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COMPARATIVE ANALYSIS OF EFFICIENCY CRITERIA FOR INVESTMENT PROJECTS

Purpose. Analysis of the advantages and disadvantages of indicators of the internal rate of return and the modified internal rate of return as criteria for the effectiveness of an investment project.

Methodology. The mathematical and graphic apparatus for studying the functions and dependencies between the economic characteristics of future financial and production activities of entrepreneurial activity was used in the process of the analysis of the most important indicators of the effectiveness of the investment project.

Findings. The characteristics of the criterion of the internal rate of return are studied on the basis of the properties of the function which describes the dependence of the net present value of the project on the value of the discount rate. The main advantages of the modified internal rate of return in comparison with its unmodified analogue are revealed. The inequalities between the indicated indicators are mathematically proved, their influence on the stability (safety) characteristics of the investment project is analyzed, and the interrelation of the criterion of the modified internal rate of return with the value of the profitability index is shown.

Originality. The originality consists in the mathematical proof of the interrelation between the indicators of the internal rate of return and the modified internal rate of return, as well as the interrelation between the criterion of the modified internal rate of return and the profitability index of the investment project.

Practical value. Theoretical conclusions and suggestions can be used in the investment analysis of future financial and production projects in the domestic economy, which opens up the possibilities of rational use of resources in entrepreneurial activity at all levels of business process management.

Keywords: *investment project, internal rate of return, profitability index, net present value*

Introduction. The current economic situation in Ukraine, the main factors of which is the war waged by the Putin regime in Russia and the consequences of the COVID-19 pandemic, is characterized by significant deterioration in almost all branches of the productive sector of the economy. Many Ukrainian companies are trying to change their location to continue working. The government has introduced a large program that supports business relocation. According to World Bank estimates, Ukraine's GDP in 2022 will decline by 45.1 % due to the war.

In addition to the war, the current state of the domestic economy exacerbates the negative effects of the COVID-19 pandemic, which has affected all, without exception, developed and developing countries.

The IMF predicts that global growth will slow from 5.9 % in 2021 to 4.4 % this year [1].

The decline will be mainly due to forced shutdowns in production and services, as well as premature austerity measures, which can only further complicate the situation. In addition,

as a result of the pandemic, social inequality may increase and geopolitical stability may weaken over the next 5–10 years [2].

According to experts, all these troubles, and especially war in Ukraine, could lead not only to the global economic crisis, but also to the threat of food shortages in some countries in Africa and Asia.

Top managers of companies should pay special attention to the rational use of all available resources and, in particular, those that are directed to investing in new production and financial projects in these economic conditions. Indicators and criteria of investment analysis, taking into account the change in the value of money over time by discounting and increasing are serving this purpose. The Internal Rate of Return (*IRR*), the Modified Internal Rate of Return (*MIRR*) and the Profitability Index (*PI*) are among such indicators, which characterize the effectiveness of the future investment project.

In the scientific literature on investment analysis, theoretical discussions about the advantages and disadvantages of these indicators and criteria, which have serious practical importance for business representatives in all countries of the world, still do not subside. Therefore, in this article we tried to highlight the disadvantages of the Internal Rate of Return in-

indicator as a characteristic of the effectiveness of the studied project and demonstrate some important mathematical interrelations between the investment analysis criteria.

Literature review. In his paper, Arjunan (2017) evaluates whether *MIRR* is an appropriate criterion for investment decision and the true annual rate of return on capital. The estimation of *MIRR* is based on the modified net cash flow (*MNCF*). The *MNCF*, derived by mathematically adjusting the actual net cash flow (*NCF*), distorts the intrinsic value of the cash inflow and its timing. With *MNCF*, the *MIRR* is lower than the *IRR* because *MIRR* failed to fully utilize the *NCF* generated as shown by the capital amortization schedule. The estimated *MIRR*, based on assumed reinvestment rate, leads to serious problems as explained above. *MIRR* (when $MIRR < IRR$) estimate does not fully utilize the benefit stream. Based on these results, it is evident that the *MIRR* is a spurious criterion.

