Investment project efficiency and risk evaluation: an integrated approach

Maria A. Shtefan
Head of Department of Accounting, Analysis and Audit
National Research University Higher School of Economics
Address: 25/12, Bolshaya Pecherskaya Street, Nizhny Novgorod, 603155, Russia
E-mail: shtefanmaria@yandex.ru

Julia M. Elizarova
Student, Economics MSc Program
National Research University Higher School of Economics
Address: 25/12, Bolshaya Pecherskaya Street, Nizhny Novgorod, 603155, Russia
E-mail: elizarova-julia7@yandex.ru

Abstract

While evaluating and selecting investment projects, modern companies are confronted with the problem of setting priorities between profitability and riskiness of these projects. Choice of a project on the basis of its profitability significantly increases risks of financial and economic activities and decreases the certainty of achieving the planned financial result. On the other hand, attempts to decrease investment projects risks may not allow one to achieve the desired profitability level. Therefore, it is vital to develop integrated multi-criteria indicators for this purpose.

This article is the result of the authors' development of an integral indicator for evaluating investment project efficiency and risks. The developed integral indicator has a matrix form. To compile the integral indicator, three groups of criteria are used: quantitative efficiency criteria, qualitative efficiency criteria and risk evaluation criteria. We propose to divide the qualitative and quantitative criteria into: 1) those defining the commercial (economic) efficiency of projects, 2) those defining their budgetary efficiency; 3) those defining their social efficiency. According to the authors, the list of criteria that define associated risks should include macroeconomic indicators and industry affiliation indicators that provide a comprehensive evaluation of the external economic situation on the corresponding market.

While evaluating efficiency and riskiness of the given projects, the integral indicator developed by the authors is converted from matrix form into a quantitative indicator that is easy to interpret. The authors propose to use principal component analysis and heuristic methods (including ranking method and hierarchy analysis method) for this purpose.

The results of this research can be used by companies to select investment projects.

Key words: investment project; automation of management decisions; integral indicator; efficiency evaluation; risk evaluation; principal component analysis.

Citation: Shtefan M.A., Elizarova J.M. (2018) Investment project efficiency and risk evaluation: an integrated approach. *Business Informatics*, no. 4 (46), pp. 54–65.
DOI: 10.17323/1998-0663.2018.4.54.65

Introduction

The problem of choosing the optimal investment project from various alternatives is becoming increasingly important for modern companies. A decision based on project profitability and focused on raising this value increases risks of financial and economic activities and decreases the certainty of achieving the planned financial result. On the other hand, choosing a less risky project is not much justified from the point of view of profitability because this decision can negatively affect not only the company's profitability, but also its operational efficiency as a whole. Therefore, both multi-criteria evaluation of investment project efficiency and integrated assessment of investment project efficiency and risks gain importance.

The article analyzes the evaluation criteria for investment project efficiency described in special literature as well as project risk evaluation methods. This allows us to develop an integral indicator that comprises three groups of efficiency and risk evaluation criteria. The authors also develop a method of converting the integral indicator into a final (quantitative) indicator by using heuristic and mathematical methods. The results of this research can be used to select the optimal investment project from various alternatives.

1. Review of the investment project evaluation criteria and methods proposed in special literature

Nowadays the combination of efficiency and risks criteria for comprehensive integral evaluation of investment projects is only rarely described in special literature. There are a significant number of articles featuring the problem of selecting and calculating efficiency criteria for investment projects, but the risk evaluation aspect is not reflected in these sources. For example, articles [1; 2] propose a general approach to efficiency evaluation and justify its necessity, textbooks [3; 4] describe the main criteria of investment project efficiency, article [5] highlights particularities of their usage, their advantages and disadvantages, and article [6] reveals multi-criteria methods of efficiency evaluation. It is important to mention that the researchers mostly focus on using quantitative criteria while qualitative criteria of project efficiency evaluation (such as the need for government support, the need to develop and implement additional innovations, the need to employ additional staff, among other needs) are hardly analyzed in special literature. However, the qualitative characteristics of projects often play a crucial role in deciding whether it is expedient to invest. Moreover, the quantitative criteria of efficiency evaluation described in the analyzed sources are usually limited to the indicators of commercial (economic) efficiency of a project while the questions of budgetary and social efficiency (which are vital for comprehensive evaluation) are hardly analyzed in special literature.

