An integrated approach to assessing the effectiveness of investment projects for the construction of industrial facilities under uncertainty

M M Gayfullina, G Z Nizamova, D R Musina, Z A Gareeva and A Yu Tumanova

1Ufa State Petroleum Technological University, 450064, Kosmonavtov str. 1, Ufa, Russia

E-mail: marina_makova@list.tu

Abstract. The article proposes an approach to assessing the effectiveness of investment projects for the construction of industrial facilities under uncertainty and risk. An integral indicator of the investment project effectiveness is proposed. The purpose of the study is to develop a methodological approach to assessing the economic effectiveness of investment projects for the construction of industrial facilities, which allows taking into account the conditions of uncertainty and risk. The object of the research is investment projects for the construction of industrial facilities of industrial enterprises. The subject of the research is methods and mechanisms for assessing the economic effectiveness of investment projects under uncertainty and risk. Research methodology - analytical, system, graphical methods, methods of detailing, analysis, comparison, grouping, and modeling were used. The main results and conclusions of the study: A scenario model is proposed for assessing the investment project effectiveness for the construction of industrial facilities based on probabilistic analysis, which allows choosing the most optimal one from several projects based on taking into account all possible scenarios for each project simultaneously and making a decision on the basis of their totality. An integral indicator of the investment project effectiveness has been developed that takes into account the significance of the investment project effectiveness criteria, as well as the probability of various scenarios, which allows a comprehensive and uniquely assessment of the investment project effectiveness based on probabilistic analysis.

1. Introduction
The high capital intensity of most investment projects for the construction of industrial facilities in various industries requires considerable caution when making investment decisions. The real investments management mechanism should provide formalization of assessment, comparison and selection of the most effective investment projects; in this case, the validity of decisions is increased. Investment project management issues are covered in the scientific works of the authors: An’ shin V.M., Berg D.B., Burkov V.N., Bagueley P., Novikov D.A., Irikov V.A., Mazur I.I., Shapiro V. D. In the scientific works of Belousova V.M., Vilenskiy P.L., Kel’chevskaya N.R., Kossov V.V., Livshite V.N., Margolin A.M., Sirotkin S.A., Smolyak S.A., Shakhnazarov A.G. the problems of investment policy, related risks, investment programs, investment strategy, and investment management are considered. However, these methods relate to investment projects in general and poorly reflect the specifics of investment projects for the construction of main pipelines.
The fundamental principles of efficiency theory are reflected in the research works of such scientists as Williams D., Gordon M., Markovitz G., Miller M., Modigliani F., Mosin J., Fischer I., Fama J., French K.

Development of the practical aspects of application of methods for assessing investments, the interpretation of concepts "effect", "effectiveness" of the investment project was carried out by such domestic and foreign scientists as Brailey R., Blekh Y., Damodaran A., Kogan A.B., Krushvitz L., Myers S., Kantorovich L.V., Carhart M., Livshits V.N., Yakovets Yu.V. et al. [12].

Accounting for risks and uncertainty in investment projects is considered in the works of Chang H., Yu W., Cheng S. et al. [2], Dixit S., Sharma K. and Singh S. [3], Jelena A.M., Jiayuan W. and Patrick Z. [7], Yu W., Chang H. and Cheng S. [16], Mutanov G. [9], as well as in the work of the authors of this article [4; 10].

In the work of Stefan M. A., Elizarova J. M. [13], an integral indicator for assessing the effectiveness of a project, taking into consideration risk criteria is proposed, but this approach does not consider and does not take into account the probable scenarios of projects implementation.

In the work of Lytvynenko V., Naumov O. et al [8] a dynamic bayesian networks application for assessing the investment projects effectiveness is proposed. The model takes into account the time component, the probability of occurrence of events, and scenario variants for the development of the situation. However, it does not offer an integral indicator of the effectiveness of the investment project.

Multi-criteria decision making approach to the assessment of investment projects under uncertainty using interval data is considered in the work of Shvetsova O.A., Rodionova E.A., Epstein M.Z. [12]. Using a combination of multi-criteria selection and interval preferences for assessing investment projects, the authors propose an improved method for calculating economic efficiency based on a one-dimensional criterion and sensitivity analysis.