Kukhta (2014) writes that the *MIRR* method is more attractive than the *IRR* as a characteristic of the real profitability of the project (or the expected long-term rate of return of the project), but Net Present Value (*NPV*) is still better for analyzing alternative projects that differ in scale because it shows in absolute terms how much the optimal project increases the value of the company. The method of *MIRR* is indispensable for the evaluation of atypical projects, where the usual *IRR* shows erroneous or ambiguous results. It is hoped that the method of modified internal rate of return will obtain the same popularity as its predecessor, the original *IRR*. Due to its properties, this method also ensures the confidentiality of project information, in contrast to *NPV*, which to some extent clarifies the scale of the project. It can be used as the main criterion when approving materials for loans for international projects, as it eliminates the necessity to compare discount rates in different countries or calculate the "global" discount rate.

Yankovyi, Melnyk (2018) point to the threat of using the Internal Rate of Return indicator because of its potential significant overestimation of the efficiency of an investment project in some cases. They recommend paying more attention to the Modified Internal Rate of Return criterion as a universal indicator of the relative profitability of a planned project.

Mytskikh (2019) casts doubt on the advisability of using the *MIRR* criterion as an indicator of the effectiveness of an investment project. In the conclusions of her article, she, in particular, asserts that the *MIRR* indicator really allows you to rank projects consistently with the ranking by the *NPV* indicator, but only for alternative projects of the same scale. The *MIRR* criterion of the original project is in fact the *IRR* criterion of the substitution project, which is not equivalent to the original project. *MIRR* has many values because it is a function of the increasing rate (capital price). A set of *MIRR* values can also take place at a given capital price, but different periods of increasing (reinvestment). The internal rate of return of the project is a characteristic of the project, and it should not depend on the price of capital used in the project, therefore, the *MIRR* indicator cannot act as an indicator of the internal rate of return of the original project. In general, the *MIRR* indicator cannot be used in the formation of the capital investment budget.

Hayes (2021) writes that cash flows are often reinvested at the cost of capital, not at the same rate at which they were generated in the first place. The *IRR* assumes that the growth rate remains constant from project to project. It is very easy to overstate the potential future value with basic *IRR* figures. Another major issue with the *IRR* occurs when a project has different periods of positive and negative cash flows. In these cases, the *IRR* produces more than one number, causing uncertainty and confusion. The modified internal rate of return improves on the standard internal rate of return value by adjusting the differences in the assumed reinvestment rates of initial cash outlays and subsequent cash inflows.

According to Ross (2021), the formula for modified internal rate of return allows analysts to change the assumed rate of

reinvested growth from stage to stage in a project. The most common method is to input the average estimated cost of capital, but there is flexibility to add any specific anticipated reinvestment rate. The *MIRR* also is designed to generate one solution, getting rid of the problem of multiple *IRRs*.

Thus, the analysis of literary sources allows us to conclude that the opinions of scientists about the expediency of applying the *IRR* and *MIRR* criteria in the process of analysing the economic efficiency of investment projects were divided. The first group of researchers (K. Arjunan, N. Mytskikh) believe that the *MIRR* indicator is a false criterion, since its comparison with the discount rate can lead to incorrect (underestimated) conclusions regarding the degree of a project's efficiency. The second group of scientists (P. Kukhta, O. Yankovyi and N. Melnyk, A. Hayes, S. Ross) are of the opposite opinion. They argue that the *MIRR* criterion improves the standard internal rate of return and is designed to generate a single solution that helps to get rid of the problem of multiple *IRRs* typical of non-ordinary cash flow.