The author of article [7] proposes to create a unified integral indicator for investment project efficiency evaluation. In his opinion, to calculate it one should also take into consideration the quantitative criteria of investment project commercial efficiency which affect the organization's financial and economic activities: capital productivity, profit growth rate, total liquidity ratio, financial stability index, etc. The integral indicator model is based on selection and complex combination of different types of criteria, with further reduction of the analytical results to a single indicator on the basis of each criterion's weight calculation.

Article [8] presents a more complex mechanism for integral evaluation of project efficiency. This mechanism can be simply represented as scaling the indicators reflecting the main characteristics of an investment project: the total discounted income from sales, the payback period and the resource costs for implementation. In our opinion, the drawback of this method is the limited number of investment project efficiency criteria which does not allow us to make a comprehensive evaluation and to draw correct conclusions.

Article [9] highlights the theoretical-probabilistic methodological approach to investment project efficiency evaluation on the basis of scenario analysis. This approach uses indicators calculated on the basis of cash flows from the company's various activities, which does not allow us to take into consideration a number of important qualitative factors.

In order to rank the efficiency criteria from the point of view of their importance for the decision-making process, modern authors often propose to use various algorithms of expert ranking: the hierarchy analysis method [4; 10], the simple ranking method [11], the Steinhaus algorithm [12], the Steinhaus–Ford–Johnson algorithm [12], the tournament algorithm [12].

As for investment project risks, special literature focuses on studying special methods of their evaluation without studying the risk evaluation criteria themselves. One of the most popular risk evaluation methods is the Hiller model that associates the project risk with cash flow variances [13]. Articles [14–16] present widely used methods such as the method of expert evaluations, the statistical method, the stability test method, scenario analysis, the decision tree method and Monte Carlo simulations. Article [17] describes the sensitivity analysis used for risk evaluation under uncertainty. Article [18] highlights the algorithm for identifying different types of risks and adjusting the key indicator of investment project efficiency evaluation – NPV (net present value), by using those identified types. The drawback of this approach is that the risk adjustment algorithm is available only for one indicator, on the basis of which it is not expedient to make a decision on a project.

Thus, analysis of special literature shows that integral evaluation of investment project efficiency and risks is hardly mentioned. One of the few attempts to include the risks factor into investment project efficiency evaluation is reflected in article [16]. The author of the article analyzes various methods of investment project risks evaluation and proposes the means to eliminate the drawbacks of using them. However, the methods analyzed by the author cannot be used as criteria for integral evaluation of investment risks, which once again emphasizes the relevance of the article presented here.

2. Formation and calculation of the integral indicator for investment project efficiency and risks evaluation

Development of an integral indicator for investment project efficiency and risks evaluation begins with selection of the necessary criteria. It is important to include in the indicator not only quantitative, but also qualitative evaluation criteria, which will allow us to evaluate investment projects from different angles.

The integral indicator is calculated on the basis of the values of three particular criteria vectors. The dimension of each vector is n_1, n_2 and n_3 respectively:

$$\mathbf{p} = \left[p_1, p_2, \ldots, p_{n_1}\right];$$
$$\mathbf{q} = \left[q_1, q_2, \ldots, q_{n_2}\right];$$
$$\mathbf{r} = \left[r_1, r_2, \ldots, r_{n_3}\right].$$

The elements of the **p**, **q** and **r** vectors correspond to the following criteria groups:

p – qualitative criteria of efficiency evaluation;

q – quantitative criteria of efficiency evaluation;

r – criteria of risk evaluation.

The quantitative and qualitative criteria of investment project efficiency evaluation (elements of the **p** and **q** vectors) include criteria that determine commercial (economic), budgetary and social efficiency (*Table 1*).

The list of elements in the third group reflecting investment project risks (**r**) is determined for each project individually. It can include macroeconomic indicators as well as industry affiliation indicators of a project which provide a comprehensive evaluation of the external economic situation on the market.

