DOI: 10.26730/2618-7434-2020-1-4-31

УДК 622.271.3

АНАЛИЗ ИНВЕСТИЦИЙ В ГОРНОДОБЫВАЮЩУЮ ПРОМЫШЛЕННОСТЬ

Михал Цехлар, Павол Рыбар, Ян Михок, Яцек Энгель

Технический университет Кошице, Республика Словакия

Информация о статье
Принята 16 февраля 2020 г.

Ключевые слова:
горнодобывающая промышленность, инвестиции, анализ чувствительности, принятие экономических решений, проектирование

Аннотация.
Задача анализа инвестиций конкретного проекта заключается в обеспечении достоверности информации, связанной с проектированием, системой разработки, производственными затратами, рекультивацией, средствами консалтинга (например, характер используемых банковских систем, геостатистических и географических информационных систем и т.д.) и многими другими переменными факторами.
Фактически необходимо использовать количественные значения для переменных проекта, основанные на техническом анализе. Только в тех случаях, когда переменные количественно определены, исследование экономической эффективности горнодобывающего предприятия может привести к правильным выводам и качественному инвестиционному решению.
Такой же подход применяется не только к решению об инвестициях до начала самого производства, например, при реализации нового проекта, но и к решению об инвестициях в уже реализуемые проекты в случае расширения производства или обновления физически и морально устаревших технологий. Ежедневная работа требует информационного анализа высокого качества управления проектами как в техническом, так и в экономическом аспекте.
Таким образом, экономическая оценка горнодобывающего проекта или установление предела экономической эффективности горнодобывающего предприятия требует большого объема информации, которая должна быть обработана в одном месте с помощью одной системы.
Поскольку процесс принятия решения в отношении вышеупомянутых последствий требует анализа многих альтернатив, необходимо также учитывать такие факты, как затраты, прибыль, экономия, продолжительность проекта, налоги, увеличение эффекта инфляции, проектный риск и другие. В данной статье рассмотрены следующие этапы: изучение базового проекта, изучение влияния налогов и амортизации, эффект кредитования, инструменты для принятия экономических решений, а также анализ чувствительности – метод, описывающий неопределенность, характерную для каждого проекта, особенно для горнодобывающих проектов.

ANALYSIS OF INVESTMENTS IN THE MINING INDUSTRY

Michal Cehlár, Pavol Rybár, Ján Mihók, Jacek Engel

Technical University of Kosice, Slovak Republic

Article info
Received February 16, 2020

Abstract.
The task of analysing the investment of concrete project is to ensure reliable of information connected with designing, mining method, production costs,

Keywords: mining industry, investments, sensitivity analysis, economic decision making, projecting

recovery, consulting means (e.g. character of used bank systems, geo-statistic and geographical information systems, etc.) and many other variable factors.
In fact it is necessary to use quantitative values for project variables, based on technical analyses. Only in instances when variables are quantified, a study of the economic efficiency of the mining business can result in conclusions and a quality investment decision can be made.
The same approach applies not only to the decision to invest before starting production itself, such as with a new project, but also for the decision to invest into already ongoing projects, in cases of expanding production or the renewal of obsolete and worn-out technologies. Everyday operation requires an information analysis of the high quality project management in both its technical and economic aspects.
Thus, the economic assessment of a mining project or setting the limit of the economic efficiency of a mining business requires a large amount of information that must be processed in one place using one system.
As an effect of the decision making process with regard to the above mentioned consequences requires the analysis of many alternatives, also the facts such as costs, profit, savings, project duration, taxes, increased inflation effects, project risk and others must be taken into consideration.
In this article, the following stages are considered: the study of the main project, the study of the impact of taxes and depreciation, the effect of credit, tools for economic decision-making, as well as sensitivity analysis - a method that describes the uncertainty inherent in each project, especially for mining projects.

Introduction

At present, there are several algorithms that can be successfully applied in the area of heavy industry and mainly the mining industry. They include:

- development of a detailed economic study of the economic efficiency of business, along with defining the rate of opportunity acceleration (*screening*),
- comparison of relative advantages of all investment resources (*ranking*),
- assessment of supplier offers from many suppliers offering identical products or services,
- decision to buy or to lease,
- definition of values or prices for product purchase and sale,
- setting of costs for loan sources, both short-term and long-term from the payable sources,
- replacement of existing equipment or services,
- choice between interesting alternatives.

When assessing the economic efficiency of investments implemented by means of a project, with the effort being to comprehend its internal consequences, it is necessary to proceed step by step, and gradually implement all variables affecting its result into the project assessment. In order to reach such an outcome, it is suitable to split the project analysis into four basic levels :

- study of the basic project,
- taxation and depreciation effects,
- loans and their effects on a project,
- study of the whole project (taxes and loan).

Activities in individual steps are displayed in Figs. 1 to 5. Figure 6 illustrates the process of assessment and selection of individual variants.

When studying the basic project, the most important thing is to identify whether the economic development of the project implementation guarantees positive results and an economic return on the spent investments. In fact, the expression of rate is not important as the actual environment in which the project will be located is considered in the following levels.

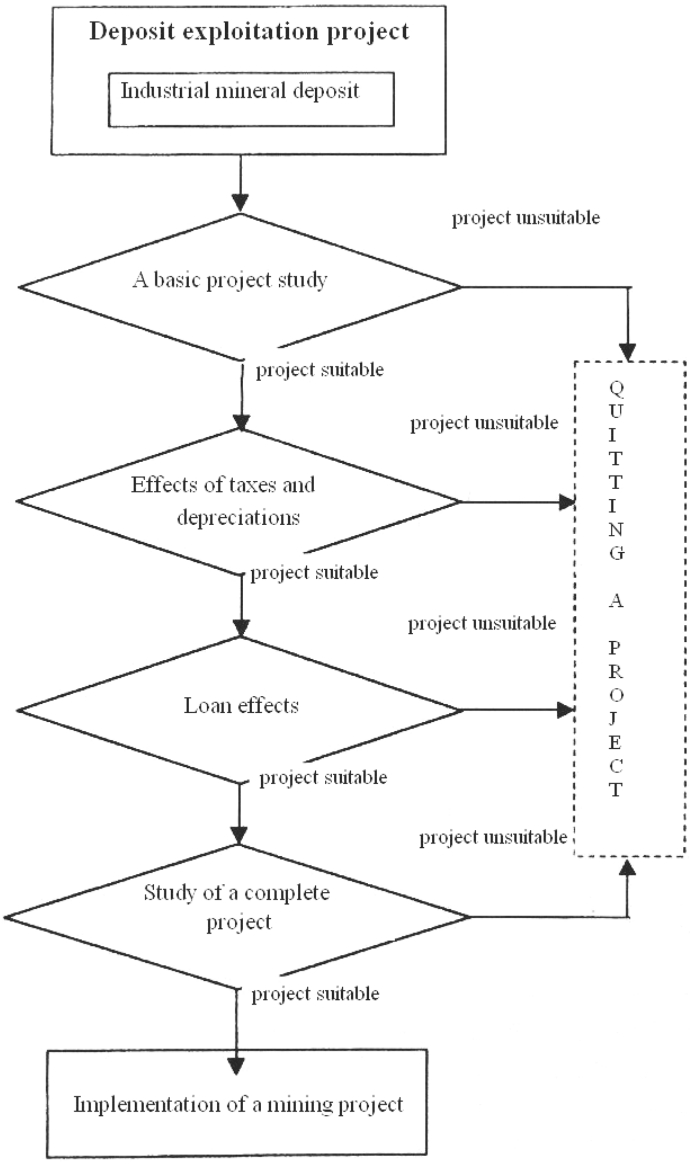


Fig.1. Assessment of the economic efficiency of investments (project).

When examining the effect of taxes with the simultaneous consideration of the effect of investments through depreciations, the project enters a real economic environment characterized by economic rules.

The task of defining impacts of a possible loan and its structure is to identify its possible positive effects on the economic results of an evaluated project.

A complete project includes the final characteristics of a project's internal structure with a complex consideration of technologies, mining methods, reserves, rock properties etc., as well as the characteristics of external factors of the economic environment with the selection of such variables (methods of financing, regional effects, socio-economic relations), which help to improve those economic parameters expressing the deposit value and economic results of the exploitation project implementation.

Study of the Basic Project

For subsequent analyses it is necessary to define a basic project, so to say, outside of the financial environment, which enables various studies. The goal is to identify the basic tendency of the economic behaviour of the project at its core. At this stage the effect of taxes and the effect of financial sources

DOI: 10.26730/2618-7434-2020-1-4-31

used for investment are excluded from the analysis. (At this stage we consider that all investment resources have been completely provided by the project owner.) The development of the annual cash flow is displayed in Table 1.

Table 1. The annual breakdown of cash-flow, without taxes and loan.

EAR	NOTE	CASH FLOW
0		$-I_0 = CF_0$
1		$-I_1 = CF_1$
X		$-I_x = CF_x$
X	END OF INVESTMENTS	$-I_x = CF_x$
X	BEGINNING OF PRODUCTION	" $-E_x+R_x = CF_x$
5		" $-E_5+R_5 = CF_5$
“		" "
“		" "
N	ADDITIONAL INVESTMENTS	$-I_N - E_N+R_N = CF_N$
“		" "
“		" "
N	END OF THE PROJECT	$+R_V - E_N+R_N = CF_N$

R_V -salvage value of tangible property, I -investments, E –costs, R-incomes.

Calculation of the annual *cash-flow* is carried out on the basis of the following relationship:

$$CF = INCOMES - INVESTMENTS - PRODUCTION\ COSTS \quad (1)$$

Effect of taxes and depreciations

Along with the implementation of taxes implemented also depreciations must be implemented into this model. The annual *cash-flow* calculation is then performed on the basis of the following relationship:

$$CF = INCOMES - INVESTMENTS - PRODUCTION\ COSTS - TAXES \quad (2)$$

Taxes are a percentage share of the tax base. The tax base is given by the following relationship:

$$TAX\ BASE = INCOMES - PRODUCTION\ COSTS - DEPRECIATIONS \quad (3)$$

The method of the tax depreciation is precisely defined by the law. For all investment activities the depreciation duration, percentage and specific features, e.g. the amount of the first instalment, are defined. Thus investments are categorised into depreciation classes. Generally, two depreciation methods, namely linear depreciation and degressive depreciation can be mentioned. The reason for this simple depreciation method is that in case of major investment ventures with a high volume of investments, equipment cannot be defined precisely, so it is not possible to set the depreciation classes to which it will belong, nor how it will be depreciated. Our calculations consider both the mentioned methods.