Unsolved aspects of the problem. We believe that the issue of choice between the *IRR* and *MIRR* criteria as indicators of the effectiveness of investment projects is quite topical and insufficiently studied. In particular, some of theoretical and practical interest is the mathematical proof of the interrelation between them, as well as their interrelations with other indicators of profitability of planned financial and production projects at the level of business entities

Setting objectives. The purpose of this study is carrying out a critical analysis of the properties, advantages and disadvantages of *IRR* and *MIRR* criteria in the process of testing the acceptability of the investment project; mathematical verification of the validity of inequalities between them; determining the interrelations between the *MIRR* indicator and the profitability index *PI* as another relative characteristic of the efficiency of the investment project.

To achieve this purpose, the following tasks were set:

1) to study the characteristics of the *IRR* criterion by analyzing the properties of the function $NPV = f(r)$, which describes the dependence of the net present value of the project on the value of the discount rate r , based on the cost of capital;

2) to reveal the characteristics of the *MIRR* criterion, accenting its advantage over the *IRR* in terms of overcoming the multiplicity of solutions;

3) to prove mathematically inequalities between *IRR* and *MIRR* indicators in case of possible situations regarding acceptance, rejection or uncertainty of the researched project;

4) to study the influence of *IRR* and *MIRR* criteria on the stability (safety) characteristics of the planned project;

5) to show the interrelations of the *MIRR* criterion with the value of *PI*;

6) to consider the possibility of applying economic criteria, such as *NPV*, *IRR*, *MIRR*, to determine the priority of realization of multiplicity of investment projects of the company.

Methods. Fundamental analysis of mathematical formulas, advantages and disadvantages of investment analysis criteria is given in the works by world famous scientists H. Bierman and S. Smidt, J. Brigham and L. Gapenski, Van Horne, J. Lorie and L. Savage. Therefore, below we will focus on considering the positions of modern authors on the discussed problem in the field of investment.

In addition, the mathematical and graphical apparatus of the study on the functions and interrelations between the economic characteristics of future financial and production activities of entrepreneurial activity was used.

Characteristics of the Internal Rate of Return criterion. By definition, the *IRR* is a discount rate of all positive and negative cash flows of an investment project when their amounts are equal to each other, i. e. $NPV = 0$.

Therefore, Internal Rate of Return is a breakeven point of the investment project based on the *IRR* discount rate of cash flows. It characterizes the maximum acceptable relative level

of costs possible during the implementation of this project without losses for the owner. Therefore, it is a comparison base when determining the stability (safety reserve) of the project to a change in the discount rate r . Obviously, the project should be assessed as acceptable if $IRR > r$, unacceptable if $IRR < r$, and undefined if $IRR = r$.

According to the definition of Internal Rate of Return, the following equation can be written

$$\sum_{k=1}^n \frac{P_k}{(1+IRR)^k} = \sum_{k=0}^n \frac{IC_k}{(1+IRR)^k}, \quad (1)$$

where P_k is revenues from the project in the k^{th} period ($k=0, 1, 2, \dots, n$); n is project duration (time periods); IC_k is investment in the project in the k^{th} period.

Here IC_0 means primary investment. Therefore, (1) can be represented as follows

$$\sum_{k=1}^n \frac{P_k}{(1+IRR)^k} = \sum_{k=1}^n \frac{IC_k}{(1+IRR)^k} + IC_0. \quad (2)$$

Formulas (1, 2) are equations of the n degree relatively to IRR , therefore calculation of its value directly in the general case is impossible. The interpolation method is usually used by sequentially changing the discount rate r , which brings the NPV value closer to zero with a given accuracy to determine the IRR value.

The disadvantages of the IRR criterion are usually attributed by some researchers to the lack of properties of choosing the only best investment project from many possible (alternative, interdependent, etc.). However, it was already proven long ago that the correct decision about the acceptance or rejection of future investment is achieved only with the integrated use of all indicators of investment analysis. For example, it is often noted that there is a contradiction between the NPV and IRR indicators of projects that differ significantly in scale or in terms of implementation.

However, there are two disadvantages of the IRR criterion, which are immanently inherent in this criterion and are admitted by the overwhelming majority of specialists in the field of investment analysis.