To choose the most suitable investment project from various alternatives, it is necessary to compare the most significant elements of the **p**, **q** and **r** vectors to the less significant elements of these vectors. To make such a comparison possible, it is necessary to ensure the same dimension for the three vectors: $n_1 = n_2 = n_3$.

The normative (recommended) values of the quantitative indicators in *Table 1* are determined on the basis of the well-established investment approaches described in special scientific and practical literature [3]. The values of the qualitative indicators are determined on the basis of expert evaluation using a three-level scale: value 3 (the highest) is the best, value 1 (the lowest) is the worst.

It is worth mentioning that not all of the efficiency evaluation criteria presented in *Table 1* are universal, for some of them are industry specific, and some of them may not be acceptable for evaluation of small projects implemented by small and medium-sized businesses which do not have a global impact on the economy of their regions or cities. Therefore, we developed recommendations for selecting criteria of investment projects and their associated risk evaluation in order to form the criteria vectors **p**, **q** and **r**.

2.1. Formation of the quantitative criteria vector (p)

Selection of quantitative efficiency criteria depends on the qualitative characteristics of the project itself (scale, urgency, risk level, etc.). The number of criteria forming the **p** vector is determined in accordance with the recommendations specified in *Table 2* that was compiled by the authors using the information about one-criteria evaluation methods described in special literature [3].

In accordance with these recommendations, it is necessary to take into consideration that the dimension of the **p** vector equals to the sum of the economic, budgetary and social efficiency criteria.

Economic efficiency criteria are determined on the basis of the recommendations specified in *Table 2* while budgetary and social efficiency criteria are included in the vector as a whole (*Table 1*).

Ranking of the criteria that are part of the **p** vector is necessary in order to compare the most important elements of one vector to the most important elements of another vector. Such ranking is performed through expert assignment of weights to each of the criteria under consideration.

2.2. Formation of the qualitative criteria vector (q)

The dimension n_2 of the **q** vector is determined on the basis of the **p** vector dimension, i.e. n_2 shall be equal to n_1 ($n_2 = n_1$).

To select the suitable number of the **q** vector elements, it is also necessary to rank its elements in order to select the most important ones. In this case, the ranking helps not only to determine the vector dimension, but also to assign weights to the elements for their further comparison.

In our opinion, the most suitable ranking method is expert evaluation of the qualitative criteria weights and assignment of values from 1 to 3 to them in order to show conformity (or non-conformity) of the criterion value with the recommended one (*Table 3*).

2.3. Formation of the risc evaluation criteria vector (r)

The dimension n_3 of the **r** vector is determined by the same method as the dimension

Table 1.

Groups and criteria of investment project efficiency and risks evaluation

Group of criteria	Efficiency criterion	Criterion type	Criterion calculation method, essence	Recommended (normative) value
Commercial (economic)	Payback period	Quantitative	Determination of the period during which the investment costs are covered with the net cash returns from the project	< Intended project implementation period
	Average profitability	Quantitative	Calculation of the average profitability of the invested funds on the basis of predictable values	>0
	Profitability index	Quantitative	Comparison of the current evaluation of future net cash flows and the current investment costs	>1
	Net Present Value (NPV)	Quantitative	Comparison of the investment amount and the current evaluation of future net cash flows for each year of project implementation	>0
	Internal Rate of Return (IRR)	Quantitative	Calculation of the discount rate that makes the Net Present Value equal to zero	>WACC (weighted average cost of capital)
	Accounting Rate of Return (ARR)	Quantitative	Comparison of the average annual profit and the average investment amount	>WACC
	Modified Internal Rate of Return(MIRR)	Quantitative	Search for the discount rate which balances the future revenue evaluation and the current evaluation of project costs	>WACC
	Discounted Payback Period (DPP)	Quantitative	Calculation of the discounted payback period for investments on the basis of the payback period indicator which takes into account the time aspect	< Intended project implementation period
	Complexity and cost of the project	Qualitative	Degree of need for material resources for project implementation	≥2
	Need for technological innovations	Qualitative	Degree of need for innovations at each project implementation stage	≥2
	Presence of buyers	Qualitative	Awareness of potential buyers presence	≥2
	Need for additional infrastructural facilities	Qualitative	Degree of need to build additional i nfrastructural facilities	3
	The company's competitiveness	Qualitative	Level of the company's competitiveness	≥2
Budgetary	Share of export duties (taxes) in the prime cost of products	Quantitative	Share of cash spent on export duties (or any other tax types)	<7% [1]
	Level of government support	Qualitative	Tax benefits granted for project implementation	≥2