DOI: 10.26730/2618-7434-2020-1-4-31

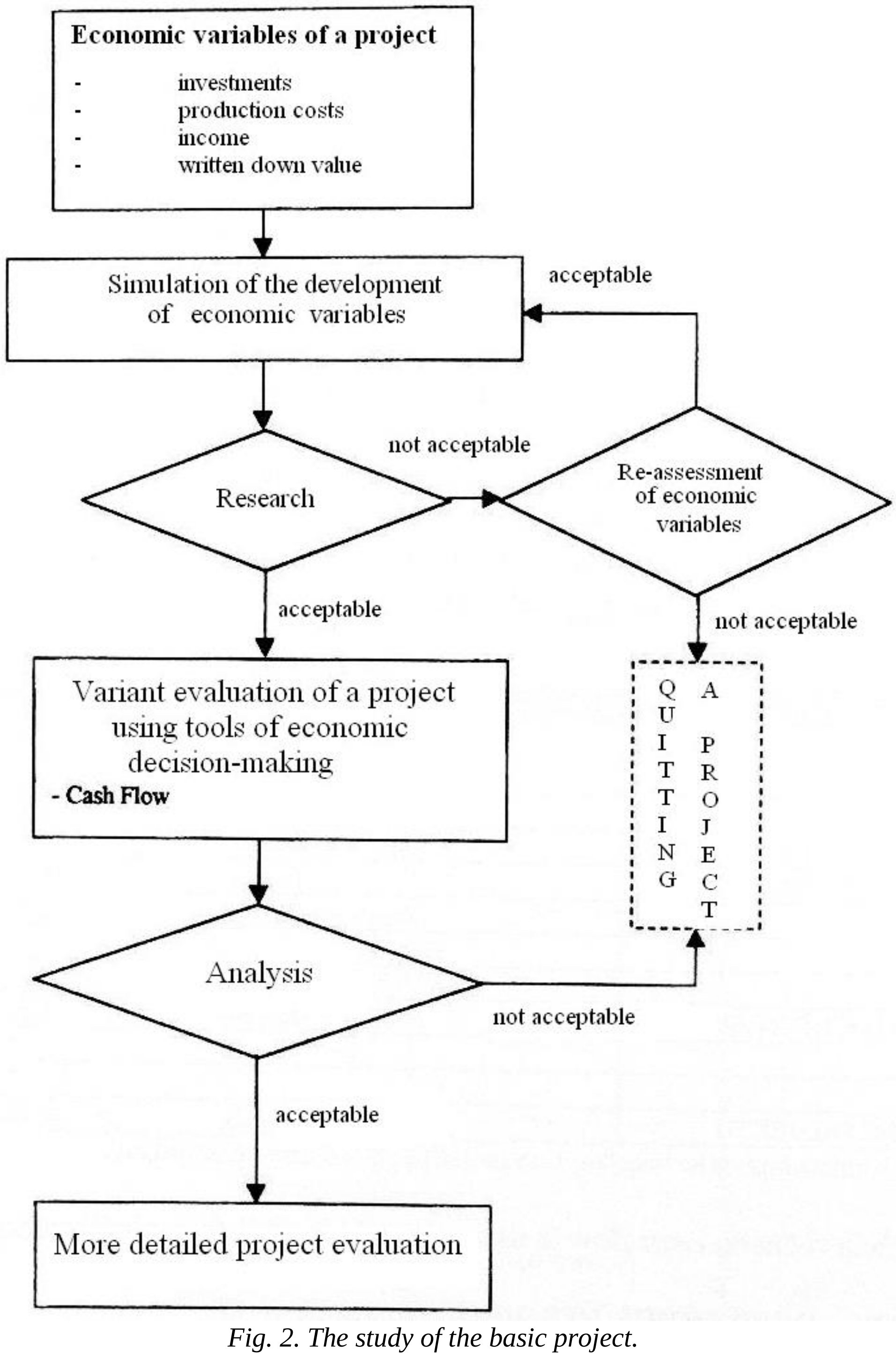


Fig. 2. The study of the basic project.

Linear depreciation

The linear depreciation is defined by:

- the first year of initial depreciation,,
- the number of years after which the considered investments will be depreciated. Thus the annual depreciation value is given by the relationship:

DOI: 10.26730/2618-7434-2020-1-4-31

$$DEP = \frac{I}{N_{DEP}}, \quad [Sk.r^{-1}] \tag{4}$$

where: DEP - annual value of depreciation [$Sk.r^{-1}$], I - investments [Sk], N_{dep} - number of years set for the depreciation of investments [r].

Degressive depreciation

The degressive depreciation is defined by:

- the first year of initial depreciation,
- a percentage expressing annual depreciation value (this value will always be applied for that part of the investment that will be depreciated in a given year).

If depreciation starts in year *p*, a depreciated amount in a year *j* will be given by the relationship:

$$DEP_i = T_{DEP} \times (I - \sum_{i=p}^{i=j-1} DEP_j, \quad [Sk.r^{-1}] \tag{5}$$

where: DEP_i - annual value of depreciation [$Sk.r^{-1}$], T_{DEP} - annual rate of depreciation [$\%.r^{-1}$], DEP_j - realised depreciation [Sk], I - investments [Sk].

Example: The value of equipment, which will be depreciated, is 200 mil. Sk.

1. **The method of linear depreciation for 3 years**

Table 2. The example of linear depreciation.

Year	1	2	3
Equipment accounts value	200x2/3	200x1/3	0
Depreciation	66,67	66,67	66,67

2. **The value of annual depreciation: 25 %**

Table 3. The example of degressive depreciation.

Year	1	2	3	4
Equipment accounts value	150	112,5	84,5	63,5
Depreciation	50	37,5	28	21

depreciation (year) = value (year-1) x rate; value (year) = value (year-1) – depreciation (year)

Note: *When using the second method, if the value of depreciation in certain projects becomes too low, in some economies (e.g. France), it is possible to change to the linear method, for the rest of the equipment's life time, for example, as stated above.*

Continuation of Table 3

5	6	7	8
63	42	21	0
21	21	21	21

Having agreed with an appropriate state authority it is possible in both cases to depreciate less than that defined by law. The reason is an effort to avoid negative economic results, mainly in the early project stage, after high investment costs. However, principally it is not possible to depreciate more than that defined by the law.

A calculation of the annual *cash-flow* is displayed in Table 4.

Table 4. The annual breakdown of cash-flow, with taxes, without considering a loan.

YEAR	NOTE	CASH FLOW
0		$-I_0 = CF_0$
1		$-I_1 = CF_1$
X		$-I_x = CF_x$
X	END OF INVESTMENTS	$-I_x = CF_x$
X	BEGINNING OF THE PRODUCTION	" $-E_x + R_x = CF_x$
5		" $-E_5 + R_5 = CF_5$
“	THE FIRST YEAR OF TAXATION	" $-E_x + R_x - TAX_x = CF_x$
“		" "
N	ADDITIONAL INVESTMENTS	$-I_N - E_N + R_N - TAX_a = CF_a$
“		" "
“		" "
N	END OF THE PROJECT	$+R_V - E_N + R_N - TAX_N = CF_N$

TAXx is the tax paid in year x.

The Effect of Loans

The annual *cash-flow* when considering a loan is calculated according to the following relationship:

$$CF = INCOMES + LOAN - INVESTMENTS - PRODUCTION\ COSTS - LOAN\ INSTALMENTS - INTEREST\ INSTALMENTS. \tag{6}$$

The loan is defined by:

- the amount of loan gained from external resources,
- the year of loan granting,
- the interest rate,
- the number of years of the first loan instalment postponement (number of years between the year of getting loan and year in which the loan instalment payments start),
- the period of loan repayability.

Let us consider the following instalment calendar:

- the amount of loan sum gained in year 0 for a period of 10 years with the interest rate i,
- the postponement of the first instalment by 2 years,
- The first year of starting paying the loan = the third year.

The total amount of the loan sum, which must be paid in year 3, is as follows:

$$B \times (1+i)^3, \quad [Sk], \tag{7}$$

DOI: 10.26730/2618-7434-2020-1-4-31

where: B - amount of loan [Sk], i – interest rate [%].

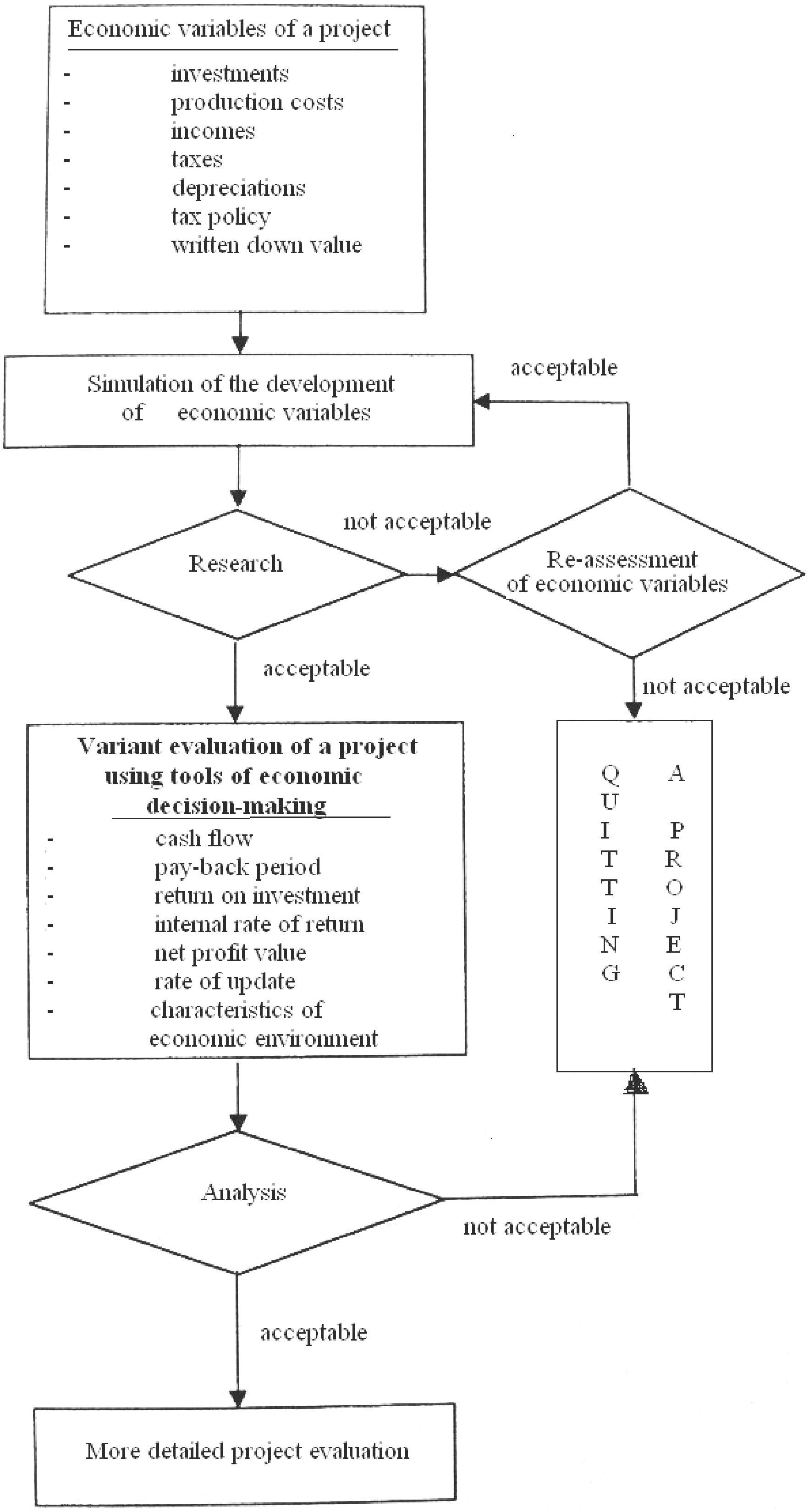


Fig. 3. Effect of taxation and depreciation.