The first disadvantage of this indicator is related to the choice of the discount rate of future cash flows – the value of the IRR instead of the generally accepted rate r . As a result of such unjustified replacement, the efficiency of the investment project (IRR) is distorted towards its overestimation. Moreover, if the values of IRR and r do not differ much from each other, the distortion of the efficiency of the project is insignificant. But in a situation where the IRR is much higher than r , the value found is subject to significant and unreasonable overstatement. From this we can conclude that high-efficiency capital investments according to the IRR criterion will erroneously look even more attractive, in contrast to low-efficiency projects.

The second disadvantage follows from the property of the function $NPV=f(r)$ for investment projects with non-ordinary cash flow. Equation (1) can have several real roots, and the graph of the function can intersect the abscissa at several points. In this case, there is uncertainty due to the plurality of IRR values. In addition, for investment projects with non-ordinary cash flows, equation (1) may have no real roots at all, and the graph of the function $NPV=f(r)$ may not intersect the abscissa axis. In this situation, the value of the Internal Rate of Return is not possible to determine either.

Characteristics of the Modified Internal Rate of Return criterion and its comparison with other indicators of investment analysis. $MIRR$ is a discount rate at which the terminal value of the project is reduced to the present moment and is equal to the present value of all investments associated with this project. The $MIRR$, by definition, is a modification of the Internal Rate of Return indicator, which is designed to eliminate the two above-mentioned disadvantages of the IRR criterion. The

$MIRR$ and IRR indicators for this investment project are fully consistent, i.e. if $IRR > r$, the inequality $MIRR > r$ is satisfied, if $IRR < r$, then $MIRR < r$ and with $IRR = r$, the equality $MIRR = r$ is solved with the corresponding conclusions on the acceptance (rejection) of the project under study.

Like the IRR , the Modified Internal Rate of Return is a relative financial measure of the efficiency of an investment project, which is often used when budgeting capital investment of companies in order to rank alternative investments of approximately the same size.

Calculations of the $MIRR$ are based on the following formula, which follows from the conditions of its construction

$$MIRR = \sqrt[n]{\frac{\sum_{k=1}^n P_k (1+r)^{n-k}}{\sum_{k=0}^n \frac{IC_k}{(1+r)^k}}} - 1. \quad (3)$$

Note that expression (3) has a real economic meaning ($MIRR \geq 0$) only if the net terminal value (fractional numerator under the root) is not less than the sum of discounted investment costs (fractional denominator under the root).

The value of (3) is always uniquely defined, in contrast to (1), which may have no solution at all, or provides a set of IRR values, for example, for a project with non-ordinary cash flow.

Thus, by applying the same discount rate r , which is calculated by top managers of the company on the basis of risk-free rate, risk premium, inflation rate, etc., criterion (3) manages to eliminate both of the above disadvantages of the IRR .

Establishing a relationship between the studied criteria. By analogy with the IRR indicator (2), equation (3) can be represented as follows

$$\frac{\sum_{k=1}^n P_k (1+r)^{n-k}}{(1+MIRR)^n} = \sum_{k=1}^n \frac{IC_k}{(1+r)^k} + IC_0. \quad (4)$$

Let us now consider the interrelation between the IRR and $MIRR$ values for the same investment project with non-ordinary cash flows. Comparison of expressions (2, 4) allows us to write

$$\sum_{k=1}^n \frac{P_k}{(1+IRR)^k} - \sum_{k=1}^n \frac{IC_k}{(1+IRR)^k} = \frac{\sum_{k=1}^n P_k (1+r)^{n-k}}{(1+MIRR)^n} - \sum_{k=1}^n \frac{IC_k}{(1+r)^k}. \quad (5)$$

Using elementary transformations, equation (5) is reduced to the following form

$$\frac{\sum_{k=1}^n P_k (1+IRR)^{n-k}}{(1+IRR)^n} = \frac{\sum_{k=1}^n P_k (1+r)^{n-k}}{(1+MIRR)^n} + \left[\sum_{k=1}^n \frac{IC_k}{(1+IRR)^k} - \sum_{k=1}^n \frac{IC_k}{(1+r)^k} \right]. \quad (6)$$

Let us analyse three possible situations concerning the acceptance (rejection) of the investment project under study.