The use of hierarchical analysis and linear programming methods in assessing investment projects in industry is considered in the work of Tarasova E., Nikolenko T., Gorbunov G. and Semina L. [15].

In the work of A. Puryaev, the categories “effectiveness” and “effectiveness of an investment project” are investigated [11]. In the work of Sukhova L. F., Glaz Yu. A., Lyubov V. Agarkova L. V. a system of indicators for assessing the economic effectiveness of projects is presented [14].

The work of Gulakova O. I., Ershov Yu. S., Ibragimov N. M. and Novikova T. S [6] presents a means of a comprehensive assessment of the impact of a large-scale infrastructure project on the economy of the region and the country as a whole. In the work the methods of project analysis and methodological approaches to the study of the economy in spatial and industrial profiles using the multi-regional optimization model "input-output" were used.

Despite the variety of works on the assessment of investment projects, there is no generally accepted methodology or approach to a comprehensive assessment of investment projects for the construction of production facilities of industrial enterprises, which tied together the results of the implementation of investment projects in terms of project implementation time, effect and effectiveness. In addition, the increase in risk factors and uncertainty during the construction of production facilities of industrial enterprises requires continuous improvement of assessment methods and mechanisms for their management, as well as consideration of various scenarios for project implementation.

2. Methods

Comparing projects to make the right investment decision is one of the difficult problems that arise at the stage of real investment management. Decision-making in the management of projects for the construction of industrial production facilities is carried out, as a rule under uncertainty due to the lack of complete information, the presence of random and counter factors: when decisions are made in a situation of activities of partners with opposite or diverging interests.

It is recommended to use scenario analysis to take into account the predictable uncertainty of the effectiveness of an investment project. At the same time, it is proposed to choose an option for implementing an investment project according to the criterion of maximizing the integral economic effect of the project, taking into account various scenarios.
The proposed algorithm for assessing the effectiveness of investment projects for the construction of industrial facilities under uncertainty and risk includes six stages.

A list of scenarios is formed and possible values of risk factors are determined, which is reflected in the value of the discount rate E.

Three scenarios are proposed:
1) main (base) scenario - the most probable scenario;
2) optimistic scenario;
3) pessimistic scenario.

Investment project effectiveness indicators are calculated for various scenarios.

The problem of assessing the effectiveness of investments is a multifactorial and multicriteria task. It is a set of criteria that makes it possible to describe an investment project in the most appropriate way. The most objective criteria for assessing the economic effectiveness of investment projects are dynamic indicators based on the principle of discounting. These indicators include net present value (NPV), discounted payback period (DPP), internal rate of return (IRR), profitability index (PI).

At this stage, the future values of these indicators are calculated for each of the considered scenarios.

Weight coefficients of significance of discount effectiveness indicators of the investment project are calculated.

When comparing investment projects, several criteria should be compared at once, but it is important to keep in mind that the values of effectiveness criteria may contradict each other.

The weight coefficients of the significance of discount effectiveness indicators of an investment project (α) are calculated by the formula:

$$\alpha = \frac{v(\alpha)}{\sum_{i=1}^{n} v(\alpha)}$$

where $V(\alpha)$ is the weight of the effectiveness indicator accepted by the expert in the range from 1 to 10;
n is the number of assessed investment projects.

The rationing of indicators of the effectiveness of the investment project is carried out. The complexity of calculating a complex investment effectiveness indicator is that the indicators NPV, DPP, IRR, PI are incommensurable, which does not allow them to be simply combined into a generalized formula in the form of an objective function, which will later help to compare the calculated values for each project with each other.

Rationing of indicators for assessing the effectiveness of investment in relation to the significance coefficient is carried out by the formula:

$$\mathcal{E}^N_i = \alpha \cdot \frac{\mathcal{E}_i}{\sum_{i=1}^{n} \mathcal{E}_i}$$

where $\mathcal{E}^N_i$ - rationed effectiveness factor;
$\mathcal{E}_i$ - the calculated value of a certain indicator of effectiveness assessing for each project.