The annual loan instalments paid over years 3 to 12, during the loan period are:

$$\frac{B\times(1+i)^3}{10}, \quad [\text{Sk.year}^{-1}]. \tag{8}$$

The loan sum that has to be paid to the loan or in year N (N means between years 3 and 12):

$$B\times(1+i)^3\times\frac{(10+3-N)}{10}, \quad [\text{Sk}], \tag{9}$$

where N is the current year.

The calculation of annual *cash-flow,* where a case of paying the loan is considered, is displayed in Table 5.

Table 5. The annual breakdown of cash-flow, without taxes, considering a loan.

YEAR	NOTE	CASH FLOW
0		$-I_0 = CF_0$
1	BEGINNING OF THE LOAN DRAWDOWN	$-I_1 + B = CF_1$
X		$-I_x + B = CF_x$
X	END OF INVESTMENTS	$-I_x + B = CF_x$
X	BEGINNING OF THE PRODUCTION	" $-E_x + R_x = CF_x$
5	BEGINNING OF THE LOAN REPAYMENT	" $-E_5 + R_5 - REP_5 - INT_5 = CF_5$
“		" "
“		" "
N	ADDITIONAL INVESTMENTS	$-I_a - E_a + R_a - REP_N - INT_a = CF_N$
“		" "
P	END OF THE LOAN REPAYMENT	$-I_P - E_P + R_P - REP_P - INT_P = CF_P$
“		" "
N	END OF THE PROJECT	$+R_V - E_N + R_N = CF_a$

B_I is loan in year I, REP_I is loan instalment in year I, INT_I is interest instalment in year I.

The interest, which has to be paid to the creditor in year N is the loan sum multiplied by the rate:

$$B\times(1+i)^3\times\frac{(10+3-N)}{10}\times i, \quad [\text{Sk}]. \tag{10}$$

DOI: 10.26730/2618-7434-2020-1-4-31

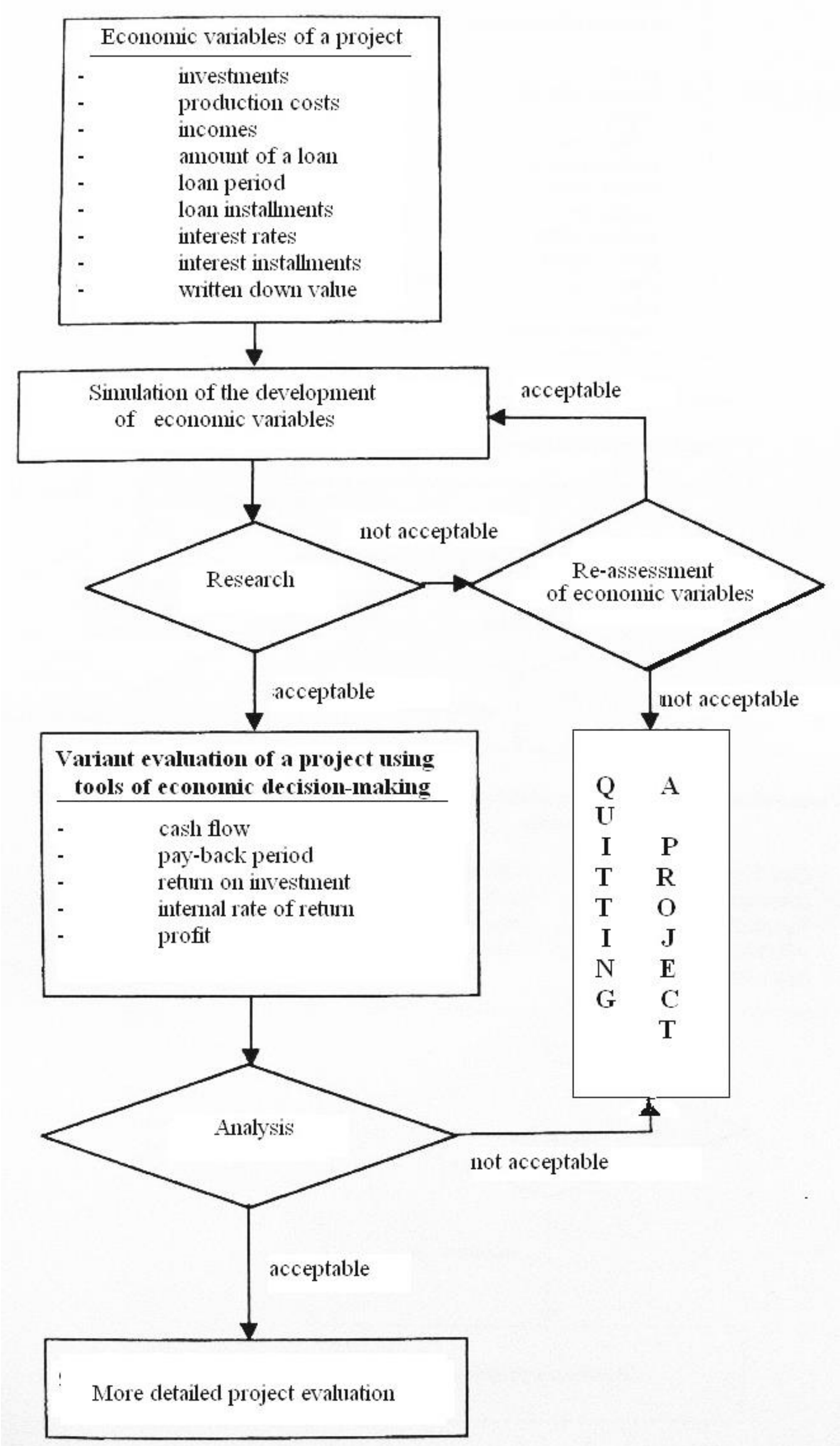


Fig.4. The effect of the loan.

There are also other methods to calculate loan parameters and its gradual repayment, which may vary in the method of loan instalment repayments or interest instalment repayments that can be variable, constant, and temporarily equal to zero or in the total amount. The chosen method must reflect the situation and environment of a concrete project as realistically as possible.

DOI: 10.26730/2618-7434-2020-1-4-31

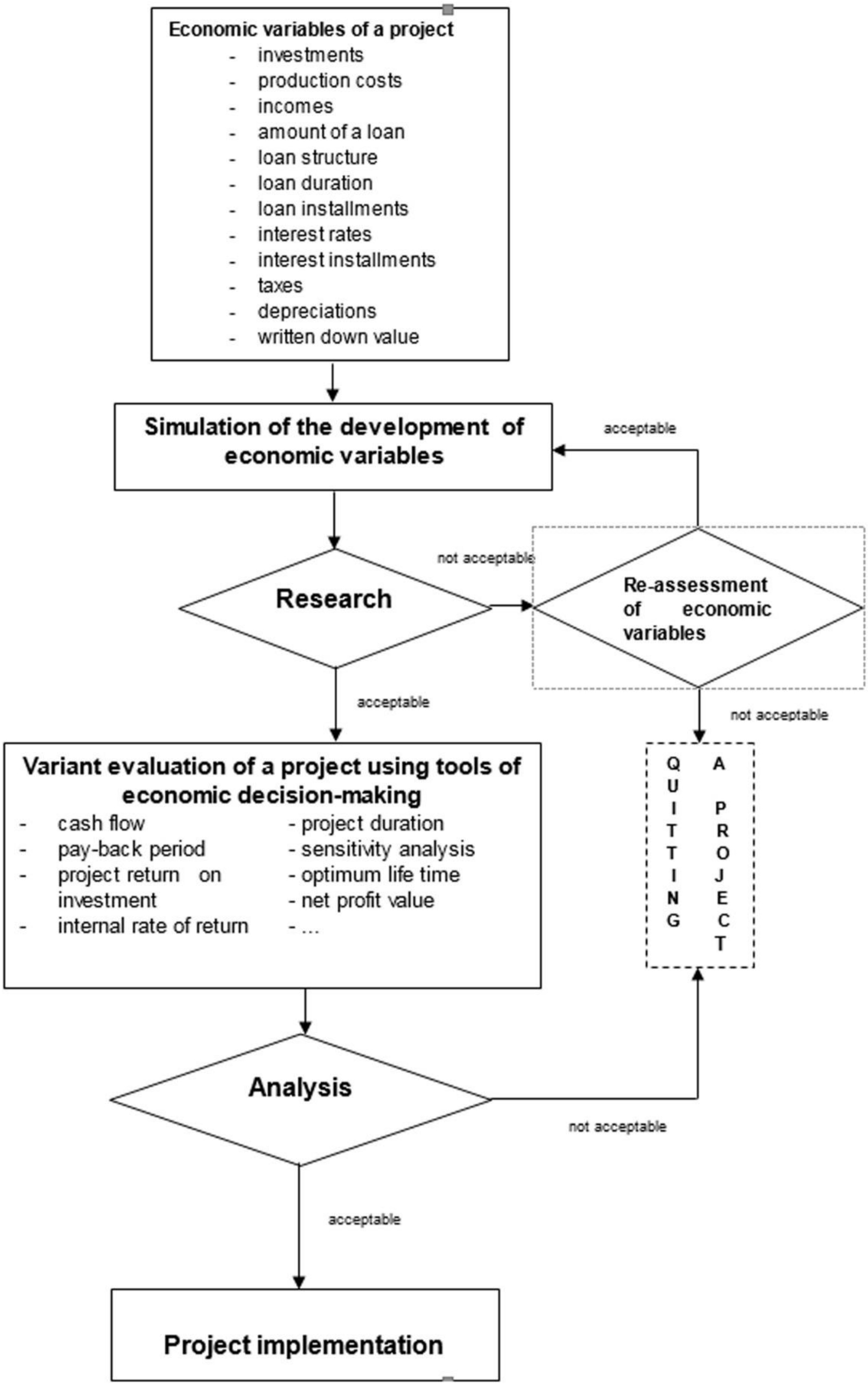


Fig. 5. The study of the complex project.