1. Uncertainty of conclusions: $r = IRR$. In this case, the interrelation (6) becomes the equality

$$\frac{\sum_{k=1}^n P_k (1+IRR)^{n-k}}{(1+IRR)^n} = \frac{\sum_{k=1}^n P_k (1+IRR)^{n-k}}{(1+MIRR)^n}, \quad (7)$$

which results in $IRR = MIRR$. Therefore, in this situation, all three criteria are equal to one another ($r = IRR = MIRR$), as shown in Fig. 1.

2. An investment project is accepted: $r < IRR$. In this case, in interrelation (6), the difference in square brackets is less than zero, since

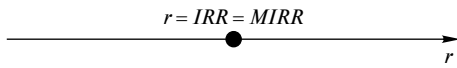


Fig. 1. Interrelations between the IRR, MIRR criteria and a discount rate r for an investment project under conditions of uncertainty

$$\sum_{k=1}^n \frac{IC_k}{(1+IRR)^k} < \sum_{k=1}^n \frac{IC_k}{(1+r)^k}.$$

And the equality in (6) is possible on one condition

$$\frac{\sum_{k=1}^n P_k (1+IRR)^{n-k}}{(1+IRR)^n} < \frac{\sum_{k=1}^n P_k (1+r)^{n-k}}{(1+MIRR)^n}. \quad (8)$$

The specified condition is fulfilled only when $(1+IRR)^n > (1+MIRR)^n$. Consequently, when accepting an investment project, the following inequality is valid: $MIRR < IRR$ (Fig. 2).

3. An investment project is rejected: $r > IRR$. In this case, in interrelation (6), the difference in square brackets is a positive value, since

$$\sum_{k=1}^n \frac{IC_k}{(1+IRR)^k} > \sum_{k=1}^n \frac{IC_k}{(1+r)^k}.$$

The equality in (6) is possible on this condition

$$\frac{\sum_{k=1}^n P_k (1+IRR)^{n-k}}{(1+IRR)^n} > \frac{\sum_{k=1}^n P_k (1+r)^{n-k}}{(1+MIRR)^n}. \quad (9)$$

It can be satisfied when $(1+IRR)^n < (1+MIRR)^n$. Consequently, if an investment project is rejected, the following relationship takes place: $MIRR > IRR$ (Fig. 3).

It is obvious that in the case of ordinary cash flows, all those relationships between the IRR and MIRR criteria for the same investment project, which have been proven above and presented in Figs. 1–3 are also observed. Admittedly, in this situation, the term on the right-hand side of (6) is equal to zero and all the arguments given for the case of non-ordinary cash flows are valid.

The IRR and MIRR criteria as indicators of the effectiveness of an investment project can be used to find the absolute (relative) Margin of Strength (MS), which characterises the sustainability and safety of the planned event

$$\begin{aligned} MS_{IRR} &= IRR - r; & MS'_{IRR} &= \frac{(IRR - r)}{r} \times 100; \\ MS_{MIRR} &= MIRR - r; & MS'_{MIRR} &= \frac{(MIRR - r)}{r} \times 100. \end{aligned} \quad (10)$$

The absolute (relative) MS of a project reflects the possible margin of variation of the actual values of the IRR, MIRR of a project, caused by various unforeseen circumstances, such as an increase in the discount rate r . In particular, if $MS > 0$, ($MS' > 0$) expressions (10) show by how many units (per cent) the potential profitability of an investment project can de-

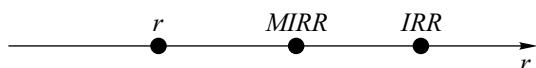


Fig. 2. Interrelations between the IRR, MIRR criteria and a discount rate r for an investment project, if it is accepted

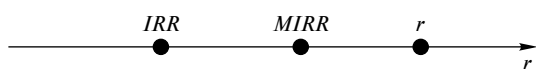


Fig. 3. Interrelations between the IRR, MIRR criteria and a discount rate r for an investment project, if it is rejected

crease without drastically changing its acceptability, i.e. without turning the project from profitable to unprofitable.

