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# IMPROVEMENT OF METHODICAL APPROACHES FOR RISK ASSESSMENT OF INNOVATIVE ACTIVITY IN STRATEGIC PLANNING OF ENTERPRISE DEVELOPMENT

# УДОСКОНАЛЕННЯ МЕТОДИЧНИХ ПІДХОДІВ ЩОДО ОЦІНЮВАННЯ РИЗИКІВ ІННОВАЦІЙНОЇ ДІЯЛЬНОСТІ У СТРАТЕГІЧНОМУ ПЛАНУВАННІ РОЗВИТКУ ПІДПРИЄМСТВА

# УСОВЕРШЕНСТВОВАНИЕ МЕТОДИЧЕСКИХ ПОДХОДОВ К ОЦЕНКИ РИСКОВ ИННОВАЦИОННОЙ ДЕЯТЕЛЬНОСТИ В СТРАТЕГИЧЕСКОМ ПЛАНИРОВАНИИ РАЗВИТИЯ ПРЕДПРИЯТИЯ

***Summary.*** *In modern conditions, companies need to have information about their environment in order to further develop. Under conditions of uncertainty, the analysis of not only the impact of the external environment, but also the internal environment becomes especially important for enterprises, which will increase the accuracy of determining the risk factors of the enterprise in the strategic planning of its development. Without taking into account key trends, systematic diagnosis of the internal environment and identification of problems (weaknesses) of the enterprise, it is impossible to effectively implement innovative projects.*

*In order to identify the most important factors of negative impact, which should be taken into account when assessing the risks of innovation in strategic planning of enterprise development, it is advisable to investigate the impact of external (macro- and microenvironment) and internal environment at each stage of the innovation project life cycle.*

*The purpose of this article is to improve methodological approaches to assessing the risks of innovation in the strategic planning of enterprise development and providing recommendations on the possibility of their use.*

*The article analyzes two methodological approaches to assessing the risks of innovation activity in strategic planning of enterprise development. The first methodological approach considered makes it possible to identify the most risk-generating factors at each stage of the life cycle of an innovation project. The* *calculation of the final value of the risk of each project of the enterprise is possible under the assessment of risk factors of the enterprise (using a rating scale that will identify risk factors of each of the factors for each of the analyzed projects). The second methodological approach will allow to estimate the probability of realization / non-realization of the project depending on the available statistical information on innovative projects and to predict the possibility of closing projects with the help of analytical models, and also allows you to assess the risk inherent in both individual stages of the life cycle of the innovation project and the innovation project for a certain planned period of time.*

***Key words:*** *innovation risk, innovation risk assessment, enterprise development.*

***Анотація.*** *В сучасних умовах підприємствам необхідно володіти інформацією щодо середовища свого існування з метою подальшого розвитку. В умовах невизначеності для підприємств набуває особливого значення аналіз не тільки впливу зовнішнього середовища, але й внутрішнього, що дасть можливість підвищити точність визначення факторів ризику підприємства при стратегічному плануванні його розвитку. Без врахування ключових тенденцій, систематичної діагностики внутрішнього середовища та виявлення проблем (слабких місць) підприємства неможливо ефективно впроваджувати інноваційні проекти.*

*З метою виявлення найбільш вагомих факторів негативного впливу, що слід враховувати при оцінюванні ризиків інноваційної діяльності у стратегічному плануванні розвитку підприємства, доцільно дослідити вплив факторів зовнішнього (макро- і мікросередовища) і внутрішнього середовища на кожному етапі життєвого циклу інноваційного проекту.*

*Мета даної статті полягає в удосконаленні методичних підходів щодо оцінювання ризиків інноваційної діяльності у стратегічному* *плануванні розвитку підприємства та наданні рекомендацій щодо можливості їх використання.*

*У статті було проаналізовано два методичні підходи щодо оцінювання ризиків інноваційної діяльності у стратегічному плануванні розвитку підприємства. Перший розглянутий методичний підхід дає змогу виділити найбільш ризикоутворюючі фактори на кожному етапі життєвого циклу інноваційного проекту. Розрахунок кінцевого значення ризику кожного проекту підприємства можливий за умови оцінки факторів ризику підприємства (за допомогою рейтингової шкали, що дасть змогу виділити ризикоутворюючі чинники кожного з розглянутих факторів для кожного з аналізованих проектів). Другий розглянутий методичний підхід дасть змогу попередньо оцінити ймовірність реалізації / нереалізації проекту в залежності від наявної статистичної інформації щодо інноваційних проектів та спрогнозувати можливість закриття проектів за допомогою аналітичних моделей, а також дозволяє оцінити ризик, притаманний як окремим етапам життєвого циклу інноваційного проекту так і інноваційному проекту на певний запланований проміжок часу.*

