. Likewise, the management may accelerate the project by additional investment if the prospective returns are higher than originally projected, or if the timing of entering into market is a critical success factor for a given mining project.

The main advantage of the real option method is that this evaluation instrument conceptually covers the entire project value, i.e. the basic project NPV plus the ability to flexibly react in the future. In other words, the flexibility has a value which must be incorporated in the project value as a whole.

Perhaps the greatest weakness of the conventional mining project evaluation methods is the assumption that uncertainty by definition reduces the value of the project. In contrast, proponents of the real option method claim that if the unknowns relevant to the project are properly identified and understood, they can be proactively managed through appropriate managerial flexibility. That way, the value of the project is increased. Accordingly, the flexibility is valuable only in an unpredictable environment, such as the most mining projects.

In the case of complete predictability regarding important or unknown parameters of the project values, the NPV method results and the real options method results converge. By following such logic, it can be concluded that in mining investment projects, real options methods are preferred in the earlier, less predictable stages with a higher number of potential risks and uncertainties. Similarly, the NPV method (as well as other conventional methods) are more appropriate for the final stages of the investment decision-making process due to their simple implementation and a much greater predictability of the project main events.

Based on previous research made by most authors [5, 6, 7], the most important advantages of using real options method in mining investment are as follows:

- The project value, estimated by the real option method is higher than the value estimated by NPV.
- Real option method is more comprehensive than the NPV method because it includes uncertainty, risk and operational flexibility.
- The difference of values estimated by the real option method and NPV method is the value of operational and management flexibility.

Real Options Analysis of open pit coal mine Radljevo-north investment project

Coal deposit Radljevo is located in the western part of the Kolubara coal basin in central Serbia, and is divided into Radljevo - south and Radljevo - north The future open pit coal mine has been planned in the section of the Radljevo - north coal body which covers an area of about 35 km^2. On the east side, this coal body meets the active open pit coal mine Tamnava - West. In the Kolubara coal basin, lignite coal mining is done by PD Kolubara, a company that operates under the Electric Power Utility of Serbia (EPS). According to the Energy Development Strategy of the Republic of Serbia, EPS has launched the project of the new open pit Radljevo - North, as a necessary project for further development of the energy sector in Serbia.

During 2007 a pre-feasibility study was prepared for the open pit for the capacity of 7 million tons of coal annually. Specifically, such coal reserves are presumed as sufficient for the new power plants under EPS. At the time of making the pre-feasibility study for the open pit, the deposit was not geologically, hydrogeologically and geotechnically explored in detail. The data used were the ones that existed at the time, as well as the experiential data from the Kolubara basin, particularly referring to the data related to Tamnava - west open pit, whose extension is the future open pit Radljevo - North.

Techno-economic analysis of annual coal production of seven million tons handled all relevant parameters required for assessing the suitability of exploitation of available coal reserves in the deposit. Economic analysis provided the following economic parameters of the project [8]:

- Internal Rate of Return– 8,1 %
- Discount Rate – 8 %
- NPV – € 3,1 milion

These economic parameters were evaluated as borderline in terms of investment. Regardless of the thresholds for future investment with the aforementioned basic techno-economic parameters, EPS has, in line with its strategic and development plans, evaluated that the project of the new open pit mine Radljevo - North has favourable economic prospects.

Such intuitive rating emerged on the basis of detailed analysis of project and investment risks of pre-feasibility study resulting from the insufficient exploration of the deposit. Such geological risk caused further series of technical and technological risks primarily related to designed exploitation options (annual capacity of open pit, mineable coal reserves, equipment selection, and so on).

The following table demonstrates the level of the analyzed project and investment risk of pre-feasibility study of open pit mine Raljevo - North.

Tab. 8. Risk level in the Raljevo - North open pit mine investment project.

Risk	Risk level				
	Low	Low-medium	medium	Medim-high	High
Geology and reserves				X	
Coal Quality				X	
Soil mechanics			X		
Dewatering		X			
Open pit mine development			X		
Basic equipment			X		
Planned time schedule				X	
Financing					X

Source: [8]

In order to eliminate the project risk, additional geological surveys were conducted so that the project team analysed geological information from 505 boreholes. All geological information have been cross-checked prior to creating the geological model using SURPAC software. Digital geological model fully defined mineable coal reserves. The quality of the coal deposit was redefined on the basis of this model. Digital model enabled further reduction of geological risk from medium-high to low.