Evidently, the higher the MS indicator is, the greater the margin of stability (safety) of the planned event is, the lower its riskiness becomes and vice versa. If $MS < 0$, ($MS' < 0$), then its value indicates by how many units (per cent) it is necessary to increase the profitability of an investment project in order to turn it from unprofitable to profitable.

Fig. 2 clearly shows that if a project is accepted, the calculation according to (10) ensures the solution to the inequalities $MS_{IRR} > MS_{MIRR} > 0$, $MS'_{IRR} > MS'_{MIRR} > 0$. This means that in this situation the Internal Rate of Return criterion gives a significantly overstated estimate of the stability (safety) of an investment project in comparison with the Modified Internal Rate of Return indicator.

Fig. 3 illustrates that if a project is rejected, the calculation by (10) proves the validity of the inequalities $MS_{IRR} < MS_{MIRR} < 0$, $MS'_{IRR} < MS'_{MIRR} < 0$. And in a situation where the project is rejected, the IRR criterion also provides an overestimation compared to the MIRR, but no longer the stability (security) of the investment project, and the necessary absolute (relative) reduction of the actual discount rate r to convert the planned event from unprofitable to profitable.

In our opinion, it is useful to compare the MIRR indicator not only with the internal rate of return IRR, but also with the Profitability Index as it is another characteristic of the efficiency of an investment project. As shown in [5, 9], these indicators are interrelated as follows

$$\begin{aligned} PI &= \left(\frac{1+MIRR}{1+r} \right)^n; \\ MIRR &= (1+r)PI^{\frac{1}{n}} - 1. \end{aligned} \quad (11)$$

Moreover, their values are completely consistent with each other and provide an identical assessment of the acceptance (rejection) of the investment project.

Use of economic criteria in determining the priority of investment projects. Of certain theoretical and practical interest is the application of the above criteria in the process of ranking the planned financial and production projects. The fact is that top managers of companies usually have m necessary investment projects, and the main limitation of their implementation is the lack of financial and material resources. Therefore, there is a problem not only to determine the acceptability and effectiveness of a concrete single project, but also to establish the priority of some investment projects over others, i.e. rank them in the future implementation while taking into account the values of all s criteria, such as NPV, IRR, MIRR. Some statistical methods for determining the priority of investment projects (graphic, taxonomic) are considered in [9].

We propose to use mathematical approaches to solving the problem, in particular, the method of main components (MMC) [10, 11]. The main idea of the method is that s economic criteria directly observed for m investment projects are a demonstration of some latent feature, which should be evaluated and used as a generalizing criterion for the priority of planned production and financial projects

$$Z = AF, \quad (12)$$

where Z is the matrix of standardized values of economic criteria of size $s \times m$; A is the matrix of factor loads of size $s \times s$; F is the matrix of principal components of size $s \times m$.

The information about the values of s criteria at the first stage of the MMC is presented in the form of the original matrix X of size $s \times m$

$$X = \begin{pmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \dots & \dots & \dots & \dots \\ x_{s1} & x_{s2} & \dots & x_{sm} \end{pmatrix}. \quad (13)$$

The rows of the matrix (13) meet certain criteria, and the columns – certain projects.