The integral indicators of the effectiveness of various options for the implementation of an investment project for various scenarios are calculated.

The directions of optimization of indicators for assessing the effectiveness of investment projects are determined for convolution:

$$\text{NPV} \to \max; \text{IP} \to \min; (\text{IRR} - E) \to \max; (\text{IRR} - E) > 0; \text{DPP} \to \min,$$

where E – discount rate.

The integral indicator of the investment project effectiveness is calculated by convolution by the combined type, which is quite common in the scientific literature when calculating integral indicators [1; 5], namely, by the weighted arithmetic mean:
\[ I Ki = N_{NPV_i} \cdot d_{NPV} + N_{PI_i} \cdot d_{PI} + N_{IRR_i} \cdot d_{IRR} + N_{DPP_i} \cdot d_{DPP} \]  

(3)

where \( N_{NPV_i}, N_{PI_i}, N_{IRR_i}, N_{DPP_i} \) – racioned values of indicators NPV, PI, IRR, DPP for the \( i \)-th scenario;

\( d_{NPV}, d_{PI}, d_{IRR}, d_{DPP} \) – weight coefficients of significance of effectiveness criteria

The probability of occurrence of various scenarios is determined.

The difficulty is that in conditions of predictable uncertainty, it is impossible to determine exactly the probability of one or another negative changes. In the scientific community, in the absence of information about the probable of scenarios, it is common to use the following probabilities:

1. S1 - pessimistic: \( P = 0.3 \);
2. S2 - the most probable (the most real): \( P = 0.6 \);
3. S3 - optimistic: \( P = 0.1 \).

An integral indicator of the project's effectiveness is calculated, taking into account various scenarios.

The integral indicator of the economic effect of the \( j \)-th project during scenario analysis is determined by summing the effect of each scenario multiplied by its probability:

\[ I_j = \sum_{i=1}^{n} I K_i \cdot P_i = 0.3 \cdot I K_1 + 0.6 \cdot I K_2 + 0.1 \cdot I K_3 \]  

(4)

where \( I K_1 \) – value of the integral indicator of the project in the pessimistic scenario, \( I K_2 \) – the value of the integral indicator of the project in the most probable scenario; \( I K_3 \) – value of the integral indicator of the project in the optimistic scenario.

\( P_1 = 0.3; P_2 = 0.6; P_3 = 0.1 \) – the probability of a pessimistic scenario, the most probable and optimistic, respectively.

\( n \) – total number of possible scenarios;

\( i \) – scenario number.

The optimal solution is the \( j \)-th project that will maximize the integral indicator:

\[ \max I_j \]  

(5)

3. Results

Approbation of the developed methodological approach was carried out on the example of a project for the construction of a main pipeline for pumping oil products. There were three alternative pipeline investment projects, differing in pipeline diameter (d). Indicators of construction options are given in table 1.

| Characteristic                          | Project 1 (d= 377 mm) | Project 1 (d= 426 mm) | Project 3 (d= 529 mm) |
|----------------------------------------|------------------------|------------------------|------------------------|
| Capital investments, million rubles    | 1451                   | 1436                   | 1841                   |
| Operating expenses per year, million rubles | 310                    | 239                    | 181                    |
| Expected revenue per year, million rubles | 713                    | 713                    | 713                    |

The accepted scenario parameters of calculations are given in table 2.

| Characteristic                          | S1                      | S2                      | S3                      |
|----------------------------------------|-------------------------|-------------------------|-------------------------|
| the tariff for pumping of oil products  | 0.24 rubles/t•km         | 0.24 rubles/t•km        | the growth rate for 5%  |
| operating costs                         | growth by 10%            | the actual value        | decrease by 10%         |

The calculated indicators of the effectiveness of projects for various scenarios and a mathematical
assessment of the risks of various projects according to various criteria are given in table 3.

