Formalization of risk analysis in software products for calculating the effectiveness of investment projects

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Abstract. Simulation is the process of transforming real processes in a mathematical form using computer technology. The main type of quantitative risk analysis is the calculation of stability analyzes, among which there is main type - sensitivity analysis (analysis of overall project sustainability). The purpose of the study is to improve the methodology for formalized risk assessment in the simulation of investment projects. It includes the following tasks: - analysis of existing approaches to risk assessment in simulation; - identification of the problems of calculating the level of risk in the simulation models of investment projects; - improvement of existing software products for calculating the effectiveness of investment projects. Sensitivity analysis finds out the reaction of the project to changes in its main parameters. One-way sensitivity analysis, implemented in almost all software products, provides limited information. Therefore, it is proposed to supplement the possibilities of programs by introducing a two-way sensitivity analysis into the structure of the section to study the effect on the result of simultaneous changes in two significant environmental factors. The calculation results will be presented in tabular and graphical form to expand the analysis capabilities. On the graph, by separating the zone with negative values and marking it with a contrasting color, the zone with unacceptable values (which correspond to ineffective design options) is very clearly visible.

1. Introduction
Simulation is the process of transforming real processes in a mathematical form using computer technology [1-6]. Simulation modeling, in contrast to analytical models, not only tries to connect the input variables and the results obtained, but also to reproduce the structure of the processes occurring in the system under study, to determine the internal relationships and their nature [7-12]. All this makes it possible to better understand the system under study, carry out numerical studies of its behavior, and improve the system based on the results obtained.

Simulation modeling has become widespread in the study of the efficiency of investment processes, including in the preparation of business plans. The first investment project simulation model was
developed in 1964 by David Hertz [13-15]. He suggested using a simulation approach to solve the problem of determining the required volume and efficiency of capital investments in conditions of uncertainty. Currently, there are quite a few simulation models built to study investment projects in the pre-investment phase. Large Western industrial and financial corporations create mathematical models for their own development and efficient capital allocation. The means of mathematical modeling are widely used by consulting firms that conduct research on the effectiveness of investment projects on the orders of clients [16-22].

One of the first simulation models that appeared in Russia for the study of investment projects, implemented in the form of a software package for a computer, was the Comfar system (Computer model for feasibility analysis and reporting), developed by UNIDO (United Nations Industrial Development Organization) [23-25]. A significant drawback of the system was that the initial information for the calculations did not correspond to the structure of costing and reporting data at Russian enterprises. As a result, the data presented in the form adopted at domestic enterprises had to be restructured so that they could be used in the Comfar system and the like [26-30]. This procedure is rather laborious and required special training of analysts.

2. Materials and methods
At present in Russia the most common simulation models implemented in the form of software products are: Project Expert, developed by Expert Systems, and Alt-Invest, by Alt-Invest [31-33]. Both software products are very popular in solving problems related to the justification of decisions on investment projects and are the standard in this area. The programs are implemented using various approaches: Alt-Invest is an open-source program, compiled for MS Excel. It allows you to view calculation formulas, so it requires less user training compared to Project Expert, which is a closed program. At the same time, Project Expert has a more powerful analytical apparatus, is more flexible (it is easier to adapt to changes in legislation) [34-38].

The main type of quantitative risk analysis is the calculation of stability analyzes, among which there are four main types: analysis of a three-component indicator (analysis of financial stability); break-even analysis (analysis of the sustainability of production activities); Monte Carlo analysis (probabilistic analysis) and sensitivity analysis (analysis of overall project sustainability) [39-48].

Among the software products for calculating the effectiveness of investment projects that have become widespread in Russia, only the Project Expert program allows you to carry out all the main types of sustainability analysis [49-53].

The purpose of the study is to improve the methodology for formalized risk assessment in the simulation of investment projects. It includes the following tasks: - analysis of existing approaches to risk assessment in simulation; - identification of the problems of calculating the level of risk in the simulation models of investment projects; - improvement of existing software products for calculating the effectiveness of investment projects.

3. Results and discussion
Currently, when studying the behavior of an investment project, a sensitivity analysis is carried out, which shows how the project reacts to a change in its individual parameters. Evaluation of project results is carried out using performance indicators, among which the main ones are: net present value (NPV); profitability index (PI); payback period (PB) and internal rate of return (IRR) [54-61] (figure 1).
Distinguish between univariate and multivariate sensitivity analysis. In the first case, the effect on the result of a change in only one indicator is studied. This is the most common form of sensitivity analysis, which is presented in almost all software products used to evaluate investment projects. In fig. 1 shows the original form of calculating one-way sensitivity analysis, implemented in the Project Expert program. As you can see, the analysis algorithm is well developed: the form is intuitive; the calculation setup is very simple. The result displayed in the form of a report has two forms of presentation: tabular (table 1) and graphical (figure 2).

