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APPLICATION OF SIMULATION MODELS FOR DECISION-MAKING PROCESSES IN AVIATION COMPANIES

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Abstract
Simulation methods are currently widely used, from simulations of various experiments to the calculation of certain integrals to the solution of differential equations. We can also use them in the economy and business operations. A specific industry, such as air transport, currently applies simulations to decision-making processes only to a small extent. The aim of the article is to point out the applicability of Monte Carlo simulation in the area of risk assessment of projects and investment activities, which is an important factor in achieving business sustainability. Through stochastic and deterministic modelling, simulations were performed using the Crystal Ball software tool. The simulation criterion is Net Present Value (*NPV*), modelled in different variants of variables in the form of own and foreign sources of financing. Simulation research in the field of financial decision-making is practically unknown and not applied to aviation companies. The process of planning investments and simulating their development in order to ensure sustainability for the future should become an integral part of all companies in aviation.
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Key Words: Simulation, Aviation, Financing, Investment, Monte Carlo, Crystal Ball

1. INTRODUCTION

Simulation can be defined as a method that allows a real system to be simulated by a surrogate simulation model. Experiments can be carried out on this model. The results of these experiments are then applied back to the real system. In this sense, we speak of a simulation model [1]. Simulation models have become important tools in various industries. There are many reasons for this, but three of the most important need to be highlighted:

- allow for the exploration of hypotheses and as such have become invaluable tools to guide research;
- these are unique approaches to integrating (in the literal sense) knowledge in the form of experimental results;
- enable the interconnection of different disciplines.

Simulation can also be defined as a process of imitation, where a real process is mimicked over time [2, 3]. Simulation modelling, including the analysis process, is undertaken by companies to understand systems in a complex context, to mediate and create conditions for development and testing, and ultimately to gain information and insights [3].

In the current market environment, all sectors and areas of social life are concerned with the issue of risk. Management and risks have become part of our everyday business and private life. The last decades have exposed our society to a number of events that have defined new risk factors with their negative impacts. In the economic sphere of the business environment, it is therefore a matter of course that companies place increasing emphasis on risk management in order to minimise their impact. For this reason, it is very important for businesses to introduce new approaches and assessments based on software tools that use simulation models into management processes.

The air transport industry is characterised by dynamic development and uniqueness in the operation of companies that are highly dependent on each other. A threat to one company will affect the functioning of other companies in the sector. The development of air transport also requires relatively high investments in individual enterprises, which also raises the question of financing these investments and the need for a change in decision-making. It is for this reason that one of the fundamental objectives of companies in aviation is to pay considerable attention to risk management in relation to management processes. The goal should be to try to eliminate or prevent individual risks.

The importance of risk in aviation is growing in all areas. In the current environment, where air transport is directly involved in the globalisation of society; the impact of risk cannot be avoided or ignored, and therefore becomes part of the decision-making processes of airlines. Uncertainty, which identifies all variables (input and output) but also the very factors that result from air transport processes, affects the set goals and their attainability in all areas of the industry and the companies themselves. This is why risk management is an industry-wide and business-wide issue [4].

An important role in this process is played by information and communication technologies, which create conditions for the application of new approaches to existing methods. For the purposes of the article, the Monte Carlo method was chosen to integrate a new approach into the process of evaluating the financing of investment activities of companies in air transport, the application of which is used in the article through the integrated software tool Crystal Ball.

The Monte Carlo method, which has been extended and modified in corporate risk decision-making, can be used as a tool to manage financial risk due to investment decisions and their financing, thanks to software support and its development. It is a tool that is often used in financial management, planning, and managerial decision-making.

The basic definition of a company is defined by Act No. 143/1998 Coll. on Civil Aviation, as amended, which defines an aerodrome as a defined area on land or water (including buildings, facilities, and equipment) intended either wholly or partly for departures, arrivals, and ground movements of aircraft [5]. Some authors [6] state that an airport can be viewed not only from a narrower perspective as a set of purely operational areas and buildings, but also more broadly as a set of buildings related to these operations and forming the commercial background of the airport.

The issue of companies in aviation is more relevant in the 21st century than ever before, as the market has seen tremendous growth in recent years. Regulation of these companies and the question of effective financing appears to be one of the main contributors to market inflexibility. In the future, many outdated methods and possibilities of managerial decision-making will need to be re-evaluated, and the conclusions of this article should draw attention to these problems.