***Ключові слова:*** *ризик інноваційної діяльності, оцінювання ризиків інноваційної діяльності, розвиток підприємства.*

***Аннотация.*** *В современных условиях предприятиям необходимо владеть информацией о среде своего существования с целью дальнейшего развития. В условиях неопределенности для предприятий приобретает особое значение анализ не только влияния внешней среды, но и внутренней, что позволит повысить точность определения факторов риска предприятия при стратегическом планировании его развития. Без учета ключевых тенденций, систематической диагностики внутренней среды и выявление проблем (слабых мест) предприятия невозможно эффективно внедрять инновационные проекты.*

*С целью выявления наиболее значимых факторов негативного воздействия, которые следует учитывать при оценке рисков инновационной деятельности в стратегическом планировании развития предприятия, целесообразно исследовать влияние факторов внешней (макро- и микросреды) и внутренней среды на каждом этапе жизненного цикла инновационного проекта.*

*Цель данной статьи состоит в усовершенствовании методических подходов к оценке рисков инновационной деятельности в стратегическом планировании развития предприятия и предоставлении рекомендаций по возможности их использования.*

*В статье были проанализированы два методических подхода к оценке рисков инновационной деятельности в стратегическом планировании развития предприятия. Первый рассмотренный методический позволяет выделить наиболее рискообразующие факторы на каждом этапе жизненного цикла инновационного проекта. Расчет конечного значения риска каждого проекта предприятия возможен при условии оценки факторов риска предприятия (с помощью рейтинговой шкалы, что позволит выделить рискообразующие факторы каждого из рассматриваемых факторов для каждого из рассматриваемых проектов). Второй рассмотренный методический подход позволит предварительно оценить вероятность реализации / нереализации проекта в зависимости от имеющейся статистической информации об инновационных проектах и спрогнозировать возможность закрытия проектов с помощью аналитических моделей, а также позволяет оценить риск, присущий как отдельным этапам жизненного цикла инновационного проекта так и инновационному проекту на определенный запланированный промежуток времени.*

***Ключевые слова:*** *риск инновационной деятельности, оценки рисков инновационной деятельности, развитие предприятия.*

**Formulation of the problem.** When developing and implementing innovative projects, the company faces uncertainty caused by risk factors of the external and internal environment of the enterprise. In order to ensure more effective strategic development planning, the company needs to pay attention to the evaluation of available information, which can lead to a risky situation. These situations are associated with the emergence during the implementation of innovative projects, on the one hand, the loss of the effect of innovation and possible losses, and on the other hand, can lead to additional competitive advantages in the future and the growth of the enterprise.

Ensuring the optimization of financial resources of the enterprise in the process of implementing innovative projects for strategic planning of enterprise development necessitates the creation of an appropriate system for assessing the risks of innovation in the enterprise and developing tools for assessing the risks of innovation in the enterprise to achieve long-term goals.

**Analysis of research and publications.** The problem of risk assessment is given much attention in the works of domestic and foreign scientists, such as Valsamakis A. C. [7], Vivian R. W. [7], Du Toit G. S [7], Burke R. [3], Gray C. F. [4], Larson E. W. [4], Veres O.M. [11], Katrenko A. V. [11], Rishnyak I. V. [11], Chaplyha V. M. [11], Harasym Yu. R. [13], Romaka V. A. [13], Rybiy M. M. [13], Balabanov I. T. [8], Granaturov V. M. [14], Mostenska T. L. [19], Skopenko N. S. [19], Donets O. M. [15], Savelyeva T. V. [15], Uretska Yu. I. [15], Kovalenko V. V. [18], Zhezhukha V. Y. [16], Yankovsky N. A. [27], Verbitska I. I. [10], Baldji M. D. [9], Ilyashenko S. M. [17], Vitlinskyi V. V. [12], Velykoivanenko H. I. [12].

**The purpose of the article**. The purpose of this article is to improve methodological approaches to assessing the risks of innovation in the strategic planning of enterprise development and providing recommendations on the possibility of their use.

**Research methods.** A complex of theoretical research methods has been used: deduction and induction, analysis and synthesis, comparison, generalization, systematization and interpretation of results. The methodological and informational basis of the work is scientific works of domestic and foreign scientists and practitioners, materials of periodicals, Internet resources.

**Result.** Theoretical study of the possibility of using existing risk assessment methods to assess the risks of innovation has shown that existing methods can not be used in full and at each stage of the life cycle of an innovation project [6].

In order to identify the most important factors of external (macro- and micro-environment) and internal environment, which should be considered when assessing the risks of innovation in strategic planning of enterprise development, it is advisable to investigate the impact of factors at each stage of the innovation project life cycle.

