УДК 330.43
JEL classification: C44

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METHODOLOGY OF SELECTING AN INVESTMENT PROJECT IN THE EVENT OF EXPERTS' DECISIONS INCONSISTENCY

МЕТОДОЛОГІЯ ОБРАННЯ ІНВЕСТИЦІЙНОГО ПРОЕКТУ В УМОВАХ НЕУЗГОДЖЕНОСТІ РІШЕНЬ ЕКСПЕРТІВ

The article studies the decision-making process on the choice of an investment project. The relevance of this study is of particular importance with limited funding, which is currently the case in Ukraine. The traditional criteria for choosing investment projects are: the criterion of net present value, the criterion of the internal rate of return, the criterion for the return period, the criterion for the return rate and the criterion for additional return. At the same time, one cannot rely solely on economic indicators, since it is an individual who makes a decision. Therefore, it is more reasonable to rely on the knowledge, experience and intuition of a group of independent experts in the relevant subject area. A review of existing methods for making collective decisions, including their application to the selection of investment projects, is conducted. Their advantages and disadvantages are noted. The expediency of applying Bayesian strategies for choosing an investment project is emphasized, since this approach allows one to integrate individual expert decisions based on a formal criterion. A developed optimal decision-making methodology provides the choice or rejection of an investment project using the Bayesian collective decision strategy. It is noted that any investment project, including the one under consideration, can be successful, i.e. make a profit or to be unsuccessful. Based on historical statistics of previously accepted investment projects, the probabilities of successful and unsuccessful projects are estimated. The developed methodology was applied to make a collective decision on the possibility of financing the current investment project by an expert group of five people. According to the applied methodology, all experts make decisions independently of each other. For each expert, a distribution of conditional probabilities of erroneous decisions is induced. The situation of collective decision making is determined. The groups of experts who made agreed decisions, were identified. A formal algorithm is applied to make an optimal collective decision. An investment project has been qualified for financing.

Keywords: investment project; making collective decisions; expert evaluation; Bayesian strategy; optimal solution

У статті проведено дослідження процесу ухвалення рішення про вибір інвестиційного проекту. Актуальність даного дослідження набуває особливого значення при обмеженому фінансуванні, що має місце в даний час в Україні. Традиційними критеріями до вибору інвестиційних проектів є: критерій чистої приведеної вартості, критерій внутрішньої норми прибутку, критерій строку повернення, критерій коефіцієнта прибутковості і критерій додаткового повернення. У той же час не можна спиратися лише на економічні показники, так як в результаті рішення приймає людина. Тому більш розумно покладатися на знання, досвід і інтуїцію групи незалежних експертів у відповідній предметній області. Проведено огляд існуючих методів прийняття

колективних рішень, в тому числі і їх застосування до вибору інвестиційних проектів. Відзначено їх переваги і недоліки. Підкреслено доцільність застосування байєсівських стратегій для вибору інвестиційного проекту, так як цей підхід дозволяє інтегрувати індивідуальні рішення експертів на основі формального критерію. Розроблено методологію прийняття оптимального рішення, що забезпечує вибір або відхилення інвестиційного проекту, використовуючи байєсівську стратегію колективних рішень. Відзначено, що будь-який інвестиційний проект, в тому числі той, що розглядається, може виявитися успішним, тобто принести прибуток або неуспішним. На підставі статистичних даних історії раніше прийнятих інвестиційних проектів оцінені ймовірності успішних і неуспішних проектів. Розроблена методологія застосована для прийняття колективного рішення про можливість фінансування поточного інвестиційного проекту експертною групою з п'яти осіб. Згідно з методологією, що застосовується, всі експерти приймають рішення незалежно один від одного. Для кожного експерта наведено розподіл умовних ймовірностей помилкових рішень. Визначено ситуація прийняття колективного рішення. Визначено множини експертів, які винесли узгоджені рішення. Застосовано формальний алгоритм для прийняття оптимального колективного рішення. Визначено інвестиційний проект для фінансування.