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[1] The recommended value of the indicator may be changed in accordance with the professional opinion of the persons making investment decisions (depending on the situation inside the company)

Group of criteria	Efficiency criterion	Criterion type	Criterion calculation method, essence	Recommended (normative) value
Social	Share of innovation costs (the industrial production index)	Quantitative	Cash spent on socially significant innovations accompanying the project	<10%[1]
	Amount of significant social programs	Quantitative	Significant social programs which are introduced for the purpose of project implementation	>1
	Need to employ new staff	Qualitative	Degree of need to employ new staff (who have not been previously employed by the company)	3

Table 2.

Recommendations for selecting elements of the quantitative criteria vector (p) for investment projects evaluation

		Criteria							
		Payback period	Average profitability	Net present value (NPV)	Profitability index	Internal rate of return (IRR)	Accounting rate of return (ARR)	Modified internal rate of return (MIRR)	Discounted payback period (DPP)
Scale of investment	Small	+	+	+	+	+	+, if all projects are of the same category	+, if all projects are of the same category	+
	Traditional	+	+	+	+	+			+
	Large	–	+	+	+	+			–
	Megaprojects	–	+	+	+	+			–
Time period	Short–term	–	+	+	+	+	+	+, if all projects are of the same category	+
	Medium–term	+	+	+	+	+	+		+
	Long–term	–	–	+	+	+	–		+
Risk level	Risk–free	–	+	+	+	+	–		+
	Risky	+	+	+	+	+	+	+	+
Composition	Monoprojects	+	+	+	+	+	+	+	+
	Multiprojects	–	+	+	+	–	+	–	–
	Megaprojects	–	+	+	+	–	+	–	–
Correlation level	Independent	+	+	+	+	+	–	+	+
	Alternative	+	–	+	+	–	–	–	+
	Interconnected	+	+	+	–	+	+	+	+

(n_2) of the **q** vector. Similarly, the elements should be ranked using expert evaluation.

Weights of the vector **r** elements should be dynamic because, as was already mentioned above, risk depends more on the macroeconomic indicators, and these values can vary from one period to another. To this end, we propose to apply principal component analysis (PCA) which is realized in the mathematical package Stata and for which it is necessary to:

1. Identify 15–20 risk types typical of the analyzed investment project (for example, risks of drastic changes in the macroeconomic situation, industrial market risks, risks of reduced demand for the company's products, environmental risks, etc.);

2. Assign to the selected risk types measurable statistical indicators whose changes cause these risks (for example, currency exchange rates, GDP level, refinancing rate, number of possible rivals on the market, indicators of the actual volume of manufactured products and manufacturing facilities, etc). Information can be found in the data from the Russian Federal State Statistics Service (Rosstat) and the Central Bank, as well as in the company's statistics;

3. Perform normalization of the values of the variables against the interval [0, 10], where "0" corresponds to the lowest risk level of the indicator and "10" to the highest;

4. Identify the number of required principal components depending on the number of required risk groups, taking into account the p vector dimension which is determined by the number of quantitative efficiency criteria;

5. Construct a matrix of correlations between

Table 3.