The proposed improved methodological approach to assessing the overall risk of innovation, taking into account the risk factors of the external and internal environment of the enterprise, is as follows:

1) determination of the main components of risk factors of the external (macroenvironment, microenvironment) and internal environment of the enterprise;

It was suggested to use the following risk factors [20; 21]:

for the macro environment – scientific and technological ($V_{1s}$), socio-cultural ($V_{2s}$), economic ($V_{3s}$), demographic ($V_{4s}$), international ($V_{5s}$), political and legal ($V_{6s}$), natural and geographical ($V_{7s}$), environmental ($V_{8s}$);

for the microenvironment – caused by competitors ($Y_{1s}$), caused by customers ($Y_{2s}$), caused by intermediaries ($Y_{3s}$), caused by suppliers ($Y_{4s}$), caused by contact audiences ($Y_{5s}$);

for the internal environment of the enterprise – production ($Z_{1s}$), marketing ($Z_{2s}$), innovation ($Z_{3s}$), information ($Z_{4s}$), time ($Z_{5s}$), financial ($Z_{6s}$), technological ($Z_{7s}$), labor ($Z_{8s}$), management ($Z_{9s}$), spatial ($Z_{10s}$).

If necessary, each company can formulate its own list of risk factors that will be most characteristic of it and take into account all the specifics of a particular company.

2) conducting a survey by pairwise comparison of the degree of influence of each of the components of the risk factors of the external (macroenvironment, microenvironment) and internal environment of the enterprise depending on the stage of the life cycle of the innovation project;

To create a matrix of pairwise comparisons in general, assume that $C_1$, $C_2$ … $C_n$ – set of objects (possible actions). Quantitative judgments about a pair of objects ($C_i$, $C_j$) is represented as a size matrix $n \times n$

$$A = (a_{ij}), (i, j = 1, 2 \dots n).$$

Elements $a_{ij}$ meet the following requirements:

If $a_{ij} = \boldsymbol{\alpha}$, then $a_{ji} = \frac{1}{\alpha}$, $\boldsymbol{\alpha} \neq 0$.

If, as a result of expert judgments, it is established that $C_i$ and $C_j$ ave the same relative importance, then $a_{ij} = 1$, $a_{ji} = 1$, in particular, $a_{ii} = 1$ or all *i*.

To make pairwise comparisons of objects using subjective judgments, it is advisable to use the Saati scale (standard comparison scale) [26, p. 547; 22, p. 53].

To determine the importance of factors, it is first necessary to build a matrix of pairwise comparisons for risk groups (Table 1), this will determine which group of factors has the greatest impact at the appropriate stage of the project life cycle. It should be noted that when comparing risk factors should take into account the possible negative impact, ie one that can lead to undesirable results.

*Table 1*

**Comparison of groups of risk factors at the stages of the project life cycle**

| | Macroenvironment ($R_{1s}$) | Microenvironment ($R_{2s}$) | Internal environment ($R_{3s}$) |
|---|---|---|---|
| Macroenvironment ($R_{1s}$) | 1 | $k_{12s}$ | $k_{13s}$ |
| Microenvironment ($R_{2s}$) | $1/k_{12s}$ | 1 | $k_{23s}$ |
| Internal environment ($R_{3s}$) | $1/k_{13s}$ | $1/k_{23s}$ | 1 |

*Source:* elaborated by the author

The matrix of pairwise comparisons in General for the risk factors of the macroenvironment of the enterprise are presented in Table 2.

*Table 2*

**Matrix of pairwise comparison of risk factors of the macroenvironment of the enterprise**

| | $V_{1s}$ | $V_{2s}$ | $V_{3s}$ | $V_{4s}$ | $V_{5s}$ | $V_{6s}$ | $V_{7s}$ | $V_{8s}$ |
|---|---|---|---|---|---|---|---|---|
| $V_{1s}$ | 1 | $h_{12s}$ | $h_{13s}$ | $h_{14s}$ | $h_{15s}$ | $h_{16s}$ | $h_{17s}$ | $h_{18s}$ |
| $V_{2s}$ | $1/h_{12s}$ | 1 | $h_{23s}$ | $h_{24s}$ | $h_{25s}$ | $h_{26s}$ | $h_{27s}$ | $h_{28s}$ |
| $V_{3s}$ | $1/h_{13s}$ | $1/h_{23s}$ | 1 | $h_{34s}$ | $h_{35s}$ | $h_{36s}$ | $h_{37s}$ | $h_{38s}$ |
| $V_{4s}$ | $1/h_{14s}$ | $1/h_{24s}$ | $1/h_{34s}$ | 1 | $h_{45s}$ | $h_{46s}$ | $h_{47s}$ | $h_{48s}$ |
| $V_{5s}$ | $1/h_{15s}$ | $1/h_{25s}$ | $1/h_{35s}$ | $1/h_{45s}$ | 1 | $h_{56s}$ | $h_{57s}$ | $h_{58s}$ |
| $V_{6s}$ | $1/h_{16s}$ | $1/h_{26s}$ | $1/h_{36s}$ | $1/h_{46s}$ | $1/h_{56s}$ | 1 | $h_{67s}$ | $h_{68s}$ |
| $V_{7s}$ | $1/h_{17s}$ | $1/h_{27s}$ | $1/h_{37s}$ | $1/h_{47s}$ | $1/h_{57s}$ | $1/h_{67s}$ | 1 | $h_{78s}$ |
| $V_{8s}$ | $1/h_{18s}$ | $1/h_{28s}$ | $1/h_{38s}$ | $1/h_{48s}$ | $1/h_{58s}$ | $1/h_{68s}$ | $1/h_{78s}$ | 1 |