The annual *cash-flow* calculation is made on the basis of the following relationship:

CF = INCOMES + LOAN - INVESTMENTS - PRODUCTION COSTS - INSTALMENT LOAN -

 DOI: 10.26730/2618-7434-2020-1-4-31

INTEREST INSTALMENTS - TAXES (11)

The tax base is calculated according to the following relationship:

TAX BASE = INCOMES – PRODUCTION COSTS - DEPRECIATIONS – INTEREST INSTALMENTS (12)

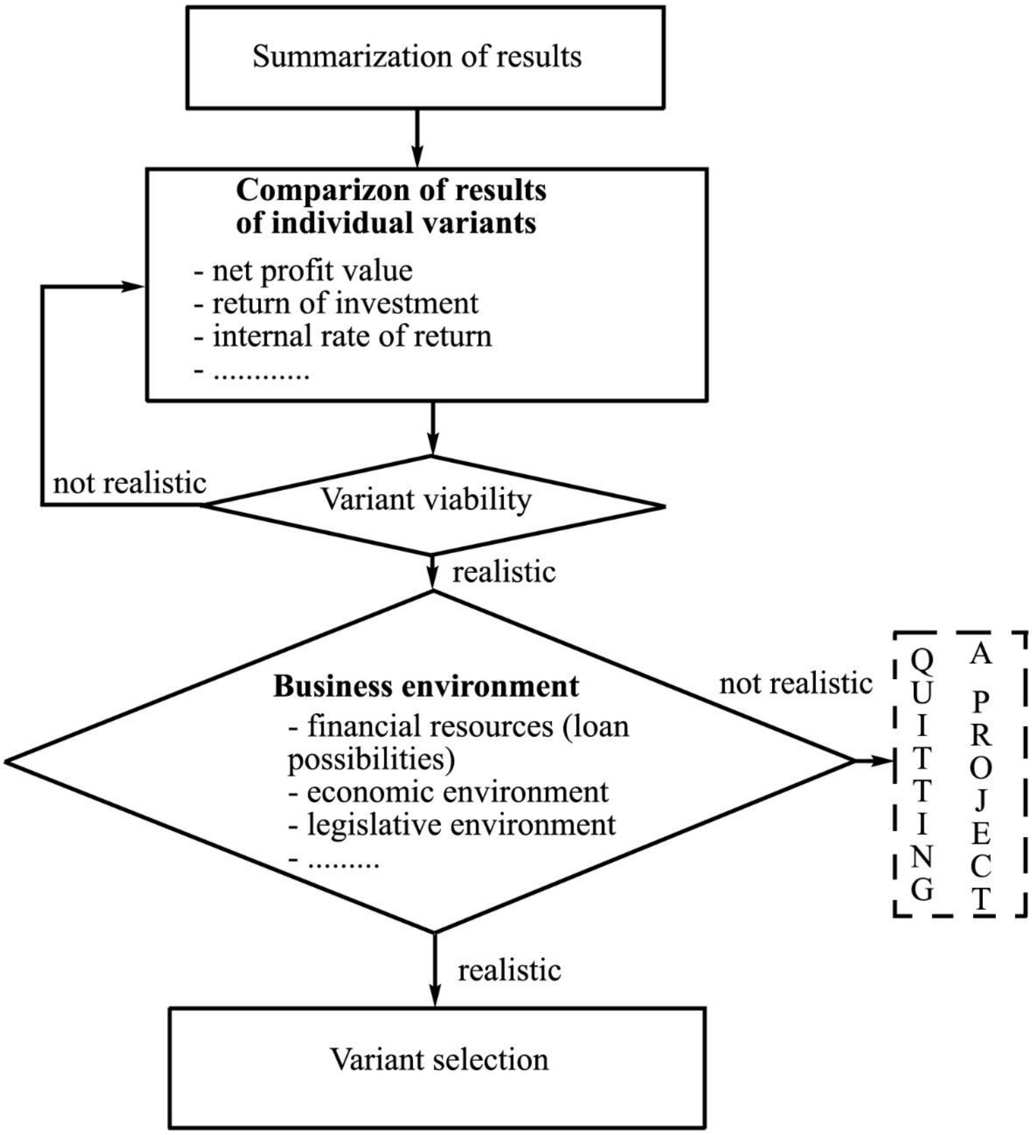


Fig. 6. Analysis of probable project results.

The analysis of probable project results is important from the viewpoint of identifying the most suitable variant for the implementation of the raw material exploitation. No single-shot economic evaluation can bring satisfactory results if made only on the basis of one calculation. The calculation variability ensures the possibility of the simulation of external and internal effects influencing the project, which may occur during the project implementation and also the search for the optimum variant of the project implementation with the purpose of maximizing its goals.

The annual cash-flow calculation is displayed in Table 6.

DOI: 10.26730/2618-7434-2020-1-4-31

Table 6. The annual The annual breakdown of cash-flow with taxes, considering a loan.

YEAR	NOTE	CASH FLOW
0		$-I_0 = CF_0$
1	BEGINNING OF THE LOAN DRAWDOWN	$-I_1 + B = CF_1$
X		$-I_x + B = CF_x$
X	END OF INVESTMENTS	$-I_x + B = CF_x$
X	BEGINNING OF THE PRODUCTION	" $-E_x + R_x = CF_x$
5	BEGINNING OF THE LOAN REPAYMENT	" $-E_5 + R_5 - REP_5 - INT_5 = CF_5$
“	THE FIRST YEAR OF TAXATION	"$-E_x + R_x - REP_x - INT_x - TAX_X = CF_x$
“		" "
N	ADDITIONAL INVESTMENTS	$-I_N - E_N + R_a - REP_N - INT_a - TAX_{and} = CF_N$
“		" "
P	END OF THE LOAN REPAYMENT	$-I_P - E_P + R_P - REP_P - INT_P - TAX_P = CF_P$
“		" "
N	END OF THE PROJECT	$+R_V - E_N + R_N - TAX_N = CF_a$

Tools of Economic Decision Making

The analysis of several alternatives for making an investment decision must consider factors such as costs, profit, savings, project duration, taxes, environmental limits, and effects of increased inflation, project risk and others.

There are many simulations applicable in the area of heavy, mainly mining, industry:

- a development of a detailed economic study of the business economic efficiency along with defining the rate of opportunity acceleration (*screening*),
- a comparison of relative advantages of all investment resources (*ranking*),
- an assessment of supplier offers from many suppliers selling identical products or services,
- a decision to buy or to lease,
- a definition of values or prices for product purchase and sale,
- a setting of costs for loan resources, both short-term and long-term from the payable resources,
- a replacement of existing equipment or services,
- a choice between interesting alternatives.

A Cash - Flow

Spent and earned money can generally be called the *cash-flow*. The *cash-flow* of the association, department, area, individual facility or project is a sum of positive and negative items, incomes and costs, connected with a certain activity. The sum of all financial flows, which result from the investment into a project are called the *cash-flow* produced by capitalized investments.

The *cash-flow* is a tool of financial analysis. The *cash-flow* represents extremely important data for each commercial unit. Each business or activity can go bankrupt, regardless of the fact of how profitable its accounting results seem to be, unless the company is able to pay invoices. Such success means the creation of a positive *cash-flow*.

A Cash – Flow Diagram

A cash-flow diagram is, simply to say, a graphical scheme representing data about the flow of money. In the diagram, the horizontal line represents time – it is a time axis. The distance on this axis represents the length of the project duration and is divided into periods, which are typical for the project (Fig. 7).

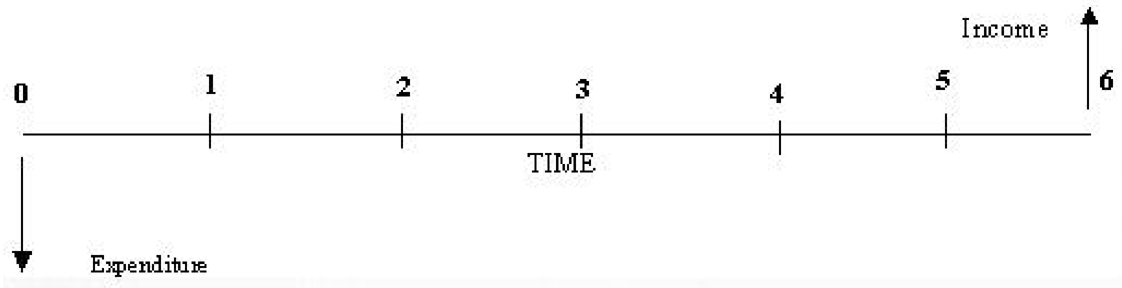


Fig. 7. Time development of cash-flow.

The assumed change of the project behaviour can be achieved by changing incomes and expenditures during the time course of the project's existence. In the diagram this is marked with arrows, which in the downward direction represent expenditures and in the upward direction represent incomes. It is common that in the same time both cash flows can occur, and this can be expressed as a resulting vector sum of these operations (Fig. 8).

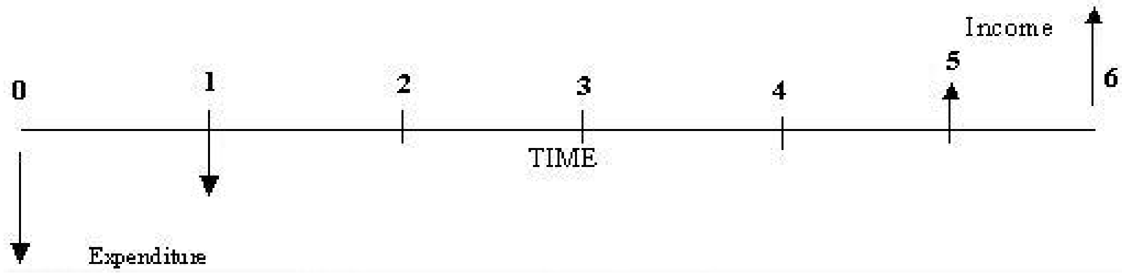


Fig. 8. The time development of cash-flow.

The length of arrows should represent the volume of moving funds and therefore it is necessary to draw them to scale. This simple and illustrative representation of the cash-flow is very useful for the display of the project financial situation over the time of its development and its course. The cash-flow increases, stagnation or decreases provides information about the state project management and about future possible reserves or problems.

Another tool suitable for the cash-flow development analysis is a table, while currently the most efficient tool for the creation of economic analysis is the table processor - spreadsheet. Physically it is a computer programme working with cells, into which primary economic data is placed. It is possible to use them in order to perform mathematical operations for the calculation of output economic data.

Table 7. The example using the table processor.

Year	Invest-ments	Product A	Product B	Product C	Production costs	Incomes	Depre-ciations	CF	DCF1	SDCF1
	[10^3 Sk]	[t]	[t]	[t]	[10^3 Sk]	[10^3 Sk]	[10^3 Sk]	[10^3 Sk]	[10^3 Sk]	[10^3 Sk]
1	50000	0	5000	650	30200	33025	12500	-47175	-47175	-47175
2	0	100	12000	650	65400	71775	12500	6375	5903	-41272
3	0	100	12000	650	65400	71775	12500	6375	5466	-35806
4	0	100	12000	650	65400	71775	12500	6375	5061	-30745

In Table 7 individual abbreviations mean the following:

Investments	- the amount of investments invested in the given project,
Product	- product of the A, B and C type
Prod. costs	- total production costs on product A, B and C,
Incomes	- total incomes earned by selling products A, B and C,
Depreciations	- depreciation of investments within 4 years by a linear method,
CF	- cash-flow,
DCF	- updated cash-flow (update rate of 8%),
SDCF	- sum of the updated cash-flow,
10^3 Sk	- thousand Sk.

Table 8 shows an example of the table processor used for a simple case, with the calculation of results such as *cash-flow*, updated *cash-flow* and sum of the updated *cash-flow*. The table processor chart is self-updating, so in case of changing any input data an immediate update occurs and we gain new results for each new consideration. For the sake of simplicity, the table does not include the loan and taxation systems. However, also in cases of containing such data the table processor operates in the same way and allows modelling of input parameters in order to obtain the best possible economic results. The example is identical with the study of the basic project included in the previous chapters.

Factors Affecting Cash -Flow

Taxation

The taxation is a very significant factor, which sometimes can have a destructive impact on the project. While the project results may appear quite optimistic at first economic considerations, its later tax analysis can prove the opposite. It is very important how the project is formed from the viewpoint of its benefit for the government. Here the issue of tax holidays becomes interesting, mainly in the early project stage, until the project starts and gains a certain dynamic.

Inflation

Cash-flow analyses are prepared in the form of money. Unfortunately, the purchasing power of money is not constant from a temporal viewpoint. It is influenced by the inflation effect and hence the value of a given amount of money lowers over time. Each month it is necessary to pay more money for the same product. Table 20 shows an example of the inflation effect on the mutual exchange rate of two currencies, which may be encountered in major projects mainly from the viewpoint of obtaining loan funds and a place of project implementation.