On the basis of quite reliable geological data, development of mining in the open pit was optimized by using simulation method. Optimization has been done on the basis of general optimization criteria of surface mining in the open pit, which implies maximum profit from the deposit exploitation. This criterion contains all operating costs, time factor, coal quality, exploitation intensity and the coal selling price.

As technological optimisation criteria of mining development within a deposit of a variable quality, coal quality is becoming one of the most influential factors onto the total cost price. Given the large stratification of the deposit, an analysis of the possibilities of selective equipment operation was simulated. The results have been documented, showing that 1m layers and even, up to 0.5 m can be selectively excavated, while being economically justified.

A reliability analysis was performed for the entire selected equipment, under the operating conditions of the Radljevo open pit and based on historical data of the Kolubara coal basin. By utilising selective exploitation, homogenization is performed from the moment of excavation to the deposition at the coal deposits, thus significantly improving the quality parameters of coal. Compared to the first techno-economic analysis, the project team considered a number of additional features of the investment project of Radljevo - north open pit, and on the basis of additional geological studies and reliable simulation methods managed to significantly reduce project and investment risks. Based on Prefeasibility study of Radljevo - north open pit, a risk analysis level within the project is given in Table 9

Tab. 9. Risk level in the Raljevo - North open pit mine investment project.

Risk	Risk level				
	Low	Low-medium	medium	Medim-high	High
Geology and reserves	X				
Coal Quality	X				
Soil mechanics	X				
Dewatering	X				
Open pit mine development	X				
Basic equipment		X			
Planned time schedule			X		
Financing					X

Source: [8]

Based on the previously mentioned optional variants, new inputs for the economic analysis of the project have been obtained and primarily indicated that the open pit can be projected to an annual capacity of 13 million tons of coal. The new economic analysis used the data obtained by analyzing only the project options and not the financial options (price, interest rate, exchange rate differences). New economic analysis provided the following economic parameters of the project [8]:

- Selling price of coal – 1,4 €/GJ
- Internal rate of return IRR – 9,5 %
- Discount rate – 8 %
- NPV – 127 miliona €

Economic parameters of the open pit Radljevo - north investment project, involving all optionally-considered techno-economic aspects of exploitation, indicate that the project is an acceptable investment. On the basis of this assessment, project Radljevo - north, with a production of 13 million tonnes of coal per year received the highest priority status of the Electric Power Utility of Serbia [9].

Conclusion

Evaluation of mining investment projects is one of the most complex investment problems. Almost the entire lifecycle of mining projects is followed by various unknowns and risks. They are particularly present in the early stages of the project, and in all stages of the investment decision-making.

The success of each investment project is evaluated on the basis of its performance over a certain period arising from the relationship of benefits and cost of the project. It is evident that an investment project is more effective if the benefits are higher in comparison to cost.

In order to express and compare the effectiveness of individual projects, various investment criteria are used. In addition to the criteria, it is necessary to define appropriate methods for determining the profitability of investment projects, and to determine the manner in which the selection will be made among a number of designed variants at a given criteria. The selection of evaluation methods depends on, among other things, the production and development goals of the company, economic environment, data availability, etc.

Modern specialised literature and business practices differentiate a number of methods for evaluating investment projects, but when making final investment decisions, particularly referring to the mining projects, it is important to keep in mind the specifics which are reflected in the fact that, in addition to economic efficiency, it is necessary to understand the technical-technological and other criteria to ensure the required reliability of the system.

As for the example of the investment project of open pit Radljevo - north, it is obvious that the mining projects that carry such extensive risk, require more than the application of NPV method for the assessment of eligibility. More sophisticated method of real options can significantly help to reduce the risks and increase the reliability of investment decision-making in mining projects.

The highest value of the real option method is the introduction of a proactive approach to the mining project management. This method does not guarantee that the decisions made on the basis of its guidelines would provide unambiguously better results in the short term. However, this method does ensure that the managers, thinking about the uncertainties and risks essential for the project, will much better cover the substance of the project as well as the options raising the project potential. The essence of the real options method is in making investment decisions based on a wider information scope.

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