*Source:* elaborated by the author

The matrix of pairwise comparisons in General for the risk factors of the microenvironment of the enterprise are presented in Table 3

*Table 3*

**Matrix of pairwise comparison of risk factors of the microenvironment of the enterprise**

| | $Y_{1s}$ | $Y_{2s}$ | $Y_{3s}$ | $Y_{4s}$ | $Y_{5s}$ |
|---|---|---|---|---|---|
| $Y_{1s}$ | 1 | $g_{12s}$ | $g_{13s}$ | $g_{14s}$ | $g_{15s}$ |
| $Y_{2s}$ | $1/g_{12s}$ | 1 | $g_{23s}$ | $g_{24s}$ | $g_{25s}$ |
| $Y_{3s}$ | $1/g_{13s}$ | $1/g_{23s}$ | 1 | $g_{34s}$ | $g_{35s}$ |
| $Y_{4s}$ | $1/g_{14s}$ | $1/g_{24s}$ | $1/g_{34s}$ | 1 | $g_{45s}$ |
| $Y_{5s}$ | $1/g_{15s}$ | $1/g_{25s}$ | $1/g_{35s}$ | $1/g_{45s}$ | 1 |

*Source:* elaborated by the author

The matrix of pairwise comparisons in General for the risk factors of the internal environment of the enterprise are presented in Table 4.

*Table 4*

**Matrix of pairwise comparison of risk factors of the internal environment of the enterprise**

| | $Z_{1s}$ | $Z_{2s}$ | $Z_{3s}$ | $Z_{4s}$ | $Z_{5s}$ | $Z_{6s}$ | $Z_{7s}$ | $Z_{8s}$ | $Z_{9s}$ | $Z_{10s}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $Z_{1s}$ | 1 | $o_{12s}$ | $o_{13s}$ | $o_{14s}$ | $o_{15s}$ | $o_{16s}$ | $o_{17s}$ | $o_{18s}$ | $o_{19s}$ | $o_{110s}$ |
| $Z_{2s}$ | $1/o_{12s}$ | 1 | $o_{23s}$ | $o_{24s}$ | $o_{25s}$ | $o_{26s}$ | $o_{27s}$ | $o_{28s}$ | $o_{29s}$ | $o_{210s}$ |
| $Z_{3s}$ | $1/o_{13s}$ | $1/o_{23s}$ | 1 | $o_{34s}$ | $o_{35s}$ | $o_{36s}$ | $o_{37s}$ | $o_{38s}$ | $o_{39s}$ | $o_{310s}$ |
| $Z_{4s}$ | $1/o_{14s}$ | $1/o_{24s}$ | $1/o_{34s}$ | 1 | $o_{45s}$ | $o_{46s}$ | $o_{47s}$ | $o_{48s}$ | $o_{49s}$ | $o_{410s}$ |
| $Z_{5s}$ | $1/o_{15s}$ | $1/o_{25s}$ | $1/o_{35s}$ | $1/o_{45s}$ | 1 | $o_{56s}$ | $o_{57s}$ | $o_{58s}$ | $o_{59s}$ | $o_{510s}$ |
| $Z_{6s}$ | $1/o_{16s}$ | $1/o_{26s}$ | $1/o_{36s}$ | $1/o_{46s}$ | $1/o_{56s}$ | 1 | $o_{67s}$ | $o_{68s}$ | $o_{69s}$ | $o_{610s}$ |
| $Z_{7s}$ | $1/o_{17s}$ | $1/o_{27s}$ | $1/o_{37s}$ | $1/o_{47s}$ | $1/o_{57s}$ | $1/o_{67s}$ | 1 | $o_{78s}$ | $o_{79s}$ | $o_{710s}$ |
| $Z_{8s}$ | $1/o_{18s}$ | $1/o_{28s}$ | $1/o_{38s}$ | $1/o_{48s}$ | $1/o_{58s}$ | $1/o_{68s}$ | $1/o_{78s}$ | 1 | $o_{89s}$ | $o_{810s}$ |
| $Z_{9s}$ | $1/o_{19s}$ | $1/o_{29s}$ | $1/o_{39s}$ | $1/o_{49s}$ | $1/o_{59s}$ | $1/o_{69s}$ | $1/o_{79s}$ | $1/o_{89s}$ | 1 | $o_{910s}$ |
| $Z_{10s}$ | $1/o_{110s}$ | $1/o_{210s}$ | $1/o_{310s}$ | $1/o_{410s}$ | $1/o_{510s}$ | $1/o_{610s}$ | $1/o_{710s}$ | $1/o_{810s}$ | $1/o_{910s}$ | 1 |