It is obvious that the criteria included in the matrix X are heterogeneous, have different scale and different units of measurement, as they describe different internal properties of investment projects. Therefore, the second stage of the MMC is to standardize the original data and bring them to the same scale. For this purpose, the following formula is used

$$Z_{ij} = \frac{x_{ij} - \bar{x}_i}{\sigma_i}, \quad (14)$$

where \bar{x}_i , σ_i is the average value and standard deviation of the criterion X_i (i is the number of the criterion, $i = 1, 2, \dots, s$; j is the number of the investment project, $j = 1, 2, \dots, m$).

Standardization of criteria allows you to get rid of the scale of their measurement, brings all the data to one scale. With the normal distribution of criteria, the range of changes of standardized values is from -3 to 3. The standardized values of the criteria found by formula (14) form a matrix Z .

At the third stage of the MMC procedure, the matrix of pairwise correlation coefficients r is calculated between all criteria – rows of the matrix X . The next matrix equation is used

$$r = ZZ^T/m, \quad (15)$$

where Z^T is the matrix transposed due to the matrix of standardized criteria Z .

The fourth stage of the MMC is devoted to determining the matrix of factor loads A

$$A = V\Lambda^{1/2}, \quad (16)$$

where Λ is the diagonal matrix of size $s \times s$ of the characteristic roots λ_s of the matrix r ; V is the matrix of size $s \times s$ of normalized characteristic vectors of the matrix r corresponding to the characteristic roots λ_s .

This stage of the MMC is the main one from point of view of the possibility of calculating the main components. In fact, having determined the matrix of factor loads A , it is easy to find the matrix F from the matrix (12).

In the last fifth stage of the MMC, the selected main components for each researched investment project are measured. Substituting in the expression (12) of the matrix of factor loads A from (16), we obtain the following calculation formula, which allows you to quantify the desired latent feature

$$F = \Lambda^{-1}A^T Z. \quad (17)$$

The value of the general component for the j^{th} investment project according to expression (17) is as follows

$$f_{1j} = \sum_{i=1}^s \frac{a_{1i} z_{ij}}{\lambda_1}. \quad (18)$$

The relative contribution (in percent) of the general component in explaining the general variation of the initial economic criteria is determined as follows

$$d_1 = 100(\lambda_1/s). \quad (19)$$

The found values of the general component are quantitative estimates of the studied latent feature which is a generalizing criterion for the priority of planned activities. The obtained standardized variables form the basis for ranking and grouping of investment projects by the value of the latent general factor that determines the variation and correlations of the observed criteria. Thus, with the help of measured values of the general component among the studied projects it is possible to excrete groups of leaders, medium and outsiders by the size of the generalizing criterion of priority of planned production and financial projects and thus to solve the problem of their ranking.

Conclusions. The mathematical results of the study prove that on condition that an investment project is adopted, the Internal Rate of Return criterion overestimates its effectiveness and the degree of its stability (safety) in comparison with the

Modified Internal Rate of Return indicator. And in a situation when the project is rejected, the *IRR* criterion also provides an overestimation compared to the *MIRR*, but no longer the stability (security) of the investment project, and the necessary absolute (relative) reduction of the actual discount rate r to convert the planned project from unprofitable to profitable.

In addition, it has been shown that such criteria as the Modified Internal Rate of Return and the Profitability Index are interconnected and can be expressed through each other. Moreover, in the process of testing an investment project, their values are fully consistent with each other.

The possibility of applying economic criteria (*NPV*, *IRR*, *MIRR*) to determine the priority of the multiplicity of investment projects of the company based on the mathematical method of the main components is shown.

As a prospect of further development in this direction, we see the study on economic factors which make influence on the differences between the values of the *IRR* and *MIRR* in the analysis of investment projects.

In addition, some theoretical and practical interest is the study on additional mathematical and statistical approaches to the use of economic criteria in order to rank the multiplicity of the planned production and financial projects of the company.

References.