Values of weights of the qualitative criteria vector (q) elements

Criterion	Low value (1)	Intermediate value (2)	High value (3)
Complexity and cost of project implementation	Project implementation requires significant material investment	Project implementation requires material investment, but not very significant	Project implementation does not require material investment
Need for technological innovations	Technological innovations are needed at each stage of project implementation	Technological innovations are needed only at the first stage of project implementation	Innovations are not needed
Presence of potential buyers	Unclear who will buy the product	There are a number of potential buyers	There are a large number of potential buyers
Need for additional investment into the infrastructure	Significant additional investment into the infrastructure is needed	Some additional investment into the infrastructure is needed	The required infrastructure already exists
Competition level on the market	The company is hardly competitive	There is some competition on the market	The company is the market leader
Need to employ new staff	A large number of new staff is needed	Some new staff is needed	All the required staff are already employed
Government support	None	Tax benefits may be granted	Tax benefits, government guarantees and discounts for purchasing raw materials may be granted

the selected principal components and the variables that are chosen in item 2. While interpreting the results, it is necessary to use only those variables whose correlation with the principal components is sufficient, i.e. falls within the ranges $(-\infty; -0.3]$ and $[0.3; +\infty)$.

It is worth noting that for a thorough content interpretation of the results obtained, it is important not only to ensure correlation between the components and a certain set of variables, but also to obtain separate clusters of variables that hardly intersect. In order to achieve this, a component loading rotation matrix is constructed, the main rotation methods being Varimax, Quartimax, Equimax, Direct oblimin, Promax [19].

6. Make sure it is expedient to use PCA in relation to the data set used by using the Kaiser–Meyer–Olkin measure of sampling adequacy. If the value of the KMO statistics is more than 0.5, the use of PCA is expedient;

7. Interpret the results for each risk type that is typical of the investment project under analysis. To this end, it is necessary to refer to the compiled correlation matrix, using one of the above rotation methods. Content interpretation is performed on the basis of conceptual combination of the corresponding variables for each component;

8. Calculate the values of the modified principal components which are linear combinations of the normalized values of each indicator at a given time with the squares of the correlation matrix weights [20];

9. Define weights of each risks group.

After identifying the risk groups that can affect the investment projects being analyzed, their recommended values are determined on the basis of preliminary expert conclusion, taking into consideration the individual features of the project.

Thus, the econometric and heuristic methods have formed three criteria vectors (**p**, **q** and **r**) of the equal dimension $n_1 = n_2 = n_3 = n$.

2.4. Formation of the integral indicator for investment project evaluation

To form the integral indicator, we introduce a new vector **f** that is integral for the three criteria groups analyzed above (**p**, **q** and **r**):

$$\mathbf{f} = [f_1, f_2, ..., f_n].$$

To form the **f** vector, we convert all the values of the criteria of investment projects and their associated risks evaluation into a binary form:

- ✦ binary value “0” is assigned to a criterion whose value is lower than the normative one;
- ✦ binary value “1” is assigned to a criterion whose value complies with the recommended one.

The normative values for each element of the **p** and **q** vectors are described above while the normative values for the **r** vector are formed in accordance with the company’s industry affiliation. Values of the qualitative indicators are formed by the company by using expert evaluation.

Then each set of three values (one from each of the three criteria groups) is converted into the corresponding value of the **f** vector:

$$p_i, q_i, r_i \rightarrow f_i,$$

where p_i, q_i, r_i are the i-th binary values of the **p**, **q** and **r** vectors respectively ($i = 1, 2, ..., n$).

Each set of three binary values of the **p**, **q** and **r** vectors is converted into a binary value of the corresponding element of the **f** vector according to the following algorithm.

The elements of each vector (**p**, **q** and **r**) are arranged in importance-descending order. Then each vector is divided into two equal parts: the first one includes more important criteria (with numbers from 1 to m, where $m = n / 2$) while the second one includes less important criteria (with numbers from $m + 1$ to n). If the total number of the criteria is even, preference is given to the first group (m is rounded up to the next whole number).

Each of the **p**, **q** and **r** vectors is divided into two parts to order to enable calculation of the final integral indicator value as an arithmetic sum of the **f** vector binary values. More important criteria (with numbers from 1 to *m*) are subject to a stricter rule of obtaining the "positive" (equal to 1) value of the **f** vector: element f_i is assigned binary value "1" if at least two elements of the corresponding set of three (p_i, q_i, r_i) have binary values "1" (otherwise, element f_i is assigned binary value "0"). At the same time, in the case of less important criteria (with numbers from $m+1$ to *n*) elements of the **f** vector are assigned binary value "1" if at least one element of the corresponding set of three (p_i, q_i, r_i) has binary value "1".