Ключові слова: інвестиційний проект; прийняття колективних рішень; експертна оцінка; байєсівська стратегія; оптимальне рішення.

Introduction. To date, one of the key issues of sustainable regional development in Ukraine is the implementation of effective investment policy. One of the main objectives of the region's investment program is the reasonable selection of those investment projects that would be most beneficial for the further development of the region [1].

Traditionally, five main criteria for investment project selection are used: the net present value (NPV), the internal rate of return (IRR), the return term (RT), the profitability ratio (PR), and the supplementary return criterion (SR) [2]. However, as practice shows [3], one cannot rely solely on these criteria. At the end of the decision-making process, there is always a person who is responsible for the decision. Therefore, it is advisable to rely on the knowledge, experience and intuition of a team of independent experts in the relevant subject area.

There are various approaches to making collective decisions for the selection of investment projects [4, 5]. For example, according to the ELECTRE method, based on the so-called indices of agreement and disagreement. However [6], the threshold levels of these indices, and therefore the result obtained, are more subjective.

There is also a well-known collective decision-making approach based on Bayesian strategies [7, 8]. This approach allows to integrate individual expert decisions on the basis of a formal criterion, without using any heuristic procedures, and therefore allows to obtain a mathematically sound collective decision through specific data.

The purpose of the article is to use the Bayesian approach to solve the problem of choosing an investment project.

Setting objectives. To develop a methodology for making the optimal decision, providing the choice or rejection of the investment project, using the Bayesian strategy of collective decisions.

Methodology. The methodology is based on the following idea [8]: suppose that some object can randomly receive one of several plural states $V=\{V_1,V_2\}$ with known a priori probabilities $P(V_1)$ and $P(V_2)=1-P(V_1)$. Without further information, to ensure a minimum likelihood of misclassification, the current state of the object must be attributed to the most probable state, in which case the value $P_0=1-\max\{P(V_1),P(V_2)\}$ determines the minimum likelihood of misclassification.

Experts $A_1,...,A_N$, based on additional information, independently make personal decisions about the current state of the object as an indicator function $\delta_i=m$, $m=1,2$, $i=\overline{1,N}$.

It is clear that, in the general case, the set

$$\mathbf{\Theta}=\{S_{m_1...m_N}:(\delta_1=m_1)\wedge...\wedge(\delta_N=m_N),\ m_1,...,m_N=\overline{1,M}\}$$

of possible situations (combinations $S_{m_1...m_N}$ of personal experts' decisions) includes M^N combinations of experts' decisions, and only in M cases personal decisions will be consistent (when all experts make decisions in favor of one class), and in other cases, the decisions are contradictory.

The "qualification" characteristic of experts is the probability $P^{(i)}(E|V_k)$, $k=1,2$, $i=\overline{1,N}$ of misclassification, which is estimated in advance on the basis of previous experience. It is natural to assume that these probabilities satisfy the conditions $P^{(i)}<P_0$, $i=\overline{1,N}$.

A collective decision will provide a minimum of average error probability on a set $\mathbf{\Theta}$, if in each particular observed situation $S\in\mathbf{\Theta}$ collective decision is made according to the scheme

$$D_S^{opt}=\arg\max_{1\le k\le M}P(V_k)\prod_{i\in J_k}[1-P^{(i)}(E|V_k)]\prod_{i\notin J_k}P^{(i)}(E|V_k) \qquad (1)$$

where

J_k – the set of experts' numbers, that in situation $S\in\mathbf{\Theta}$ made a personal decision $\delta_i=k$, $k=1,2$,

$$J_\mu\cap J_\nu=\varnothing\quad\forall\mu,\nu=\overline{1,M},\ J_1\cup...\cup J_M=\{1,...,M\},$$

and $P^{(i)}(E|V_k)$ – is a distribution of conditional probabilities of erroneous decisions of each expert.