To understand the broader context of financing, it is necessary to consider the ownership [6, 7]. In the European Union (EU), the system of ownership and financing of airports is fundamentally different. Above all, we cannot talk about a holistic system because airports in the EU have different ownership and institutional structures in different countries and even within member States. Compared to the United States (US), airports in the EU are heavily privatised [8], through different ways of privatisation – directly or indirectly [7, 9]. At the same time, the higher level of airport privatisation in the EU meant that it was necessary to create economic regulatory frameworks in the field of airport fees [10], which individual member states set according to their national preferences and the interests of their countries.

A specific problem for Slovakia and the EU is the relatively large number of regional airports with less flight traffic and the resulting problems with financing, which can be supported by state aid in the field of operational and investment financing.

2. MATERIALS AND METHODS

2.1 Problem statements

The purpose of our article is to propose procedural steps for the identification and assessment of the risk of planned investments, focusing on the possibilities of financing this investment under the conditions of companies in aviation in the Slovak Republic.

The basic goal of the research is the verification and evaluation of the methodological approach to increasing the competitiveness and sustainability of companies in aviation from the point of view of quantitative and qualitative interpretations. Fulfilment of the main goal can be achieved by verifying the algorithm integrating new approaches into the planning and decision-making processes of companies through sophisticated tools. The research task worked with two hypotheses.

Hypothesis 1 (H1). The compiled algorithm, through measurable indicators, will enable aviation companies to eliminate the risk of incorrect financial and investment decisions.

Hypothesis 2 (H2). There is an assumption that the algorithm applicable in aviation companies in Slovakia will also be applicable within the European integration processes in aviation companies in other countries that operate in a similar economic and business environment.

The methodology is presented through a process algorithm, which is a clear tool providing guidance for research the issue of decision-making processes or project planning of companies in aviation. The algorithm integrates mathematical modelling through deterministic variables and stochastic Monte Carlo modelling using other simulation tools. The algorithm presented in this way can be applied in the process of decision-making about investments and finances.

2.2 Methodology for decision-making processes

The result of the authors' research is the development of a procedural procedure for the assessment of sources of financing for investment activities in aviation companies. Based on this process, a design of process steps is created that is based on simulations using the Monte Carlo software tool. The process model works on the basis of economic variables, which represent the basic inputs to the simulation processes in each phase of decision-making management. Individual variables are arranged in the apparatus through mathematical relationships and statistical-mathematical dependencies. The methodology of the research process and the processing of outputs for the purposes of the article are shown in Fig. 1.

The aim of the research was to assess the possibilities of implementing uncertainty into clearly defined models based on discounted cash flows (*DCF*) in aviation. This process is based on the identification of the uncertainty of the input variables and their probability distribution. By using probability in valuation models, uncertainty is implemented in the analysis and thus it removes the shortcomings of the existing model [11, 12]. Monte Carlo simulation takes place through three basic steps:

- First, it is necessary to develop a model based on a detailed description of the monitored variables.
- Subsequently, a simulation will take place consisting of a large number of experiments with respect to the criterion value [13].
- Finally, it is necessary to implement an evaluation of the outputs based on statistical interpretation. The method of discounted cash flows is the most suitable approach in the process of assessing the investment activities of companies [14].

