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EVALUATION OF THE ECONOMIC EFFICIENCY OF INVESTMENT PROJECTS IN INFORMATIZATION THROUGH THE METHOD OF COMPUTER SIMULATION

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Abstract: *The economic efficiency of informatization investment projects (i-projects) is a crucial factor in decision-making processes, especially considering the growing complexity and uncertainty in the technological environment. A comprehensive analysis is necessary to select the most effective i-project, and computer simulation plays a vital role in evaluating various scenarios and potential outcomes. The findings emphasize the significance of simulation in addressing the inherent variability of i-project investments, facilitating better-informed decisions and optimizing resource allocation.*

Keywords: *mathematical model; investment sources; capital investments; objective function; IT project.*

JEL: M310, M370, M150, C61.

1. Introduction

In today's dynamic economy, assessing the economic efficiency of informatization investment projects (i-projects) is crucial for organizational success. These projects are complex, involving a diverse range of resources, technologies, and interests, requiring thorough efficiency analysis. According to ISO 9000 standards, efficiency is defined as "the ratio between the result achieved and the resources used" [4], emphasizing that project efficiency is influenced by numerous factors and external variables.

The efficiency of an i-project is determined by specific criteria and methods, both of which play a vital role in decision-making. Evaluation methods include gathering and analyzing project data using both quantitative indicators and qualitative interpretations. Criteria, meanwhile, serve as indicators that reflect the system's state and act as the foundation for evaluating outcomes against established objectives [6].

A key element in evaluating the economic efficiency of i-projects is net profit, defined as the difference between the revenues generated and the expenses related to the project's implementation and operation. Net profit can be expressed through cash flow and net cash flow, consisting of two fundamental components: revenues and costs. Calculating these values can be challenging, and simulation emerges as an effective solution in this context.

Simulation enables better management of imprecise and incomplete information when evaluating the economic efficiency of i-projects. It allows decision-makers to analyze multiple project scenarios and select the solution with the highest potential for success. By using simulation, projections based on various assumptions about future conditions can be generated. This method effectively answers critical "what if...?" scenarios by adjusting exogenous variables and economic parameters to estimate their impact on i-project efficiency [8].

There are several strong arguments for using simulation in evaluating the economic efficiency of i-projects:

1) In many cases, evaluation problems cannot be expressed through standardized mathematical formulas, which necessitates the use of alternative methods such as simulation [7].
2) Even when analytical methods are available, their application may require excessive computational effort or lengthy timeframes, which is not always justified in relation to the benefits obtained [10].
3) Inaccurate or incomplete data can render precise analytical methods useless, making simulation a more viable option for obtaining relevant results [1].
It should be noted that simulations in an informatization investment project are based on building a model from decision variables, which reflect the mechanism of the analyzed decision-making situation. These simulations allow for identifying the most appropriate option based on a set of predetermined decision criteria. Therefore, simulation not only enhances the evaluation of economic efficiency but also provides the ability to adapt to ongoing market changes.

Basic content

The simulation technique is based on the imitation or reproduction, using models, of the systematic behavior of certain components of the IT project, with the aim of gaining a deep understanding of their functioning so that management decisions can be made based on this knowledge. In general, the simulation is conducted sequentially, as illustrated in Figure 1:

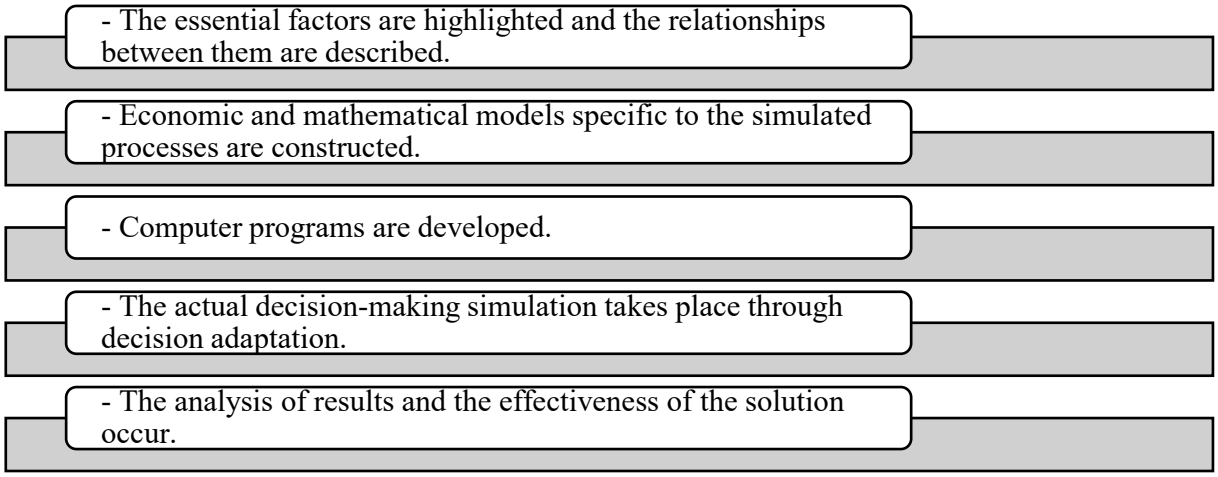

Figure 1. Stages of decision simulation in the analysis of IT project efficiency

Source: developed by author based on the conducted study and scientific research

Since, in the evolution of IT projects, they are influenced by random factors such as unpredictable cost variations, fluctuations in available resources, unexpected changes in requirements, or uncertainties related to technological performance, a procedure for generating statistical selections of these random variables and stochastic processes defined in the problem formulation is utilized with the help of a computer.
Additionally, a characteristic problem of simulation models lies in tracking the dynamics of the simulated system's states—meaning monitoring them through "clock time." By its nature, the simulation model is discrete, successively highlighting the state changes of the system.
In this context, a simulation model includes input and output elements, each defined as variables or parameters. The distinction between a variable and a parameter is given by the possibility of the variable to change its value during the execution of the calculation program—while the parameter

remains constant throughout a calculation sequence. Within the simulation model designed to identify the efficiency of IT projects, we have two types of variables:

✓ *Input variables* can be deterministic (read from the external environment or identified based on strictly determined rules) or stochastic. The generation of stochastic variables depends on certain input parameters. A stage during the execution of the calculation program where the input variables remain constant is called the simulation step.

✓ *Output variables* depend on the input variables through a specific mechanism (which describes the logical conditions and types of mathematical processing that can be applied). This dependence is determined by the internal logical structure of the theoretical model considered. The value of an output variable is the result of executing a step of the calculation program associated with the model. If at least one of the input variables is stochastic, then at least one of the output variables is also stochastic.

At the same time, it should be noted that any structure of a simulation model intended for evaluating the efficiency of an IT project contains the following basic elements:

a. *Decision-making rule* – this influences how the intermediate and final results of the project are obtained;

b. *Entities* – the variables to which different numerical values (quantitative variables) and/or logical values (qualitative variables) are assigned, relevant to the informatization process;

c. *Linkage relationships* – which describe the interconnections between the quantities involved in the informatization project;

d. *State of the system* – any informatized system is described in a certain state that can be either static (in the case of certain Markov processes) or dynamic (through various state equations);

e. *Exogenous events* – events that may occur independently of the state of the system at a given moment, thereby influencing the project's efficiency;

f. *Feedback links (or feedback relationships)* – through which the output magnitudes (final results or responses) adjust, according to certain rules, the input variables in the model;

g. *Simulation stopping criteria* – to delineate the time horizon, accuracy, and "fineness" of the model, ensuring the relevance and accuracy of the evaluation of the informatization project's efficiency.

After constructing the simulation model, the process involves modifying the values for various system characteristics, such as input variables or parameters, and deducing the mechanism through which the output variable values are generated. This adjustment is essential for evaluating the efficiency of investment projects in informatization, highlighting the impact of calculations on other components of the system and allowing for the identification of the most effective implementation strategies. By testing and modifying the variables, one can analyze how each efficiency criterion influences the final outcomes. This provides a solid foundation for identifying the most efficient strategies for each IT project.

In the process of analyzing the efficiency of IT projects, a series of relevant indices are utilized, such as the discounted payback period, *economic return on investments (ERI), net present value (NPV), internal rate of return (IRR), profitability index (PI), adjusted expenses (AE), and total cost of ownership (TCO)*. Evaluating these indices through simulation facilitates the identification of successful projects and provides a better understanding of the critical factors influencing the outcomes

of an IT project, while also allowing for the assessment of various scenarios and the selection of the most efficient option.

Thus, computer simulation not only aids in evaluating the performance of IT projects but also contributes to optimizing the decision-making process, evaluating the economic efficiency of investment projects, analyzing multiple possible project alternatives, and choosing the one that yields the greatest effect.