Table 8. Inflation and currency exchange rate.

	Slovakia	France
Exchange rate (1st year)	6 Sk	1 FrF
Inflation	10%	2%

According to this theory the mutual exchange rate between Sk and FrF is equal to:

$$6\,\frac{(1+10/100)}{(1+2/100)}\mathrm{Sk} = 1\mathrm{FrF}\,. \tag{13}$$

This does not represent the actual development of the mutual exchange rate between two currencies over a short time period, but it is a standard development from the long term viewpoint. This procedure can be used in financial analyses and serves to reveal general trends that are inevitable for the analysis of a long term project.

Consideration of the inflation by means of goods prices:

Table 9. Inflation and purchasing power.

	Slovakia [Sk]	France[FrF]	Purchasing power
First year	6	1	1 loaf of bread
Second year	6,6	1,02	1 loaf of bread

A loaf is a loaf, no matter whether you buy it in Slovak Crowns or French Francs. From the viewpoint of this meaning, the second row of Table 22 allows the calculation of a mutual exchange rate in the second year as follows:

$6{,}6\mathrm{Sk} \Leftrightarrow 1{,}02\mathrm{FrF}$

$6{,}6/1{,}02\mathrm{Sk} \Leftrightarrow 1\mathrm{FrF}$

The result is the same as in the theoretical relationship.

Inflation, offer and demand

Assuming that some currencies are goods, we can buy a certain amount of Slovak crowns or French francs for a USD. In that case it is more advantageous to buy French francs than Slovak crowns as francs lose their value less – only by 2%, according to inflation. It means that to buy something in the given currency you need only 2% more if you save one franc in a deposit for two years. To buy a loaf of bread you will need 0.02 francs more. In case of Sk, if the transaction is carried out in this currency, you would need 0. 6 Sk more.

This is the reason for a higher demand for francs compared with crowns, hence the price of francs in USD increases compared with the price of Sk in USD.

Note: This argument cannot be applied to countries where exchange rate operations are controlled and offer and demand in the local currency are controlled by the government, not by the market. Despite this, international financial institutions regulate too high deviations.

Modelling of the prices increase under the inflation effect

Not all prices change at the same rate as inflation. Some changes are faster, others are slower.

If "p“ represents price at the beginning of the first year, at the end of that year this price as increased by the inflation rate and can be expressed as: „$p + p\,I_I$“ or „$p\,(1 + I_I)$“. The second year starts with „$p\,(1+I_I)$“, so eventually it will be expressed by:

$$p(1+I_I) + p.I_I(1+I_I) = p(1+I_I)(1+I_I) = p(1+I_I)^2 \quad . \tag{14}$$

The basic mathematical relationship for the inflation at a constant rate will take the following form:

$$p_i = p_i(1+I_I)^t \ , \tag{15}$$

where: p_i - the average price or annual costs for the starting year, p_t - the average price or average costs for year t, I_I - the constant annual rate of inflation $[(p_2/p_1) - 1]$.

A mathematical expression (15) can be used in the economic analysis for the calculation of inflation for goods or services costs. However, it is obvious that with this kind of presentation the constant inflation rate is considered for the next years. If however, we assume changes of inflation over time, it is necessary to modify the equation as follows:

$$p_t = p_i(1+I_{Ia})^a(1+I_{Ib})^b(1+I_{Ic})^c \tag{16}$$

where: I_{Ia},, I_{Ib},, I_{Ic} are inflation rates for periods a, b and c, if $t = and + b + c$.

Another necessary modification of the equation (36) is the case when various goods or services will, due to the inflation effects, change their price differently. One type of goods or services will change its price with the rate „*X*“, another type with the rate „*Y*“ *and* the third one with the rate „*Z*“. Then the following modification is required:

$$\begin{gathered} p_{tx} = p_{ix}(1+I_{E_x})^t(1+I_I)^t = p_{ix}[(1+I_{E_x})(1+I_I)]^t \\ p_{ty} = p_{iy}(1+I_{E_y})^t(1+I_I)^t = p_{iy}[(1+I_{E_y})(1+I_I)]^t \\ p_{tz} = p_{iz}(1+I_{E_z})^t(1+I_I)^t = p_{iz}[(1+I_{E_z})(1+I_I)]^t \end{gathered} \tag{17}$$

where: p_{tx}, p_{ty}, p_{tz} are average prices /costs for goods or activities *x, y and z* in year *t*,
p_{ix}, p_{iy}, p_{iz} are average prices/costs for goods or activities *x, y and z* in the 1st year,
I_I is an annual rate of inflation,
I_{Ex}, I_{Ey}, I_{Ez} are annual increase rates or costs for goods or activities *x, y and z.*

Return on Investment (ROI) and Profit to Investment Ratio (PIR)

Return on investment („ROI“) is probably the oldest but still most frequently used parameter for the assessment of the economic efficiency of spent investments. It is the total income, which results from concrete investments, divided by the amount of investment funds. This indicator is completely time independent. *Profit to Investment Ratio* („PIR“) is another form of the same indicator. Profit to Investment Ratio PIR is equal to Return on Investment minus one.

These two indicators are important, as they can assess the state, when some incomes can come and be used earlier, before the project has been completely prepared and launched. Hence not the whole volume of funds is required for the project implementation, as a part of the funds has returned to the company before starting it. However, this indicator cannot be favourised, because, as mentioned above, it lacks the time factor.

Unfortunately, having been applied under various conditions and projects, this indicator is significantly modified and it was given many names and forms, e.g.:

$$return\ on\ investment\ ROI = \frac{cumulative\ incomes}{total\ investments}\ , \tag{18}$$

$$profit\ to\ investment\ ratio = \frac{cumulative\ income - total\ investments}{total\ investments}\ , \tag{19}$$

$$rate\ of\ maximum\ expenditure = \frac{cumulative\ cash\text{-}flow}{max.negat.state\ of\ CF}\ . \tag{20}$$

Payback Period (pBp)

A payback period is the project duration from its beginning, until when the cumulative *cash-flow* becomes positive. For some projects it is the risk measurement that indicates, how long the investment capital is endangered. Similarly to the previous case, when it is used as a single indicator, it does not have a complete assessment value, as it only gives information about a project during the payback period. Although in the case of some projects the assessment results based on the payback period may seem interesting, this indicator does not say anything about the project's future course from the viewpoint of its cash-flow development. This could be either positive or negative, but unfortunately, such information cannot be ascertained from the payback period. This indicator does not specify in detail the cash-flow development until the payback period is reached, either.

Time Value of Money – the Current Value Concept

Time is a very important factor for the ability of investments to make profit. A crown earned today is much more valuable, than a crown earned sometime in the future. The value of money, which can be earned, or which must be spent, is directly connected to the certain time schedule of the cash flow in the project. This is a core issue that must be respected and used in project evaluations. We can say simply that time is money.

Let us consider the following situation, when two alternative of the time schedule for gaining funds from the project are available:

- the investment of 5 000 Sk will bring 800 Sk annually during the period of four years and 10 900 Sk at the end of the fifth year,
- the investment of 5 000 Sk will bring 15 000 Sk at the end of the fifth year.

The first alternative indicates a financial profit of 9 100 Sk and the second alternative that of 10

 DOI: 10.26730/2618-7434-2020-1-4-31

000 Sk, both in the duration of 5 years. The second alternative seems to be better, because its results are higher by 900 Sk. However, this is a very simple comparison and does not include the time effect.

At first it assumes that both alternatives include a certain risk. Between time "one", when the funds are invested and the time, when the project is completed, a lot of things can happen that can affect the assumed project results. This simple comparison ignores, for example, the effect of funds available during the project course. There are also many other arguments that point out the meaning of the time value of money.

So, let us compare the profits gained from both mentioned projects again. The first produces an annual income, and thus money is available to the owner earlier. When the effect of inflation or political risks of the extraction are taken into account, own funds can be gained earlier, and can help to reduce the possibility of losses resulting from the aforementioned risks. As payments come earlier, the amount of funds affected by these risks is smaller each year. Intuitively, now the first alternative looks more profitably. Unfortunately our intuition is not always correct.

Project duration and its effects on cash - flow

The assumption of gaining one crown in one year is not the same as gaining this one crown today. The crown gained today can be invested and can start "working". If deposited in the bank account with an interest rate of 7%, the increase in a year will be 0.07 Sk. So if 0.93 Sk is deposited to this bank account, in one year it will increase to approximately 1 Sk. Based on the assumption that in a year it is possible to gain 1 Sk, its present value is only 0.93 Sk at an increase rate of 7%.

A concept of the interest rate is the basis for the calculation of the money time value. The interest rate should not be perceived simply as the amount or increase of a certain volume of funds deposited in a financial institution. The interest rate is expressed in a percentage and represents the share of the whole during the period of one year.

future value of = current value + interest rate, or
future value = current value + (i) x (current value), hence

$$v_f = v_p\,(1+i), \tag{21}$$

where: v_p = the current value being an investment needed to gain future value, v_f = the future value gained at a certain value of update, i = interest rate (update).

Example: $v_f = (1\,000\ Sk)\,(1+0,1) = 1\,100\ Sk.$

The interest for 1 000 Sk for the period of one year is 100 Sk. If this interest gained during one period is left in the same conditions also for the next period, it becomes a basis for the next period during which it will produce another interest amount:

$v_{f1} = (1\,000\ Sk)\,(1,1) = 1\,100\ Sk$ 1. period,
$v_{f2} = (1\,100\ Sk)\,(1,1) = (1\,000\ Sk)\,(1,1)\,(1,1) = 1\,210\ Sk$ 2. period,
$v_{f3} = (1\,210\ Sk)\,(1,1) = (1\,000\ Sk)\,(1,1)\,(1,1)\,(1,1) = 1\,331\ Sk$ 3. period,

hence: $v_{fn} = v_p\,(1+i)^n$, where n is a number of periods.

Then for the current expression of the future money value applies that

$$v_p = v_{fn}\,\frac{1}{(1+i)^n} = v_{fn}\,(1+i)^{-n} \tag{22}$$

where: $(1+i)^{-n}$ is the update rate.

This is the case of duration and its effects on the cash-flow. The calculation of future annual cash-flow is carried out on the basis of future data and results. To determine its value and behaviour today, it is necessary to make an update by means of the update rate.

DOI: 10.26730/2618-7434-2020-1-4-31

The updated value of future money

The update process is just the opposite to the process of the volume increase by means of the interest rate. For example, in case of the sum of 1 000 Sk invested with an interest rate of 10% it will increase to 1 100 Sk during one year. However, using the update process the amount of 1 000 Sk is reduced to 1000 Sk/1.10 or 909.09 Sk due to its effect. Table 10 shows an example, in which both effects, the interest rate and update rate effects on the financial volume, are calculated at 15%.

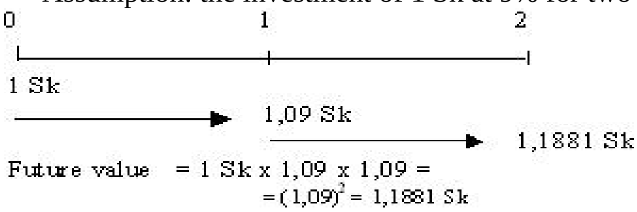
Table 10. The interest rate and update rate of 15%, calculated annually.