### Table 3. The calculation of indicators of effectiveness of projects and scenarios.

| Project, S1 | S2   | S3   | Average | Standard deviation | Coefficient of variation | Risk |
|-------------|------|------|---------|--------------------|--------------------------|------|
| NPV, million rubles | 2108,73 | 2143,04 | 2307,49 | 2186,4              | 86,75                    | 0,040 | low   |
| IRR, %       | 17,8 | 18,1 | 18,2 | 18,0 | 0,17 | 0,009 | low   |
| PI           | 9,6  | 9,6  | 11,2 | 10,1 | 0,75 | 0,074 | low   |
| DPP, years   | 5,7  | 5,7  | 5,5  | 5,6  | 0,09 | 0,017 | low   |

Based on the results of calculations, all projects meet the conditions of effectiveness and can be selected for their implementation. For all criteria, scenarios and projects, there is a low coefficient of variation, and, therefore, a low level of risk. However, due to limited financial resources and technical necessity, it is recommended to make a choice in favor of one of the projects that is optimal in terms of profitability and risk.

Integral effectiveness indicators (table 4) are calculated to select the optimal option for implementing an investment project.

### Table 4. Integral effectiveness indicators of projects by scenarios

| Characteristic | Weight value (d) | Project 1 | Project 2 | Project 3 |
|----------------|------------------|----------|----------|----------|
| Normalized value | NPV              | 0,333    | 0,956    | 0,928    | 0,333    | 1,00    | 0,991   | 0,00    | 0,00    | 0,00    |
|                | PI               | 0,173    | 0,907    | 0,928    | 0,333    | 1,00    | 0,991   | 0,00    | 0,00    | 0,00    |
|                | IRR              | 0,227    | 0,924    | 0,907    | 0,928    | 0,333    | 1,00    | 0,991   | 0,00    | 0,00    | 0,00    |
|                | DPP              | 0,267    | 0,924    | 0,907    | 0,928    | 0,333    | 1,00    | 0,991   | 0,00    | 0,00    | 0,00    |
| Scenario probability (P) | 0,3 | 0,6 | 0,1 | 0,3 | 0,6 | 0,1 | 0,3 | 0,6 | 0,1 |
| Integral indicator (Ij) | 0,924 | 0,799 | 0,000 |

Considering that $Ij$ should be maximum, we can conclude: the most optimal is Project 1 (construction of a pipeline with a diameter of 377 mm). For this project, the value of the integral indicator, taking into account the probability of scenarios, is 0.924. The implementation of this project under various scenarios will ensure the achievement of the following indicators:

1) NPV – in the range from 2108,73 to 2307,49 million rubles
2) IRR – from 17.8 to 18.2%
3) PI – from 2.54 to 2.69 years.

4. Conclusion
1. A scenario model for assessing the effectiveness of an investment project based on probabilistic analysis has been developed, including the calculation of the integral indicator of the project, determined on the basis of the rationed values of the project effectiveness criteria for each scenario and the weight significance of these criteria.

2. Based on the results of calculations of the oil trunk pipeline construction project for all scenarios, it was found that all projects meet the effectiveness conditions and can be selected for their implementation. For all criteria, scenarios and projects, there is a low coefficient of variation and, accordingly, a low level of risk. However, due to limited financial resources, it is necessary to make a choice in favor of one of the projects that is optimal in terms of profitability and risk. Of this project under various scenarios will provide: NPV - in the range from 2108.73 to 2307.49 million rubles; internal rate of return - in the range from 17.8 to 18.2%; profitability index - in the range from 2.54 to 2.69; the payback period is in the range from 5.5 to 5.7 years.

3. On the basis of rationed indicators, unified integral indicators for assessing the effectiveness of investment project options are formed. It has been established that the most optimal, taking into account the requirement to maximize the integral indicator, is the project for the construction of a pipeline with a diameter of 377 mm. Taking into account the probability of scenarios the value of the integral indicator for this project is 0.924.

Using the proposed approach makes it possible to make more informed management decisions when choosing investment projects for financing, taking into account various scenario parameters and the probability of implementation of various scenarios.