Based on the research conducted, it was found that two types of models are used for studying the efficiency of investment projects in informatization, as presented in Figure 2:

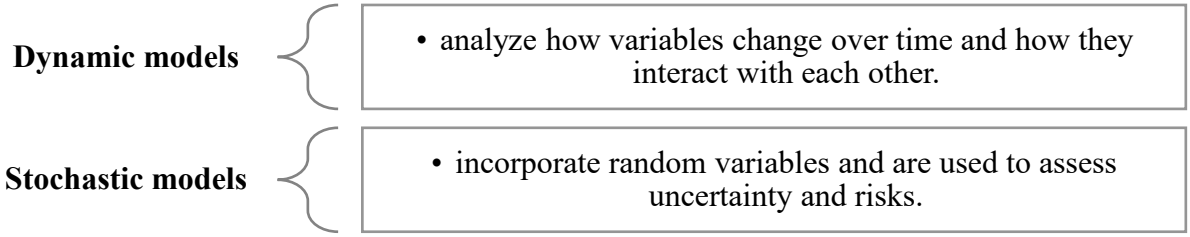

Figure 2: **Types of models used in the analysis of the efficiency of IT investment projects**

Source: developed by author based on the conducted study and scientific research

According to the information presented in Figure 2, dynamic models are useful for simulating the evolution of complex systems and for understanding the impact of changes on investment project outcomes. In contrast, stochastic models allow for the simulation of various scenarios, taking into account external fluctuations that may influence project efficiency.

The models for simulating IT projects are designed to quantify the impact of certain variables (products, demand volume, etc.) on net revenues over a period of time. One of the most general methods for analyzing phenomena that occur in systems characterized by a large number of variables, parameters, complex relationships between components, and disturbing factors is considered to be Monte Carlo simulation. The Monte Carlo simulation model is useful for comparing the indices of IT projects as it can provide an accurate estimate of the results, accounting for the variation and uncertainty associated with them.

The Monte Carlo method is essential for assessing the risks and uncertainties associated with investment projects in informatization, providing a stochastic approach for the comparative analysis of efficiency indices such as NPV, IRR, and PI. This method allows for the simulation of multiple possible scenarios based on probabilistic distributions of critical variables, such as costs, implementation duration, and project returns.

By utilizing the Monte Carlo method in informatization projects, various scenarios can be simulated where the values of input variables, such as available resources or budgets, are randomly altered. The results of these simulations provide a probabilistic perspective on project performance, allowing for the analysis of the impact of each efficiency criterion on the final outcomes. Thus, the method becomes a tool for the comparative evaluation of projects aimed at identifying optimal solutions and mitigating risks.

In [9] and [3], Monte Carlo simulation has been used to assess financial risks and determine the likelihood that the project's duration and costs will exceed initial estimates. Similarly, in informatization projects, this method aids in identifying potential deviations from initial plans, contributing to a more accurate estimate of the economic efficiency of the investment. Additionally,

the proposed risk scale in [3] can be adapted for classifying risks in IT projects, providing a clear view of potential losses.

The application of the Monte Carlo method in analyzing the efficiency of informatization projects involves generating random variables for each project and calculating efficiency indices for each scenario. This can be achieved through simulation algorithms that generate random variables X_i and calculate performance indicators such as NPV, IRR, and PI, which are computed according to established formulas:

1) **Net Present Value** (**NPV**) expresses the surplus value that returns to the investor by the end of the investment's lifespan and is determined as the difference between the discounted future cash inflows and the amount of capital invested [2, 11]:

$$NPV = \sum_{t=1}^{L} \frac{CF_t}{(1+d)^t}, \quad (1)$$

where d is the discount rate (which may also be dependent on t), and L – is the duration of the project implementation, τ is the investment absorption duration, D – is the useful life of the product, and, and $L = \tau + D$ is the total duration of the project. The coefficient d_n is determined according to the formula [2] $d_n = (1 + d)^n$, where d is the *discount rate*. Thus, the indices can be static (which do not take the time factor into account) and dynamic (which do consider the time factor). Static indices are usually used for estimating the efficiency of investment projects with a duration of up to one year, while dynamic indices are used in other cases.

If we analyze the NPV's dependence on the discount rate, it is obvious that the profit from the project will decrease with the increase of the discount rate (see Figure 3).