As a result, we calculate the integral indicator value T which is an arithmetic sum of the binary values of all elements of the vector **f**:

$$T = \sum_{i=1}^{n} f_i ,$$

where f_i is the binary value of the i-th element of the **f** vector.

A simple rule is used for interpreting the integral indicator value: if $T > n/2$ (i.e. if the majority of binary values f_i are equal to 1), then the investment project is recommended for implementation, otherwise (if $T \leq n/2$) the project is rejected.

3. Approbation of the integral indicator for investment project evaluation

Approbation of the proposed integral indicator calculation method will be carried out on the basis of the data from an investment project of the oil and gas industry. Let us suppose that a certain company considers a project of purchasing a beamless pumping unit for oil extraction, the project implementation period being 15 years.

We start with forming the quantitative evaluation criteria vector **p**. The project has the following qualitative characteristics: it is a traditional, long-term, risky, alternative monoproject. In accordance with *Table 2*, the criteria of net present value (NPV), profitability index and discounted payback period (DPP) can be used to evaluate the economic efficiency of the project. Moreover, we propose to use additional budgetary and social efficiency criteria: the mineral tax share in the profits, the number of significant social programs and cost of innovations. It is worth mentioning that the mineral tax criterion is connected to the industry affiliation of the project.

The quantitative efficiency criteria are ranked using expert evaluation in descending order: NPV, number of significant social programs, DPP, cost of innovations, profitability index, mineral tax share in the profits. As a result, the dimension of the **p** vector is equal to 6.

The qualitative efficiency criteria are also ranked in the following order: complexity and cost of project implementation, need for technological innovations, competition level on the market, presence of potential buyers, government support, need to employ new staff.

The actual values of the chosen quantitative and qualitative efficiency criteria are presented in *Table 4*.

To identify and rank the risks evaluation criteria, we will use principal component analysis. Theoretical qualitative analysis helped to identify 16 risk types that investment projects in the oil and gas industry are exposed to. The risk types were then assigned measurable statistical indicators whose changes cause these risks. By calculating the variance of each indicator, it was revealed that the greatest variability from 2005 to 2016 was shown by the USD to Russian Ruble exchange rate (*doll*), the producer price index (*ippp*), the oil price (*price*), the refinancing rate (*r*), the GDP (*gdp*), the volume of petroleum products export (*exp*), the volume of oil extraction (*extr*), the number of operating companies in the oil industry (*q*), emission of pollutants into the atmosphere (*pollution*). The values of these variables were normalized into the interval [0, 10], where 0 corresponds to the lowest risk level of the indicator while 10 to the highest one. For the next step, we select 6 components which constitute more than 96% of the sample.

Table 4.

Identification of principal components

Components	Importance	Cumulative value
Component 1	0.4733	0.4733
Component 2	0.1875	0.6608
Component 3	0.1207	0.7815
Component 4	0.0764	0.8580
Component 5	0.0688	0.9267
Component 6	0.0429	0.9696
Component 7	0.0172	0.9869
Component 8	0.0093	0.9961
Component 9	0.0039	1.0000

Further on, we determine a matrix of correlations between the identified principal components and all the variables. To interpret the results, we will only use those variables whose correlation with the obtained components is sufficiently large: more than 0.3 or less than –0.3. Application of several rotation methods (Varimax, Quartimax, Equimax, Direct Oblimin, Promax) shows that the best results for interpretation are obtained through the Promax method (*Table 5*).

While checking with the Kaiser–Meyer–Olkin measure of sampling adequacy, it turned out that the value of KMO statistics is > 0.5, which means that application of PCA is expedient.

Table 5.

Promax rotation matrix

Variables	Component 1	Component 2	Component 3	Component 4	Component 5	Component 6
doll		0.859				
ippp				0.984		
price	0.716	–0.422				
gdp	0.476					
r	–0.451					
exp			0.968			
extr						0.994
q						
pollution					0.991	

Table 6 represents interpretation of each risk group and provides the values that are recommended for them:

Table 6.