*Source:* elaborated by the author

3) use of the method of analysis of hierarchies in order to obtain the weights of risk factors of each expert and calculate the coefficient of consistency of responses of each expert on risk factors of external (macroenvironment,

microenvironment), internal environment and groups of risk factors depending on the life cycle of the innovation project;

After presenting quantitative judgments about pairs of objects $(C_i, C_j)$ in the numerical expression $a_{ij}$, it is necessary $n$ possible objects (actions) $C_1, C_2 \dots C_n$ to match the set of numerical weights $\omega_1, \omega_2 \dots \omega_n$, which would correspond to the obtained judgment.

After pairwise comparisons, the matrix must be normalized. This is done by summing the numbers in each column and then dividing each element of the column by the amount obtained for that column.

The next step is to calculate the coefficient of consistency and check its value. The purpose of this step is to verify the consistency of the specified benefits of the original data.

The calculation of the coefficient of consistency consists of three stages [26, c. 553]:

calculation of the degree of consistency for each criterion;

calculation of the consistency index ($CI$);

calculation of the coefficient of consistency ($CR$), calculated by the formula:

$$CR = \frac{CI}{RI} \qquad (1)$$

where $CI$ – Consistency Index; $RI$ – Random Index.

In the Table 5 shows the values of the randomization index for different matrix sizes.

*Table 5*

**Randomization index for different matrix sizes** [26, p. 553]

| *n* | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| *RI* | 0 | 0,58 | 0,9 | 1,12 | 1,24 | 1,32 | 1,41 | 1,45 | 1,51 |

It should be noted that if the consistency ratio is too high (more than 0.10 according to Saati), then the expert was not consistent enough in his assessments and it is necessary to return and review the results of pairwise comparisons.

4) calculation of the concordance coefficient by risk factors of external (macroenvironment, microenvironment), internal environment of the enterprise and groups of risk factors depending on the stage of the innovation project life cycle for agreed answers of experts and adjustment of concordance coefficient by excluding answers of experts contradicting the majority;

The concordance coefficient is used to determine the consistency of experts' opinions, calculated by the formula [25, c. 378]:

$$w = \frac{S}{\frac{1}{12}(m^2\,(n^3 - n) - m\sum_{j=1}^{m} T_j)} \qquad (2)$$

where S – the sum of the squares of the deviations of all estimates of the ranks of each object of examination from the average value; n – number of objects of examination; m – number of experts; Tj – an indicator that takes into account the coincidence of ranks and is calculated according to the formula [25, c. 378]:

$$T_j = \sum_{k=1}^{n}(t_k^3 - t_k) \qquad (3)$$

where tk – the number of repetitions of rank k when ranking factors by the j-th expert.

The concordance coefficient varies in the range 0<W<1, where 0 – is complete inconsistency, 1 – is complete unity.

5) calculation of the total weights of each external risk factor (macroenvironment, microenvironment), internal environment of the enterprise and groups of risk factors depending on the stage of the life cycle of the innovation project for agreed answers of experts by calculating their arithmetic mean;

6) obtaining equations to calculate the impact of risk factors of external (macroenvironment, microenvironment), internal environment of the enterprise

and groups of risk factors depending on the stage of the life cycle of the innovation project;

The objective function in general will look like:

$$R = \sum_{i=1}^{n} w_i \times R_i \quad (4)$$

where $w_i$ – the weight of the i-th factor, $w_i > 0$; $R_i$ – the value of the i-th factor; n – the number of factors.

Taking into account the analyzed factors of the external and internal environment, the formula of the general risk assessment of innovative activity should be presented as follows:

$$R = K_{1s} \times R_{1s} + K_{2s} \times R_{2s} + K_{3s} \times R_{3s} \quad (5)$$

where $R_{1s}$ – risk caused by the impact of the macro-environment of the enterprise at the appropriate stage of the project life cycle; $R_{2s}$ – the risk caused by the impact of the microenvironment of the enterprise at the appropriate stage of the project life cycle; $R_{3s}$ – the risk caused by the impact of the internal environment of the enterprise at the appropriate stage of the project life cycle; $K_{1s}, K_{2s}, K_{3s}$ – the corresponding weights of each risk group, calculated by pairwise comparisons, at the appropriate stage of the project life cycle; *s* – the appropriate stage of the project life cycle.