Year	1 Sk and the interest rate	1 Sk and the update rate
0	1,0000	1,0000
1	1,1500	0,8696
2	1,3225	0,7561
3	1,5209	0,6575
4	1,7490	0,5718
5	2,0114	0,4972
6	2,3131	0,4323
7	2,6600	0,3759
8	3,0590	0,3269
9	3,5179	0,2843
10	4,0456	0,2472

Updated cash-flow

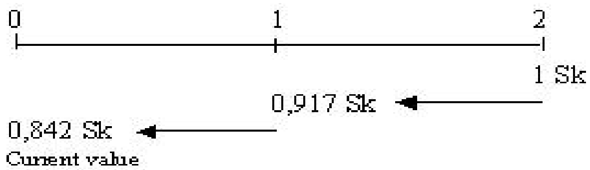
Interest rates:

Assumption: the investment of 1 Sk at 9% for two years



Update:

Assumption: profit of 1 Sk for two years



Check: $1\text{Sk x } \dfrac{1}{1{,}09 \text{ x } 1{,}09} = \dfrac{1\text{Sk}}{(1{,}09)^2} = 0{,}842\text{Sk}$

From the above example it results that if 1 Sk is invested with an interest rate of 15%, after ten years it will have increased to 4.05 Sk. On the contrary, one crown gained as the result of investment

 DOI: 10.26730/2618-7434-2020-1-4-31

activities has the value of less than 25 halers, unless it can be gained earlier than after 10 years. The update effect is analysed in detail in Table 11.

The update process is very important in order to determine the economic efficiency of a mining venture. It is done by means of a table processor and the results are stored in tables in a compendious form. The results should clearly display the cash-flow development. The following Fig. 9 shows the effect of various update rates on the development of the current value of 1 Sk over the duration of 25 years. The higher the update rate, the lower the current value of the future money, and also the longer the time interval for the unavailability of the money, the lower the current value of such future money. It also shows the development of updated cash-flow.

Table 11. Current value of updated 8%.

Year	The current value of 1 Sk (update rate is 8%)
0	1,000
1	1,00 / (1+0,08) = 1,00 / 1,08 = 0,926
2	1,00 / $(1,08)^2$ = 1,00 / 1,17 = 0,857
3	1,00 / $(1,08)^3$ = 1,00 / 1,26 = 0,794
4	0,735
5	0,681
6	0,630
7	0,583
8	0,540
9	0,500
10	0,463

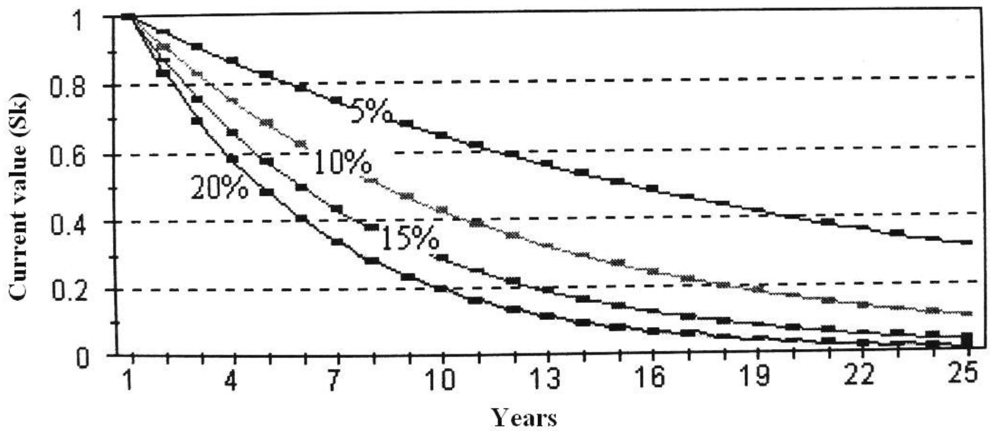


Fig. 9. The effect of 5, 10, 15 and 20% update rate on 1 Sk during 25 years.

The cash-flow indicates many economic decisions. The cash-flow update in the real time provides a realistic view on the efficiency of investments. The ignoring of the update process causes problems in evaluation, mainly in case of long term projects. The assessment without update can precisely calculate a bookkeeping state of the project. Unfortunately, without considering the update, i.e. the inflation effect, natural development of currency and other risk defining factors, it is not possible to create an accurate image of the purchase power of one crown in 10 years.

Internal Rate of Return (IRR)

 DOI: 10.26730/2618-7434-2020-1-4-31

Internal rate of return called also internal revenue rate (Internal Rate of Return - IRR) is a change of the update rate to the indicator of the economic assessment of the project. The IRR measures an effective rate of the investment return at which the investments return without producing other funds from the project, if the investments were gained from loan resources at a certain IRR interest rate. The IRR is an indicator, which considers the duration of the entire project.

The existing cash-flow IRR is an update rate, at which the current value of cash-flow is equal to zero. The IRR cannot be calculated directly, only by means of the cash-flow and update rate modelling in the table processor, in accordance with previous criteria. It can be graphically interpreted, as shown in Fig. 10; or with a change of the update rate it can approximate the already mentioned current value of the cash-flow equal to zero.

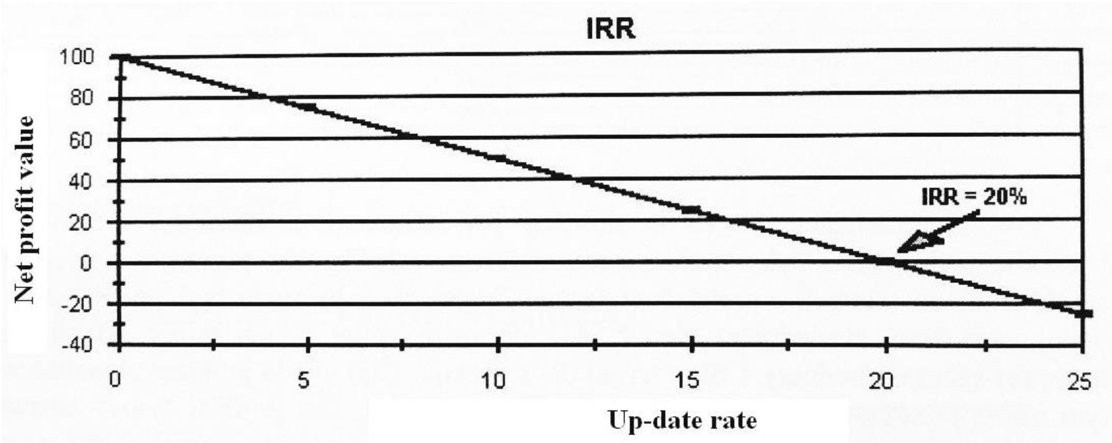


Fig.10. Graphical display of the IRR values.

The IRR is the most frequently used indicator when making an economic decision to invest. In combination with other indicators, it represents a very effective tool. The issue of the IRR will be dealt with in more detail in connection with other indicators.

Net Present Value (NPV)

On the basis of the above facts it can be stated that it is better to own one crown today than two crowns tomorrow. Money that can be gained through the investing in a year is more secure than that, which can be gained in twenty years. This is one reason why it is worth assessing the project by means of the annual updated *cash-flow*, the sum of which, dependent on the project duration, is called the *Net Present Value* (NPV).

$$NPV = \sum_{i=1}^{n} \left\{ \left(-I + CF_i \right) / (1+a)^i \right\}, \tag{23}$$

where NPV - net present value, I - investments, CF - cash-flow, a - update rate, i - current year, n - project duration.

This is the method of how to use the cash-flow and its certain rate of uncertainty expressed in the update factor (1+a), exponentiated by the distance between present day and future data. The selection of „a“ depends on the interest rate at which investments can be obtained. It is also possible to select this value in accordance with the uncertainty of predicting the future. The more accurate the future and its impact on finances can be predicted, the lower the value of „a“. Thus a theoretical limit is „0“, when the update in fact lapses. And this is the current case.

The net present value can be expressed also in a more demonstrative way, as follows:

$$NPV = (R_0 - C_0) + \frac{R_1 - C_1}{1+a} + \frac{R_2 - C_2}{(1+a)^2} + ... + \frac{R_n - C_n}{(1+a)^n}, \tag{24}$$

DOI: 10.26730/2618-7434-2020-1-4-31

where R – incomes,C – costs.

Each member in this formula represents the annual updated cash-flow in general. The more distant the future, the higher the update rate, and this fact reduces the current value of future money.

When evaluating a mining project it is important to get a positive NPV value, because when it is positive, the project brings back both invested funds and a corresponding profit under conditions of a certain uncertainty in the future and with calculating the risk, which is expressed by means of the update. If the NPV value is negative, the project should be ceased and money designed for this project should be invested somewhere else.

Another case of the NPV calculation can occur when there are not enough available funds for the project, and for the full investments budget it is necessary to also obtain other external sources. In such cases, when the part of the investments is formed by a loan with a certain interest rate, the NPV can be calculated as follows:

$$\mathrm{NPVCI} = \sum_{i=1}^{n} \left\{ \left[-(I - L) + (CF_i - rep_i) \right] / (1+a)^i \right\}, \tag{25}$$

where: NPVCI - Net Present Value of own investments, L - loan, rep - interest instalments.

The NPVCI is a result of private investments only. In case of the assessment of the economic efficiency of a mining venture it is possible to make several studies, which will vary only in the ratio between loan and private investment funds. It enables the identification of their optimum ratio, not only from the viewpoint of their profit maximization, but also from the viewpoint of considering the project risk. In certain cases it may be more suitable to use loan resources to a larger extent and deposit private funds in the area of a relatively lower risk, for example in the bank. This is the way to gain higher revenues from the same source. Another possibility is to invest private saved funds that have been replaced by the loan, into another business project. Thus more than one project can be operated using the same source.

When calculating NPV and the cash-flow as positive each year, we can compare the NPV to the earnings that could be gained by depositing our private funds in the bank. The payback period of the ROI investments from the project is in this case identical with the interest rates provided by the bank. If they are equal, it is better to deposit funds to the bank and avoid business risk.

The first problem occurs in cases where the cash-flow is not always positive, and the calculation becomes very complicated, even impossible. The comparison can only be made in cases when each annual negative cash-flow is represented as the depositing of funds in the bank account in a corresponding year. Then the comparison is the same as in case of the constantly positive cash-flow.

Another problem occurs when two projects are compared and their NPV and ROI values show the opposite trends. The NPV of the 1st project is higher that the NPV of the 2nd project and vice versa - the ROI of the 1st project is smaller than the ROI of the 2nd project (NPV1 > NPV2; ROI1 < ROI2). In this case no exact mathematical formula defining which of the two projects is better exists. The investment volume and rate of project risks are likely to play the most significant role. The project evaluator's intuition and experience as well as other arguments can affect investment decisions.

Note: As a rule, when granting loans banks prefer return on investments ROI, because as has been already mentioned, it is very similar to loan interest conditions.

On the basis of the NPV formula it is also possible to calculate the period of the return on investment. The return on investment period can be calculated using the following equation:

$$\sum_{i=1}^{n} \left\{ \left[-I + CF_i \right] / (1+a)^i \right\} = 0 \tag{26}$$

or

$$\sum_{i=1}^{n} \left\{ \left[-(I - L) + (CF_i - rep_i) \right] / (1+a)^i \right\} = 0 \tag{27}$$

it means, when the project the invested funds.