Recommended values of the selected risk evaluation criteria

Components	Designation (interpretation)	Recommended (normative) value
Component 1	Risks associated with changes in the economic situation of the country	Almost none, due to favorable trends in the economic situation of the country
Component 2	Risks associated with price volatility	The price volatility in the last few years has been low
Component 3	Risks associated with the petroleum products export volume	Export is without interruption
Component 4	Risks of price changes with the production structure being unchanged	Prices are relatively constant with the production structure being unchanged
Component 5	Environmental risks	None
Component 6	Risks of changes in the extraction volumes	Significant changes in the extraction volumes are not expected

The equations of weights to rank the risk groups are as follows (the calculation takes into account the values of the parameters for the 4th quarter of 2017):

$$v_1 = 0.716^2 \cdot y_{price} + 0.476^2 \cdot y_{gdp} + 0.451^2 \cdot y_r =$$
$$= 0.716^2 \cdot 8.29 + 0.476^2 \cdot 0 + 0.451^2 \cdot 0.476 = 4.349$$

$$v_2 = 0.859^2 \cdot y_{doll} + 0.422^2 \cdot y_{price} =$$
$$= 0.859^2 \cdot 10 + 0.422^2 \cdot 8.29 = 8.859$$

$$v_3 = 0.968^2 \cdot y_{exp} = 0.968^2 \cdot 4.95 = 4.638$$

$$v_4 = 0.984^2 \cdot y_{ippp} = 0.984^2 \cdot 4.81 = 4.657$$

$$v_5 = 0.991^2 \cdot y_{pollution} = 0.991^2 \cdot 0 = 0$$

$$v_6 = 0.994^2 \cdot y_{extr} = 0.994^2 \cdot 1.35 = 1.334.$$

The actual values obtained on the basis of the company's expert evaluations for each risk type as well as conversion of the actual values of each criterion into binary values are presented in *Table 7.*

Then we form the **p**, **q** и **r** vectors on the basis of which the integral indicator value *T* is calculated by using the proposed algorithm:

$$\mathbf{p} = [1;\ 1;\ 1;\ 1;\ 1;\ 0]$$
$$\mathbf{q} = [1;\ 1;\ 0;\ 0;\ 1;\ 0]$$
$$\mathbf{r} = [0;\ 1;\ 0;\ 1;\ 1;\ 1]$$
$$\downarrow$$
$$\mathbf{f} = [0;\ 1;\ 0;\ 1;\ 1;\ 0]$$
$$\downarrow$$
$$\mathrm{T} = 3$$

As the value of the project efficiency integral indicator is equal to 3, the analyzed investment project is not recommended for implementation.

Conclusion

The proposed approach to evaluation of investment projects and identification of the preferable implementation variant enables us to solve the problem that companies are often confronted with: choosing between a more efficient project and a less risky one. The integral indicator developed here includes criteria of qualitative and quantitative efficiency as well as criteria for risk evaluation. In addition, the authors give recommendations concerning application of PCA to identify the groups of investment project risks in accordance with industry affiliation of the project as well as determination of weights for these groups. ■

Table 7.

Conversion of the actual values of the project efficiency criteria into binary values

Criterion type	Criterion rank	Criterion designation	Actual value	Binary value
Quantitative efficiency criteria	1	NPV (rubles)	37 328 670	1
	2	Number of significant social programs	2	1
	3	DPP (years)	12	1
	4	Share of innovation costs (%)	7	1
	5	Profitability index (%)	118	1
	6	Share of the mineral tax in the profits (%)	8.5	0
Qualitative efficiency criteria	1	Complexity and cost of new field development	2	1
	2	Need for technological innovations	3	1
	3	Level of competition on the market	1	0
	4	Presence of potential buyers	1	0
	5	Government support	2	1
	6	Need to employ new staff	1	0
Risk evaluation criteria	1	Risks associated with unstable prices	High price volatility	0
	2	Risks of price changes with the production structure being unchanged	Prices are constant with the production structure being unchanged	1
	3	Risks associated with the petroleum products export volume	There are problems with export	0
	4	Risks associated with changes in the economic situation of the country	There is a favorable trend in the economic situation of the country	1
	5	Risks of changes in the extraction volumes	None	1
	6	Environmental risks	None	1

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