The group of risks associated with the macro-environment has the greatest degree of uncertainty, as the company cannot influence them. To assess the risk of the macro-environment of the enterprise at the appropriate stage of the life cycle of the enterprise, it is proposed to use the following formula:

$$R_{1s} = H_{1s} \times V_{1s} + H_{2s} \times V_{2s} + H_{3s} \times V_{3s} + H_{4s} \times V_{4s} + H_{5s} \times V_{5s} + \\ + H_{6s} \times V_{6s} + H_{7s} \times V_{7s} + H_{8s} \times V_{8s} \quad (6)$$

where $H_{1s}, H_{2s}, H_{3s}, H_{4s}, H_{5s}, H_{6s}, H_{7s}, H_{8s}$ – the corresponding weights of each risk factor of the macro-environment of the enterprise, calculated by pairwise comparisons, at the appropriate stage of the project life cycle; *s* – the appropriate stage of the project life cycle.

To assess the risk of the microenvironment of the enterprise at the appropriate stage of the life cycle of the enterprise, it is proposed to use the following formula:

$$R_{2s} = G_{1s} \times Y_{1s} + G_{2s} \times Y_{2s} + G_{3s} \times Y_{3s} + G_{4s} \times Y_{4s} + G_{5s} \times Y_{5s} \qquad (7)$$

where $G_{1s}, G_{2s}, G_{3s}, G_{4s}, G_{5s}$ – the corresponding weights of each risk factor of the enterprise microenvironment, calculated by pairwise comparisons, at the appropriate stage of the project life cycle; *s* – the appropriate stage of the project life cycle.

To assess the risk of the internal environment of the enterprise at the appropriate stage of the life cycle of the enterprise, it is proposed to use the following formula:

$$R_{3s} = O_{1s} \times Z_{1s} + O_{2s} \times Z_{2s} + O_{3s} \times Z_{3s} + O_{4s} \times Z_{4s} + O_{5s} \times Z_{5s} + \\ + O_{6s} \times Z_{6s} + O_{7s} \times Z_{7s} + O_{8s} \times Z_{8s} + O_{9s} \times Z_{9s} + O_{10s} \times Z_{10s} \qquad (8)$$

where $O_{1s}, O_{2s}, O_{3s}, O_{4s}, O_{5s}, O_{6s}, O_{7s}, O_{8s}, O_{9s}, O_{10s}$ – the corresponding weights of each risk factor of the macro-environment of the enterprise, calculated by pairwise comparisons, at the appropriate stage of the project life cycle; *s* – the appropriate stage of the project life cycle.

7) identification of the most risk-generating factors depending on the stage of the life cycle of the innovation project to provide recommendations to enterprises to develop optimal ways of risk management;

8) calculation of the impact of each risk factor at the appropriate stage of the life cycle of the innovation project of the enterprise by interviewing experts of the enterprise by scoring, where 10 – the greatest impact, 0 – the least impact, for each proposed innovation project;

9) calculation of risk, in order to compare each of the considered innovative projects of the enterprise, as well as assigning risk to one of the five areas of risk: risk-free area, minimum risk area, high risk area, critical risk area and unacceptable risk area [24].

To calculate the total risk of non-implementation of an innovative project, we use the theorem of multiplication of probabilities of two dependent events. Event B is called event A dependent if the probability of event B changes depending on whether event A occurred or did not occur. The probability of event B, calculated under the condition that another event A took place, is called the conditional probability of event B and is denoted by $P_A(B)$[23, c. 20-21].

The probability of the product of two events is equal to the product of the probabilities of one of them by the conditional probability of the other, which is calculated provided that the first event occurred:

$$P\ (AB) = P\ (A)\ \times P_A(B) \tag{9}$$

Probability of product of several events [23, c. 20-21]:

$$P(A_1A_2 \ldots A_n) = P(A_1) \times P_{A_1}(A_2) \times P_{A_1A_2}(A_3) \times \ldots \times P_{A_1A_2\ldots A_{n-1}}(A_n) \tag{10}$$

The probability of each subsequent event is calculated provided that all previous ones have taken place.

The considered methodical approach allows to allocate the most risk-forming factors at each stage of a life cycle of the innovative project. The calculation of the final value of the risk of each project of the enterprise is possible under the assessment of risk factors of the enterprise (using a rating scale that will identify risk factors of each of the factors for each of the analyzed projects).