 DOI: 10.26730/2618-7434-2020-1-4-31

Coverage rate

It is very important to have positive cash at the end of the project NPV; however, it is better not to go bankrupt before. A project can be operated only under the condition that you have available cash; it means positive *cash-flow* each year. It applies also for the early project stages, when there is ether no or only very low production. This situation is characterized by the „coverage rate“ indicator.

$$coverage\ rate = \frac{cash\text{-}\ flow + interest}{instalment\ loan_i + interest_i} \tag{28}$$

If the result of *coverage rate* = CR<1, then the project is not able to settle its liabilities to the creditor in that year. The solution lies either in a sufficient amount of funds in the form of cumulative *cash-flow* (collected during previous periods) or another bridging loan compensating the difference.

Another very important above mentioned indicator is the IRR, internal rate of return. Its calculation is possible only on the basis of the already calculated NPV.

$$\mathrm{NPV} = 0 = (\mathrm{R}_0 - \mathrm{C}_0) + \frac{\mathrm{R}_1 - \mathrm{C}_1}{1+\mathrm{IRR}} + \frac{\mathrm{R}_2 - \mathrm{C}_2}{(1+\mathrm{IRR})^2} + ... + \frac{\mathrm{R}_n - \mathrm{C}_n}{(1+\mathrm{IRR})^n}\ . \tag{29}$$

As it is obvious from this relationship, and also results from the above mentioned, that the IRR is the update rate, when the Net Present Value is equal to zero. It is not easy to solve this equation, as it is necessary to come out of actually calculated NPV with a selected update rate, and only then retrospectively model the update rate to achieve NPV = 0. Another complication when calculating the NPV for the entire project is represented by the fact that also the effect of taxes enters the calculation. A tax base and tax volume is changed and R – incomes and C – costs represent a comprehensive set of data entering the cash-flow. Therefore, as mentioned above, it is again necessary to use a table processor for the calculation of the IRR.

Sensitivity Analysis

A sensitivity analysis is a method that describes the uncertainty, characteristic of each project, especially for mining projects. Along with a simple description of the uncertainty, the sensitivity analysis also reveals all the parameters that participate in defining the project strategy by means of multiple modifications of the project's economic analysis. When studying sensitivity it is possible to monitor each mentioned parameters independently, and check how its change is reflected in the final project result, but also how it is reflected during the project's course. Due to this method it is possible to develop an effective tool describing possible situations in the project development, ranging from the pessimistic to the optimistic.

The sensitivity study requires a certain input data assessment. When possible limits of uncertainty or possible intervals in the input parameter development are not defined, these parameters could have an inadequate effect on the project and other input data. This would reduce the narrative value of the analysis.

The most common input parameters for the sensitivity analysis are:

- investments,
- production volumes,
- production costs,
- product price.

Based on these input parameters their effect on the Internal Rate of Return IRR is calculated.

Even if the analysis shows a too variable effect of one or more parameters of the project, it does not mean that such a situation will occur. The input parameter interval itself does not have to be selected only in accordance with its probable development or risk, but, on the contrary, in accordance with the fact of how exactly and to what extent it is necessary to define its importance in affecting the project. It helps to focus on such reorganization of the project, that could take maximum advantage of this information and parameter effects on the project positive result maximization.

The study results can be used not only to identify the economic efficiency of the project, but having started the project, they can help to concentrate the attention of the project management on those values, which can have the biggest impact on the project implementation.

 DOI: 10.26730/2618-7434-2020-1-4-31

Spider diagram

A spider diagram (Table 12) is the final expression of sensitivity analysis results. It displays the IRR changes based on the changes of used input parameters. The degree of its effects on the IRR is shown by the rise and fall of the course of its changes on the basis of the rate of changes of the variables. Table 24 is displayed in Fig. 11.

The same method as the one used to define the sensitivity effect on the IRR can be used to define the sensitivity to other economic parameters of the project. This is, for example, the NPV coefficient.

Table 12. Data table for the spider diagram construction.

-2.50	-1.25	0	1.25	2.50	-
%	%	%	%	%	-
-	-	– *Investments*	-	-	-
7.00	14.00	20.00	26.00	33.00	IRR
-	-	– *Production*	-	-	-
24.00	21.50	19.15	17.00	15.00	IRR
-	-	Production costs	-	-	-
26.00	22.50	19.15	15.50	11.50	IRR
-	-	– *Price*	-	-	-
5.50	13.00	19.15	25.00	30.00	IRR

Optimum Lifetime of the Project

The optimum lifetime of the project is such a lifetime or production rate at which the net present value or the internal rate of return is maximized. This can be achieved only by optimisation of project costs and incomes at various production rates. The result will be significantly affected by the change of ratio between incomes and costs, mainly due to the changed ratio between variable and fixed costs.

.

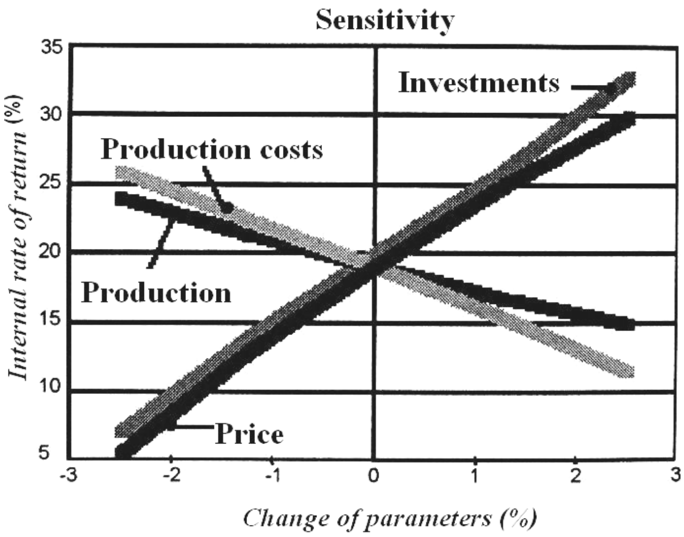


Fig. 11. Spider diagram.

The project profitability is based mainly on the following parameters:

- *cut off grade* of reserves,

DOI: 10.26730/2618-7434-2020-1-4-31

- tonnage of reserves,
- price of produced material,
- investment and production costs,
- rate of production.

As already mentioned, the *cut off grade* is the lowest value of chemism of mined reserves that ensures an economic method of extracting raw material from the deposit. The *cut off grade* is a parameter, which from the economic viewpoint is defined as a limit concentration capable of ensuring return on investment and gaining of the set profit. A decrease of *cut off grade* results in the increase in the amount of reserves, however their overall quality is then reduced. An increase of its value results in a reduction of the amount of reserves and their enhanced quality. This is reflected in changes of investment and production costs and in the change of incomes. It is obvious that each change of the *cut off grade* also affects the project lifetime, and consequently conditions for the *cash-flow* development and the overall project economy.

The *cut off grade* is the result of the deposit geological research and subsequently of the deposit model, the location, quality and quantity of which is defined within mining blocks. Then it is necessary to perform several simulations with modified *cut off grade* parameters, and check their effect on the overall deposit model. Results are used to identify the optimum *cut off grade,* and having specified the volume of reserves we can deal with the rate of production.

Incomes are estimated on the basis of market prices and forecasts of their development, on the basis of contractual prices or production prices depending on the character of the traded commodity.

Capital costs can be divided into two basic components. The first are the investments or capital needed for the project construction, i.e. to provide structures, equipment and other project components. The other is operating capital. It is created by investment costs, which are necessary for the project operation until it becomes capable of self-financing by selling its products. The operating capital is unique for each project and increases with the increase of the project volume.

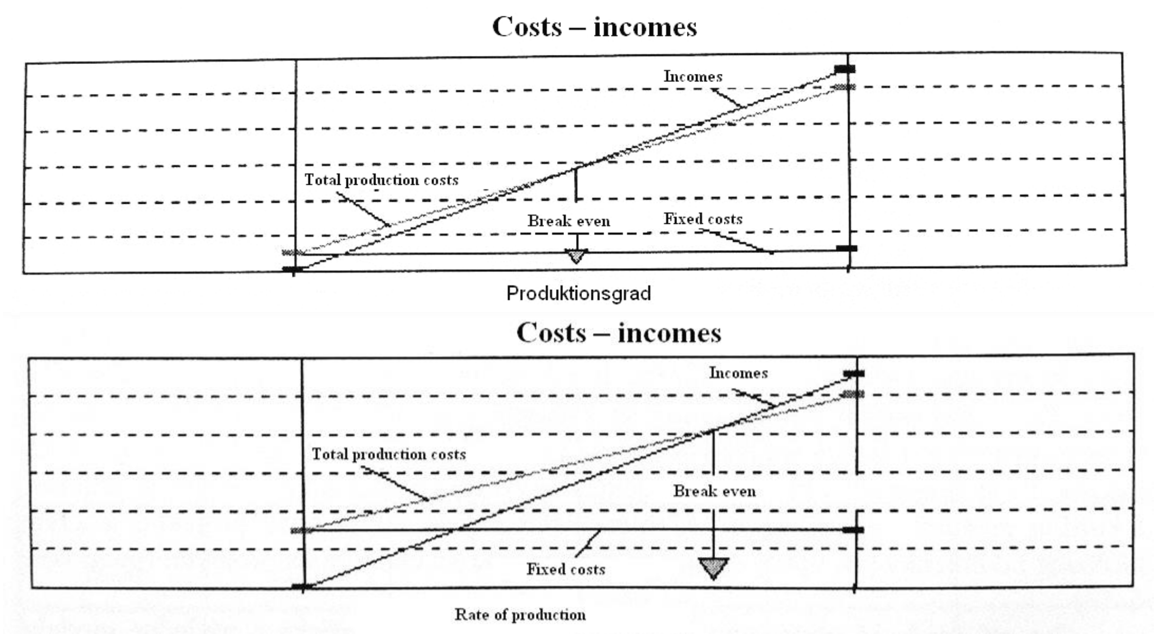


Fig. 12. «Break Even» as a ratio between production costs and incomes..

Production costs, i.e. costs for production at common project operations are also divided into two components, namely variable costs and fixed costs. Fixed costs are constant and not affected by the changed production rate. In major projects they represent about 20% or less of the total production costs. Variable costs change with the changes in the production volume and are related to the produced unit i.e. a ton. Fig. 12 displays a possible ratio between indirect or fixed costs and direct or variable costs. In

DOI: 10.26730/2618-7434-2020-1-4-31

their confrontation with incomes we can obtain the production rate at which incomes become higher than production costs. This underlines the importance of changes in the ratio between fixed costs and variable costs in favour of variable costs. The given point is called *Break Even.*

Based on the above figures it becomes obvious that the increase of the ratio of fixed costs on the overall production costs is unfavourable from the viewpoint of time of reaching break even point and hence positive cash-flow.

Dependencies between the change of the operating capital and production costs and the production rate are documented by Fig. 13 that displays data from a quarry for the extraction of gold.