1. *The IMF has downgraded the forecast of global economic recovery* (2022). Retrieved from <https://finclub.net/ua/news/mvf-pohirshyv-prohnoz-zrostantia-svitovoi-ekonomiky.html>.
2. *The Global Risks Report* (2021). Retrieved from https://www3.weforum.org/docs/WEF_The_GlobalRisks_Report_2021.pdf.
3. Arjunan, K. (2017). Modified *IRR* (*MIRR*) is a Spurious criterion and should not be used in cost-benefit analysis and investment analysis. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.2942456>.
4. Kukhta, P. (2014). Features of the *MIRR* method in evaluating the efficiency of investment projects. *Bulletin of Taras Shevchenko National University of Kyiv. Economics*, 8(161), 52-56.
5. Yankovyi, O. H., & Melnyk, N. V. (2021). The modified internal rate of return as a criterion of financial evaluation of the investment project. *Ukrainskys zhurnal "Ekonomist"*, (9), 82.
6. Mytskikh, N. (2019). *IRR* and *MIRR* indicators – myths and reality. *Bankaŭski viesnik, lipieŭ 2019*, 20-30. Retrieved from <https://www.nbrb.by/bv/articles/10643.pdf>.
7. Hayes, A. (2021). *Modified Internal Rate of Return (MIRR)*. Investopedia. Retrieved from <https://www.investopedia.com/terms/m/mirr.asp>.
8. Ross, S. (2021). *Modified Internal Rate of Return (MIRR) vs. Regular Internal Rate of Return (IRR)*. Investopedia. Retrieved from <http://www.investopedia.com/ask/answers/061515/why-modified-internal-rate-return-mirr-preferable-regular-internal-rate-return.asp>.
9. Yankovyi, V., Koval, V., Dudka, T., & Bykhovchenko, V. (2021). Statistical assessment of project economic priority in company's investment management. *Revista gesti3n de las personas y tecnolog3a*, (42), 98-119. <https://doi.org/10.35588/gpt.v14i42.5284>.
10. Kendyukhov, A. V., & Tolkachov, D. O. (2013). PCA method used in estimating of machine-building enterprise competitiveness. *Marketing and Management of Innovations*, (4), 219-225.
11. Borychenko, O. V., Chernyavs'kyy, A. V., & Ostapchuk, Yu. Yu. (2018). Application of the main component method for assessing energy efficiency. *Visnyk NTU "KhPI"*, 16(1292), 9-15.

Порівняльний аналіз критеріїв ефективності інвестиційних проєктів

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Мета. Аналіз переваг і недоліків показників внутрішньої норми прибутку й модифікованої внутрішньої нор-

ми прибутку як критеріїв ефективності інвестиційного проекту.

Методика. У процесі проведеного аналізу важливіших індикаторів ефективності інвестиційного проекту був задіяний математичний та графічний апарат дослідження функцій і залежностей між економічними характеристиками майбутніх фінансово-виробничих заходів підприємницької діяльності.

Результати. Досліджені характеристики критерію внутрішньої норми прибутку на базі властивостей функції, що описує залежність чистої приведеної вартості проекту від величини ставки дисконтування. Виявлені головні переваги модифікованої внутрішньої норми прибутку в порівнянні з її немодифікованим аналогом. Математично доведені нерівності між указаними індикаторами, проаналізовано їх вплив на характеристики стійкості (безпечності) інвестиційного проекту, показано взаємозв'язок критерію модифікованої

внутрішньої норми прибутку з величиною індексу прибутковості.

Наукова новизна. Полягає в математичному доведенні співвідношень між показниками внутрішньої норми прибутку й модифікованої внутрішньої норми прибутку, а також взаємозв'язку критерію модифікованої внутрішньої норми прибутку з індексом прибутковості інвестиційного проекту.

Практична значимість. Теоретичні висновки та пропозиції можуть бути використані у ході інвестиційного аналізу майбутніх фінансово-виробничих заходів у вітчизняній економіці, що відкриває можливість раціонального застосування ресурсів у підприємницькій діяльності на всіх рівнях управління бізнес-процесами.

Ключові слова: *інвестиційний проект, внутрішня норма прибутку, індекс прибутковості, чиста приведена вартість*

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