This will allow to generalize the risk factors depending on the stage of the life cycle of the innovation project and will allow to pay attention to those factors that most influence and have the greatest possible degree of damage. This will allow the company to increase the efficiency of risk assessment in order to achieve the strategic goals of the enterprise, as well as to compare the riskiness of potential innovative projects in order to implement the development strategy of the enterprise.

Although the considered methodological approach has a number of advantages, namely identification of the most risky stages, identification of the most risky risk factors at each stage of the innovation project life cycle, calculation of the overall risk of project failure, however, it requires significant calculations and a large number of surveys. Also, the use of such a method requires considerable experience from experts and the ability to assess the probability of occurrence of certain events, as well as a deep understanding of the specifics of the enterprise and the features of the project to be implemented. This method should be used by companies that implement a large number of projects in one area and can influence the most risky risk factors in order to reduce the overall risk of non-implementation of the project.

In order to pre-assess the probable risk at each stage of the project life cycle, as well as the overall risk of project failure when it is impossible to use a methodological approach which makes it possible to identify the most risk-generating factors, it is advisable to use a alternative methodological approach.

We hypothesize the possibility of abstraction and formalization of the process of assessing the risks of innovative activities of the enterprise using a mathematical apparatus.

The duration of the project life cycle is a random variable, denote it by *X*. We set the function of the distribution of the life cycle of the project as a function whose value is for the argument $t \geq 0$ (where $t$ $-$ stage) shows the probability ($P$) hat the duration of the project life cycle will be less than or equal to $t$ stages. That is, the function of the distribution of the life cycle of the project is denoted by

$$F\ (t) = P\ (X \leq t) \tag{11}$$

In practice, to assess the risks of innovative activity of the enterprise, it is more convenient to use not the distribution function itself, but the project survival function obtained on its basis. Function $S\ (\ t\ )$ is defined as the survival function of the project, which for the argument $t \geq 0$ shows the probability that the duration of the project life cycle will be more than $t$ stages:

$$S\ (t) = \ P\ (X > t) = 1 - \ P\ (X \leq t) = \ 1\ -\ F\ (\ t) \tag{12}$$

To formalize the process of assessing the risks of innovation, the survival function of the project must have the following properties:

$S(0) = 1$, because potentially the project can go through all stages of its life cycle, $S\ (\infty) = 0$, because hypothetically the duration of the project life cycle is a finite value, in practice it is necessary to determine the maximum number of stages of the project $\omega$ and assume that $S\ (t) = 0$ when $t > \omega$.

$S(t)$ is descending, when $t_1 > t_2$ the condition is fulfilled $S(t_1) < S(t_2)$, $S(t)$ is continuous, so that the mathematical characteristics of the survival function do not contradict its meaning.

To do this, the innovative activity of the enterprise is considered as a set of innovative projects, which are characterized by a life cycle, stages (components of the life cycle of an innovative project). It is emphasized that the duration of the life cycle of an innovation project will not mean the calendar duration (in years, months, days, etc.), but a set of individual stages (components of the life cycle of the innovation process), which form the content of the innovation process as milestones.

To build the survival function, it is first necessary to form a table of stages of project closure, which can be obtained from empirical data (survey data) and / or statistics. To build a survival function you need:

identify the stages / substages of the life cycle of the innovation project that will be specific to your company or use the generally accepted theoretical developments of scientists;

determine the number of projects, information about which you can analyze and determine at what stage / substage of the life cycle of the innovation project they ceased to exist;

for each project or group of projects (if it is possible to collect data from a group of enterprises) to calculate the probability of transition to the next stage / substage of the life cycle of the innovation project;

calculate the weighted average value of the probability of transition of an innovative project from one stage to another $f(t)$;

calculate F (t) for each selected stage according to the formula of probability of product of several events by product of weighted average values of probability of transition of the innovative project from one stage to another of all previous stages. That is, F (1) = $f(1)$; F (2) = $f(1) \times f(2)$; ...; F (X) = $f(1) \times f(2) \times ... \times f(X)$.

calculate S(t) by formula 12.

For a group of $l_0$ newly created projects, denote by $l_x$ the average number of projects in this group that continue to exist in the x-th substage. Then

$$l_x = l_0 S\ (x) \tag{13}$$

The average number of projects in this group that ceased to exist (closed) in the period from *x* to *x*+*t* substages, denote $d_x$

$$d_x = l_x - l_{x+t} = l_0 (S\ (x) - S\ (x+t)) \tag{14}$$

The variance of the number of enterprises in this group that ceased to exist (closed) in the period from *x* to *x*+*t* substages, is calculated by the formula:

$${}_tS_x^2 = d_x\ (1 - \frac{d_x}{l_0}) \tag{15}$$

The density function of the life cycle distribution of project *X* closed project curve) is determined by:

$$f\ (t) = -S\ '(t) = F\ '(t), \tag{16}$$

$$S\ (t) = \int_t^{\infty} f\ (t)\ dt\ , \tag{17}$$

The curve of closed projects roughly reflects the average number of projects from the initial population that were not implemented between *t* and *t+1* stages.