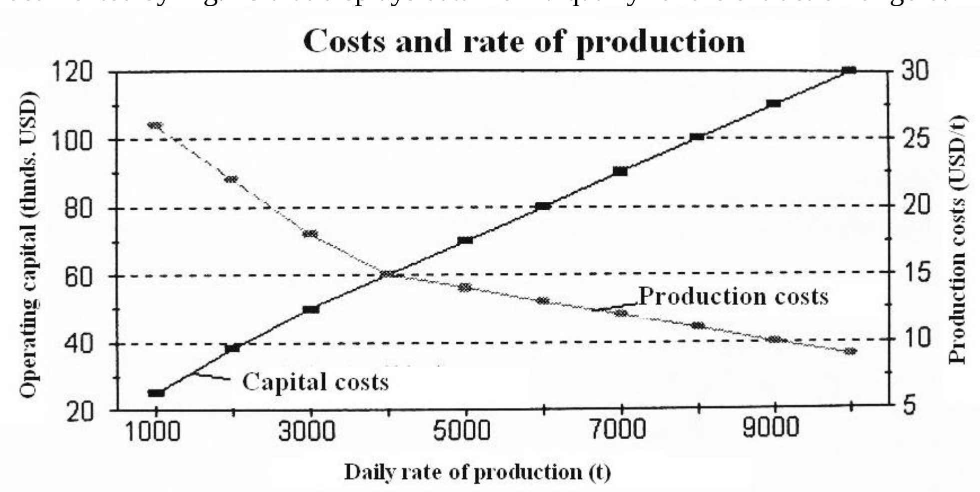


Fig. 13. Capital and production costs with the change of production rate.

Conclusion

The evaluation of the economic effectiveness of the mining business belongs in the recent economic environment between basic activities which should necessarily be done to obtain a contribution from a project from the point of view of an optimum utilisation of the Earth, human and financial resources and a contribution or minimum impact from the point of view of environmental protection.

The economic evaluation of projects focuses on the financial environment in which the aim is to invest in a project in such a way so as to gain value at its termination which refund paid in investments and at the same time to bring financial means which can be used for the further development of the firm e.g. investing into new technologies or to increase the company's assets.

The economic evaluation of projects respects recent trends in adjudicating the economic effectiveness of projects developed in the most advanced economic systems and at the same time adapts it to particular project conditions. This approach respects not only economic but also mining, geological and environmental factors and their effects on the project results, thus giving a view of the complex interrelations of all project variables. The financial analysis is also suitable due to the reason that financial experts, based on the study, have the possibility to understand whether the project is profitable and what its main risks and advantages are.

Список источников / References

1. Armstrong, M. - Dowd, P.A.: Geostatistical simulations. Proceedings of the Geosta-tistical Simulation Workshop, Fountainebleau, France. 27-28 May, 1993. Kluwer academic publishers. Dordrecht, Boston, London. 1994 s. 255.
2. Cavender, B.: Determination of the optimum lifetime of a mining project using discounted cash-flow and option pricing techniques. Mining Engineering, New York, 1992.
3. Cehlár, M. – Engel, J. – Mihók J. – Rybár, R.: Povrchové dobývanie, Edičné stredisko/AMS, F BERG, TU v Košiciach, 2005, ISBN: 80-8073-271-X
4. Ciruelos, J. - Duchene, M.: Modele sur micro-ordinateur pour l'analyse de la faisabilite financiere d'un projet minier. Industrie minérale – Les techiniques, dec. 1983.
5. Clark, I.: Practical Geostatistics. Applied Science Press, London. 1979.

6. Coube, P.: Mining microeconomics in Slovakia. Centre de Geotechnique d'Exploitation du Sous-sol, Ecole Nationale Superieure des Mines de Paris, 1993.
7. Duchene, M.: Economie de l'enterprise miniere. Lectures, Centre de Geotechnique d'Exploitation du Sous-sol, Ecole Nationale Superieure des Mines de Paris, 1990.
8. Goetz, D.: Economie de l'enterprise miniere. Lectures, Centre de Geotechnique d'Exploitation du Sous-sol, Ecole Nationale Superieure des Mines de Paris, 1995.
9. Fraser, H.A. - Richard, D.,S.: Economics of Worldwide Petroleum Production. Oil & Gas Consultants International, Inc., Oklahoma USA, 1993.
10. Gentry, D.W., O'Neil,T.J.: Mine Investment analysis. Soc. of Min. Engineers of. Am. Inst. of Min., Metall., and Petroleum Endineers. New York 1984, s. 502.
11. Krejter, V.M.: Poisky i razvedka mestoroždenij poleznych iskopajemych. Gosudarst-vennoje naučno-techničeskoje izdateľstvo literatury po geologiji i ochrane nedr. Moskva, 1961.
12. Kudelas, D., Rybár, R.: Pneumaticko-akumulačný systém umožňujúci využívanie nízkopotenciálovej veternej energie na dodávku elektrickej energie, AT&P Journal, Bratislava 5/2005, ISSN 1335 – 2237.
13. Kudelas, D., - Rybár, R.: Technická analýza vhodnosti využitia rôznych typov veterných rotorov pre pohon kompresora akumulačného systému umožňujúceho využitie nízkopotenciálnej veternej energie. Acta Montanistica Slovaca, Košice 1/2005, ISSN 1335-1788.
14. Kudelas, D., Rybár, R., Tauš, P.: Reálne možnosti využitie veternej energie na Slovensku. Časopis Elektroenergetika, Bratislava 2/2005.
15. Němec,V. - Rybár, P.: Návrh využití ložiskových a těžebních modelů v podmínkách ČSSR. Zb. Hornická Příbram ve vědě a technice, mat. metody v geologii. Přibram, 1987.
16. O'Hara, T.A. - Suboleski, S.C.: Cost and Cost Estimation. SME Mining Engineering Handbook, 2nd Edition, 1992.
17. OSN, Ekonomická komisia pre Európu: Systém medzinárodnej klasifikácie zásob a zdrojov. 20, 1997.
18. Rybár, P.: Ohodnocovanie ložísk nerastných surovín pre privatizačné účely. Bul. SBS. Banská Bystrica 1995, s. 27-32.
19. Rybár, P.: Plánovanie a riadenie ťažby v lomoch pomocou počítačových modelov. Acta Montanistica Slovaca. Roč.1, č.1. Košice, 1996, s.13-19.
20. Rybár, P.: Zemské zdroje. Monografia. Acta Montanistica Slovaca. Roč.2, 1997, č.1., s.1-53.
21. Rybár, P.: Automatizácia plánovania a riadenia ťažby v lomovom dobývaní (1). AT&P Journal 2, 1997, Bratislava, s. 29-30.
22. Rybár, P.: Automatizácia plánovania a riadenia ťažby v lomovom dobývaní (2). AT&P Journal 3, 1997, Bratislava, s. 28-30.
23. Rybár, P.: Plánovanie a riadenie ťažby v lomoch pomocou počítačových modelov. 9 Medzinárodná banícka konferencia. Zb. Dobývanie ložísk nerastov, využívanie a ochrana zemských zdrojov, podzemné staviteľstvo a geotechnika, ISBN 80-88896-03-7. Košice, 1997, s. 12-16.
24. Rybár, P. – Cehlár, M.: Economic Evaluations of Mining Projects. Szkola Ekonomiki i zarzadzania w Gornictwie 97. Ustroň, 1997. s. 461 – 475.
25. Rybár, P. - Hronec, J.: Banpor ver. 1.0. Počítačový program pre plánovanie a riadenie ťažby vo vápencovom lome Vajarská, HIROCEM a.s. Rohožník. F BERG Košice, 1994.
26. Rybár, P. - Hronec, J.: BANPOR ver.2.0. Počítačový program pre plánovanie a riadenie ťažby v ložiskách korekčných ílov Hrabník a Konopiská, HIROCEM a.s. Rohožník. F BERG Košice, 1996.
27. Rybár, P. - Hronec, J.: BANPOR ver. 3.0. Počítačový program pre plánovanie a riadenie ťažby na ložiskách cementárskych surovín v podmienkach HIROCEM a.s. Ro-hožník. F BERG TU Košice, 1998.
28. Rybár, P. - Malindžák, D.: Plánovanie a riadenie ťažby pomocou heuristických modelov. Ostrava, 1998.
29. Rybár, P. - Sasvári, T.: Zem a zemské zdroje. Vysokoškolská učebnica pre študentov 1. ročníka F BERG. Vyd. Štroffek, Košice, 1998. s. 175.
30. Rybár, P. – Oreská Ľ.: Computer planning and control of mining cement raw materials in open pits of Hirocem a.s. Rohoznik. Slovakia. 17th World Mining Congress 1997, Acapulco, Mexiko. s. 703.
31. Rybár, R., Kudelas, D.: Posudzovanie konfigurácie kolektorového poľa z pohľadu insolácie. Časopis Elektroenergetika, Bratislava 2/2005.
32. Rybár, R., Kudelas, D., Fischer, G.: Alternatívne zdroje energie 3, 1. vyd. - Košice : Edičné stredisko/AMS, 2004. - 99 s. - 1. vyd.. - ISBN 80-8073-144-6.
33. Rybár, R., Tauš, P., Kudelas, D.: Využívanie solárnych zariadení na ohrev TÚV v mestskej zástavbe Košíc. AT&P Journal, Bratislava 3/2005, ISSN 1335 – 2237.
34. Seják, J. a kol.: Oceňování pozemku a přírodních zdrojů. Grada Publishing 1999.
35. Soukup, B.,: Hodnocení nerostných ložisek a geologického průzkumu. Academia Praha, 1988, s. 130.

DOI: 10.26730/2618-7434-2020-1-4-31

36. Torries, Th.F.: Evaluating Mineral Projects: Applications and Misconceptions. Soc. for Min., Metal. and Exploration, Littleton, 1997, s. 153.
37. Wackernagel, H.: Multivaiate geostatistics. Springer Verlag. Berlin, Heidelberg, 1995, s. 232.

Авторы

Михал Цехлар,
декан факультета горного дела, экологии, контроля процессов и геотехнологий,
e-mail: michal.cehlar@tuke.sk
Технический университет Кошице, республика Словакия

Павол Рыбар,
доктор технических наук, профессор факультета горного дела, экологии, контроля процессов и геотехнологий,
e-mail: pavol.rybar@tuke.sk
Технический университет Кошице, республика Словакия

Ян Михок,
инженер,
e-mail: jan.mihok@gmail.com
Компания «Сидерит», республика Словакия

Яцек Энгел,
доктор технических наук, профессор факультета горного дела, экологии, контроля процессов и геотехнологий,
e-mail: jacek.engel@tuke.sk
Технический университет Кошице, республика Словакия

Authors

Michal Cehlár,
Dean of the Faculty of Mining, Ecology, Process Control and Geotechnologies
e-mail: michal.cehlar@tuke.sk
Technical University of Kosice, Slovak Republic

Pavol Rybár,
Dr.h.c., Professor of the Faculty of Mining, Ecology, Process Control and Geotechnologies
e-mail: pavol.rybar@tuke.sk
Technical University of Kosice, Slovak Republic

Ján Mihók,
Engineer,
e-mail: jan.mihok@gmail.com
ŽELBA, š.p., odštepný závod SIDERIT

Jacek Engel,
Dr.h.c., Professor of the Faculty of Mining, Ecology, Process Control and Geotechnologies
e-mail: jacek.engel@tuke.sk
Technical University of Kosice, Slovak Republic

Библиографическое описание статьи

Цехлар М., Рыбар П., Михок Я., Энгель Я. Анализ инвестиций в горнодобывающую промышленность // Техника и технология горного дела. – 2020. – № 1 (8). – С. 4-31.

Cite this article

Cehlár, M., Rybár, P., Mihók, J., and Engel, J. (2020) Analysis of investments in the mining industry, *Journal of mining and geotechnical engineering*, 1(8):4.