Results of the research. In accordance with the aforementioned methodology, we assume that any project, including the one under consideration, can be successful, i.e. make a profit (class V_1) or unsuccessful (class V_2). Based on statistical processing of the history of previously accepted investment projects in a particular area, one can find the frequency of successful and unsuccessful projects and thereby estimate the probabilities $P(V_1)$ i $P(V_2)$.

Based on the previous decisions of individual representatives of the expert group, it is possible to assess the probability of errors made by a particular expert

when considering a specific project. Moreover, under the expert's mistake, we consider the expert to make a decision about the success of the project, which turned out to be unsuccessful, and vice versa, when the expert rejected the project, which, despite his opinion, was accepted and was successful.

Following [9], we will evaluate the likelihood of successful or unsuccessful completion of the project, using previously gained experience. According to the statistics of the investment fund for the previous ten-year period, 75.6% of the funded projects were successful, i.e. $P(V_1) = 0{,}756$, and, accordingly, $P(V_2) = 0{,}244$.

To make a decision on the possibility of financing the current project, an expert group of 5 people was involved. Error probabilities estimates of these experts for previous decisions are summarized in table 1.

Table 1 – Distribution of conditional probabilities of erroneous decisions

Expert	Erroneous decision probability	
	$P^{(i)}(E \mid V_1)$	$P^{(i)}(E \mid V_2)$
1	0,067	0,073
2	0,011	0,06
3	0,068	0,089
4	0,011	0,021
5	0,064	0,052

As a result of the examination, the first, third and fifth experts considered the project successful (class V_1), and the second and fourth considered it to be unsuccessful (class V_2), i.e. a contradictory situation of individual expert opinions is observed:

$$S_{12121} : (\delta_1 = 1) \wedge (\delta_2 = 2) \wedge (\delta_3 = 1) \wedge (\delta_4 = 2) \wedge (\delta_5 = 1).$$

We shall identify the set of experts, who have given a consistent decision: $J_1 = \{1,3,5\}$, $J_2 = \{2,4\}$ in the given situation S_{12121}

According to scheme (1) for making the optimal collective decision we shall calculate the following values:

$$P(V_1) \prod_{i \in J_1} \left[1 - P^{(i)}(E|V_1)\right] \prod_{i \notin J_1} P^{(i)}(E|V_1) =$$

$$P(V_1)\left[1 - P^{(1)}(E|V_1)\right]P^{(2)}(E|V_1)\left[1 - P^{(3)}(E|V_1)\right]P^{(4)}(E|V_1)\left[1 - P^{(5)}(E|V_1)\right] =$$

$$= 0{,}756 \cdot (1 - 0{,}067) \cdot 0{,}011 \cdot (1 - 0{,}068) \cdot 0{,}011 \cdot (1 - 0{,}064) = 7{,}45 \cdot 10^{-5},$$

$$P(V_2) \prod_{i \in J_1} \left[1 - P^{(i)}(E|V_2)\right] \prod_{i \notin J_1} P^{(i)}(E|V_2) = 7{,}58 \cdot 10^{-5}.$$

Therefore,

$$D_S^{opt} = \arg\max_{1 \le k \le 2} P(V_k) \prod_{i \in J_k} [1 - P^{(i)}(E \mid V_k)] \prod_{i \notin J_k} P^{(i)}(E \mid V_k) = 2,$$

that is, we make the final decision in favor of the class V_2.

Thus, by the minimum criterion of the average error probability, it is advisable to refuse to finance the investment project, despite the fact that successful projects are more common and three experts have attributed this project to successful (class V_1).

Conclusions. A general, Bayesian strategy based decision-making methodology for investing in a project has been developed. The methodology is based on a priori knowledge about the probabilities of successful and unsuccessful projects and the qualifications of experts who characterize the probabilities of erroneous decisions. Such estimates can be obtained on the basis of statistical processing of the results of previous examinations. The constructivity of the proposed methodology is demonstrated by the example of choosing an investment project. Further development of the proposed methodology will be aimed at generalizing the collective decision-making process by the criterion of minimum average risk.

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