To formalize the process of assessing the risks of innovation, the function that describes the curve of closed projects must have the following properties: $f(t) \geq 0; \int_0^{\infty} f(t)dt = 1,$ because there really is a survival function of the innovation project for which the following is performed $f(t) = -S'(t)$.

We formalize the value of $\mu_t$ as the intensity of project closure, it should approximately show the probability that the project, which is in $t$ stage, will be closed during the next stage, and is calculated by the formula:

$$\mu_t = \frac{f(t)}{1-F(t)} = \frac{f(t)}{S(t)} = -\frac{S'(t)}{S(t)} \tag{18}$$

To formalize the process of assessing the risks of innovation, the intensity of project closure should have the following properties: $\mu_t \geq 0$; $S(t) = e^{-\int_0^t \mu_u du}$, where $u$ – stages of possible liquidation, which occur after the project $t$ stages.

For practical application, the above characteristics must be represented in the form of functions (analytical models of project closure) of a certain type, depending on the parameters. Parameters can be determined from empirical or statistical data. As analytical models of project closure, it is possible to use the following: de Muavre model [2], Gompertz model [1], Meikham model [5].

To compare the stages / stages of projects in different areas in which they closed, it is advisable to formalize the average life cycle of the project (mathematical expectation of the life cycle of project $X$) as :

$$\mathrm{E(X)} = {}^{0}e_0 = \int_0^\infty tf(t)dt = \int_0^\infty S(t)\,dt \tag{19}$$

and the variance ${}^{0}\sigma_t^2$:

$${}^{0}\sigma_t^2 = M(X^2) - {}^{0}e_0^2 \tag{20}$$

$$MX^2 = \int_0^\infty t^2 f(t)\,dt = 2\int_0^\infty tS(t)dt \tag{21}$$

where M – mathematical expectation of the value.

It is also possible to calculate the probability that the project in stage $x$ will go through $t$ more stages, but will be liquidated during the next $u$ stages (${}_{t/u}q_x$):

$${}_{t/u}q_x = \frac{S(x+t)-S(x+t+u)}{S(x)} = {}_{t}P_x - {}_{t+u}P_x = {}_{t+u}q_x - {}_{t}q_x \tag{22}$$

The calculation of these characteristics will allow the company to compare innovative projects in different industries and identify the most promising that can be further implemented for the development of the enterprise.

This methodological approach has a number of advantages, namely the ability to pre-estimate the probability of non-implementation of the project, does not require significant calculations and expert assessments, however, at the same time it requires a significant amount of data on project mortality (because only in this case ). If the company implements a significant number of projects and has its own statistics, then this method will help to cut off projects that are not implemented in the near future and not to use time-consuming calculations. However, if the company does not have such statistical information, it is necessary to spend time conducting an expert survey.

If the company implements a significant number of projects, data on non-implementation of projects will allow to analyze the most risky stages and stages, as well as using formulas to calculate the probability that the project, which is currently at a certain stage, will pass a certain number of stages or implemented.

**Conclusions and prospects for further research.** Thus, it can be argued that the considered methodological approaches have their advantages and disadvantages, as well as features of application. The methodological approach which makes it possible to identify the most risk-generating factors allows to identify the most risk-forming factors at each stage of the innovation project life cycle and allows to identify risk-forming factors of each of the considered factors for each of the analyzed projects of the enterprise. alternative methodological approach will allow to estimate in advance the probability of realization / non-realization of the project depending on the available statistical information on innovative projects and to predict the possibility of closing projects with analytical models.

The scientific novelty of the obtained results is to improve the methodological approach to assessing the overall risk of innovation, taking into account the risk factors of the external and internal environment of the enterprise, which in contrast to the known stage of the innovation project life cycle; and allows to take into account each alternative opinion of the expert by using the method of analysis of hierarchies in order to objectively identify the risk factors of each stage; as well as improving the methodological approach to determining the risk of an innovation project, which, unlike the known ones, is based on the differentiation of the innovation life cycle; and allows to assess the risk inherent in both individual stages of the life cycle of the innovation project and the innovation project for a certain planned period of time.

In further researches it is planned to compare calculations on each of the offered methodical approaches and to give recommendations on expediency of use of the specified approaches depending on branch of functioning of the enterprise, the size of the enterprise and its stage of a life cycle.

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