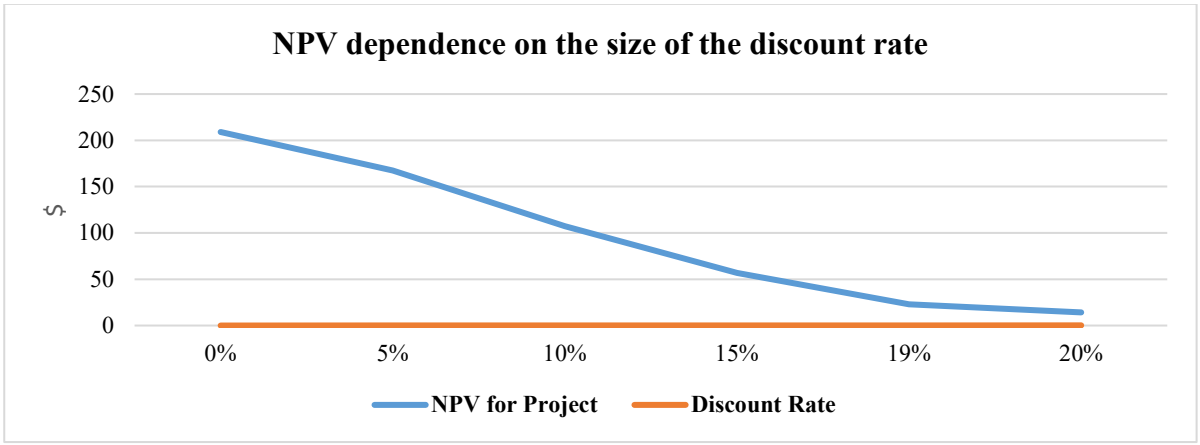

Figure 3. Dependence between NPV and discount rate

Source: developed by author based on the conducted study and scientific research

For the case when a project is fully financed by a bank loan, and the average risk-free bank interest rate is 12%, then it can be said that the i-project is beneficial.

2) **Internal Rate of Return** (**IRR**) represents the discount rate for which the NPV index has a value of zero, meaning it is determined from the equation:

$$-\sum_{t=1}^{r} \frac{I_t^C}{(1+IRR)^t} + \sum_{t=r+1}^{L} \frac{P_t + AA_t}{(1+IRR)^t} = 0, \quad (2)$$

Knowing the value of IRR, it can be stated that if IRR < d, then NPV will have a negative value, meaning that the project is not efficient. Conversely, if IRR > d, then NPV > 0, and the project, based on the NPV index, can be considered acceptable. The IRR index, in fact, determines the interest rate from the project implementation, and then compares this rate with the risk-adjusted repayment rate. If the repayment exceeds the risk-adjusted recovery, then the investments make sense.
Unlike NPV, IRR is an absolute measure that allows not only decisions to be made on i-projects, but also to compare projects with completely different levels of funding and completely different budgets [3].
3) **The Profitability Index (PI)** expresses the relative profitability over the project's lifespan [11] and, taking into account (2), is determined as follows:

$$IP = \frac{1}{I^C} \sum_{t=r+1}^{L} \frac{CF_t}{(1+d)^t} = \frac{NPV + I^C}{I^C} = 1 + \frac{NPV}{I^C}, \qquad (3)$$

It specifies the size of the discounted profit that corresponds to one unit of invested capital. The value d may also depend on t. According to this index, the project that ensures the highest value of the Profitability Index (PI) is accepted.
Based on the information presented, Monte Carlo simulation proves to be a valuable tool in the decision-making process for IT projects, providing a detailed analysis of their performance and contributing to the effective foundation of investment strategies. This stochastic method allows for addressing complex problems through the modeling of random variables, facilitating the simulation of an artificial random process that reflects the essential characteristics of the studied system.
By utilizing the Monte Carlo technique, virtual experiments can be conducted, replacing real conditions with simulations that generate random numbers with a distribution similar to the behavior of the real phenomenon. The practical value of the method lies in its ability to determine, through repeated experiments, the probabilities and average values of the variables of interest. This approach proves useful in evaluating the risks and uncertainties associated with IT projects, providing a solid basis for the comparative analysis of efficiency indices such as NPV, IRR, and PI.
Modeling through Monte Carlo simulation involves identifying the cumulative frequency function for a specific sample, which can be extrapolated to reflect the real behavior of the system. Thus, if certain values of the random variable correlate with the expected outcomes, these values can be used to anticipate the performance of the projects.
To ensure the validity of the calculations and the relevance of the conclusions, the associated stochastic process must accurately reflect the initial problem. This means that the arithmetic and logical operations used for the generated variables must conform to the established relationships, so that the obtained results are representative of the problem-solving objectives. The results are expressed in the form of statistical sequences, including means and variances, which, according to the law of large numbers, approximate the solution to the studied problem, providing a solid foundation for making informed decisions in the field of IT investment.

2. Conclusions

The article presents an analysis of the economic evaluation of informatization projects, highlighting the application of computer simulation methods as an essential tool in managing uncertainties and risks. The use of Monte Carlo simulation proves to be particularly effective in optimizing the

decision-making process, providing relevant results that can enhance current approaches to IT project evaluation.

Based on the findings of this study, future research could expand the application of comparative analysis of efficiency indices for each project individually. By simulating various scenarios, decision-makers can anticipate the impact of critical variables on economic outcomes, thus facilitating informed decision-making. Therefore, the integration of Monte Carlo simulation and comparative analysis in the evaluation of informatization projects contributes to more efficient and strategic management of investments in information technologies.

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