**Figure 1.** Calculation of one-way sensitivity analysis in Project Expert v.7.57.

| No | Parameters       | -20%        | -10%        | 0%          | 10%          | 20%          |
|----|-----------------|-------------|-------------|-------------|-------------|-------------|
|    | NPV             | 1 963 768.91| 1 637 962.40| 1 321 457.53| 1 013 835.03| 714 700.45  |
| 1  | Tax rate        | 1 757 044.23| 1 539 250.88| 1 321 457.53| 1 013 664.17| 815 870.82  |
| 2  | Investment size | -239 720.92 | 540 868.30  | 1 321 457.53| 2 102 046.75| 2 882 635.97|
| 3  | Sales volume    | 3 732 483.64| -1 205 513.06| 1 321 457.53| 3 848 428.11| 6 375 398.70|
| 4  | Direct costs    | 4 814 220.25| 3 067 838.89| 1 321 457.53| -424 923.84 | -2 171 305.20|
| 5  | Total costs     | 5 693 197.51| 1 445 427.52| 1 321 457.53| 1 978 487.54| 1 073 517.55|
| 6  | Loan rates      | 1 459 409.00| 1 390 433.26| 1 321 457.53| 1 252 481.79| 1 183 506.05|

In a tabular form, you can very clearly see the boundaries of the change in indicators at which the investment project retains its profitability. The wider the boundaries for obtaining positive results (in terms of NPV), the more stable the project is in relation to the negative influence of external and internal factors. Under normal conditions, a sufficient condition for the sustainability of the project is to obtain positive values (by NPV) in the interval from -20% to + 20% of the change in the selected environmental factors.
The graphical form clearly allows you to highlight those environmental factors, the change of which has the greatest impact on the efficiency of the project. These are the indicators, the graph of which deviates to the greatest extent from the basic calculation option. In the example shown in Fig. 2, the most significant factors of the investment project environment are: sales price, direct costs and sales volume. The influence of the rest of the calculation parameters in comparison with the named ones is minimal.

Multivariate sensitivity analysis examines the simultaneous impact of two or more environmental factors on project results. Unfortunately, this form of sensitivity analysis is practically not presented in software products for calculating the effectiveness of investment projects. The only exception is the What is-analysis program, which is part of the Project Expert software package. A big drawback of this software product is the discreteness of the analysis, which makes it difficult to assess the stability in this case. The program specifies the parameters of individual scenarios (for example, a simultaneous decrease in the selling price by 10%, an increase in the loan rate by 5% and an increase in wages by 5%).

In order to determine the sustainability of an investment project by at least two parameters, it is necessary to set up several separate scenarios, carry out a calculation, summarize the data obtained, and, only after that, the results can be analyzed.

Table 2. Two-way sensitivity analysis. Tabular form, rubles.

| Sales volume | -20%            | -10%            | 0%              | 10%              | 20%              |
|--------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Direct costs | -20% 2554489.27 | -10% 3684354.8  | 0% 4814220.25   | 10% 5944085.75  | 20% 7073951.24  |
|              | -10% 1157384.17 | -10% 2112611.5  | 0% 3067838.89   | 10% 4023066.25  | 20% 4978293.61  |
|              | 0% -239720.92   | 0% -424923.84   | 0% -1636826     | 0% -1030875     | 0% -826978.33   |
|              | 10% -1636826    | 10% -1030875    | 10% -424923.84  | 10% -181027.25  | 10% 786978.33   |
|              | 20% -3033931.1  | 20% -2602618    | 20% -2171305.2  | 20% -1739992.25 | 20% -1308679.3  |

Figure 2. One-way sensitivity analysis (NPV). Graphic form, rubles.
To increase the degree of automation of the process of conducting multivariate sensitivity analysis, reduce labor costs, and increase the visibility of the results obtained, it is proposed to supplement the structure of the Project Expert program with the possibility of conducting a two-factor sensitivity analysis in tabular and graphical forms (table 2, figure 3).

The analysis is proposed to be carried out according to the following scheme: at the first stage, using a one-way sensitivity analysis, it is necessary to select the project factors that most affect the result. In our example, these are three factors. At the second stage, it is necessary to calculate the results of the pairwise influence of the selected parameters on the results and present them in the form of a table and graph.

The table presents the numerical results of the two-way sensitivity analysis. On the graph, by separating the zone with negative values and marking it with a contrasting color, the zone with unacceptable values (which correspond to ineffective design options) is very clearly visible. For example, these are almost all cases of a decrease in sales volume below 10% of the planned level.

4. Conclusion
A quantitative risk assessment is one of the most important elements in assessing the effectiveness of an investment project. Therefore, it is very important to improve the methodology of formalized risk assessment. Among the main tools is sensitivity analysis to find out the reaction of the project to changes in its main parameters. One-way sensitivity analysis, implemented in almost all software products, provides limited information. Therefore, it is proposed to supplement the possibilities of programs by introducing a two-factor sensitivity analysis into the structure of the section to study the effect on the result of simultaneous changes in two significant environmental factors. The calculation results will be presented in tabular and graphical form to expand the analysis capabilities.

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