References
[1] Burenina I V, Evtushenko E V, Kotov D V, Battalova A A, Gaifullina M M and Gamilova D A 2018 Integral Assessment of the Development of Russia’s Chemical Industry Journal of Environmental Management and Tourism 8 (5) pp 1075-108
[2] Chang H, Yu W, Cheng S. et al. 2019 The Use of a Multiple Risk Level Model to Tackle the Duration of Risk for Construction Activity. KSCE J Civ Eng 23 pp 2397–2408
[3] Dixit S, Sharma K and Singh S. 2020 Identifying and analysing key factors associated with risks in construction projects. In: Babu K., Rao H., Amarnath Y. (eds) Emerging Trends in Civil Engineering. Lecture Notes in Civil Engineering 61 Springer, Singapore pp 25
[4] Gaifullina M M, Nizamova G Z, Musina D R and Alexandrova O A 2017 Formation of strategy of effective management of fixed production assets of oil company Advances in Economics, Business and Management Research 38 pp 185-190
[5] Gaifullina M M, Nizamova G Z and Makov V M 2018 Forming a strategy for effective management of human resources of an oil company Oil industry 4 pp 8-11
[6] Gulakova O I, Ershov Yu S, Ibragimov N M and Novikova T S 2018 Evaluation of the Public Efficiency of an Infrastructure Project: a Case Study of the Eastern Siberia–Pacific Ocean-2 Oil Pipeline Regional Research of Russia 8 pp 193-203
[7] Jelena A M, Jayuan W and Patrick Z 2019 Fuzzy Logic-Based Method for Risk Assessment of Belt and Road Infrastructure Projects 2019 Journal of construction engineering and management 145(12)
[8] Lytvynenko V, Naumov O, Voronenko M, Krejci J, Naumova L, Nikytenko D, Savina N Dynamic bayesian networks application for evaluating the investment projects effectiveness 2020 International Scientific Conference “Intellectual Systems of Decision Making and Problem of Computational Intelligence” (ISDMCI 2020: Lecture Notes in Computational Intelligence and Decision Making) pp 315-330
[9] Nizamova G Z, Gayfullina M M, Musina D R, Tumanova A Yu and Battalova A A 2020
Development of a risk assessment methodology for the implementation of investment projects of a construction organization. 

IOP Conference Series: Materials Science and Engineering, International Scientific Conference "Investments. Construction. Real estate: new technologies and targeted development priorities-2020" 23-24 April 2020, Irkutsk, Russian Federation 880

[10] Puryaev A About the Essence of Categories “Efficiency” and “Efficiency of the Investment Project” 2020 In: Solovev D., Savaley V., Bekker A., Petukhov V. (eds) Proceeding of the International Science and Technology Conference "FarEastCon 2019". Smart Innovation, Systems and Technologies 172

[11] Shvetsova O.A, Rodionova E.A, Epstein M Z 2018. Evaluation of investment projects under uncertainty: multi-criteria approach using interval data Entrepreneurship and Sustainability 5(4) pp 914-928

[12] Shtefan M A, Elizarova J M 2018 Investment project efficiency and risk evaluation: an integrated approach Business Informatics 4(46) pp 54-65

[13] Tarasova E V, Nikolenko T Yu, Gorbunov G L and Semina L V 2018 Implementation of Investment Projects at Industrial Enterprises Russian Engineering Research 38 pp 295-300

[14] Yu W, Chang H and Cheng S 2018 A new method to tackle the duration risks of a construction project 8th International Conference on Engineering, Project, and Product Management Lecture Notes in Mechanical Engineering pp 255-264

[15] Shvetsova O A, Rodionova E A, Epstein M Z 2018 Evaluation of investment projects under uncertainty: multi-criteria approach using interval data Entrepreneurship and Sustainability 5(4) pp 914-928

[16] Shtefan M A, Elizarova J M 2018 Investment project efficiency and risk evaluation: an integrated approach Business Informatics 4(46) pp 54-65

[17] Tarasova E V, Nikolenko T Yu, Gorbunov G L and Semina L V 2018 Implementation of Investment Projects at Industrial Enterprises Russian Engineering Research 38 pp 295-300

[18] Yu W, Chang H and Cheng S 2018 A new method to tackle the duration risks of a construction project 8th International Conference on Engineering, Project, and Product Management Lecture Notes in Mechanical Engineering pp 255-264