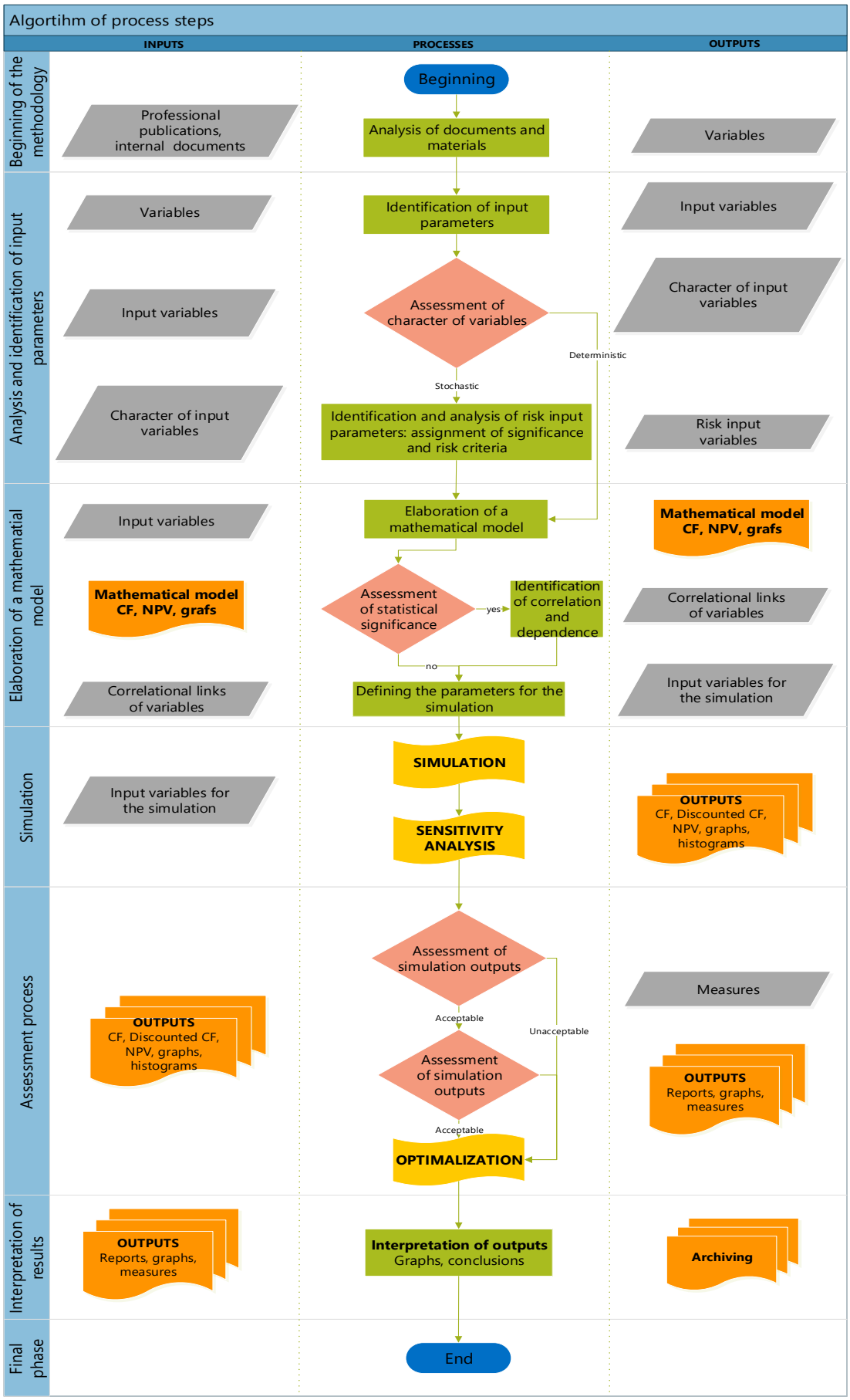

Figure 1: Algorithm of process steps.

The applicability of the Monte Carlo method in the business practise can be defined by a process model that is structured in nature and defines the steps for researching the problem of decision-making processes in companies while accepting the principles used in risk management according to ISO 31000 and the principles of simulation using the Monte Carlo method. The process model can be divided into five steps:

1. Analysis and identification of input parameters, where the variable to be simulated is defined and subjected to Monte Carlo simulation. It is necessary to consider its dependence on the other parameters and to identify the nature of the variable, i.e., whether it is deterministic or stochastic in nature. The deterministic nature is defined by the certainty of the calculation. If at least one input variable can be varied and is stochastic in nature, the outputs need to be defined only on the basis of a certain.
2. Development of a mathematical model that serves for the needs of the simulation model. All input variables need to be applied to the mathematical model. Even those that have been identified as risky and assign them a probability distribution. In this step, distribution functions are used (using the *FIT* function), which are mainly based on available historical data of a stochastic nature. In some cases, defining the distribution functions in this way is problematic and therefore it is necessary to define it based on trend and forecasts. Defining all dependencies at this stage is responsible for the confidence level of the simulation result. In the case of defining the functions, it is necessary to rely primarily on expert estimates and the opinions of practitioners. At this stage, the statistical dependence of the variables based on the correlation between the inputs should also be identified.
3. Simulation, which is realised by using Crystal Ball simulation software, is a tool that is an integrated part of the MS Excel environment. The result is the simulation using these tools and the forecast of the simulated variable defined in the first step. The software tool allows to predefine simulation parameters, such as the number of iterations, simulation techniques, simulation speed, expected result, or the form of displaying the results. The reliability of the forecast depends on these parameters.
4. The process of assessing the simulation results and their impacts against predefined objectives and criteria. In cases where the output values do not correspond to the accepted parameters, the possibility of optimisation should be considered. Optimisation, in this case, acts as a sub-process of the simulation model. Consequently, measures need to be proposed to reduce the risk arising from the parameter.
5. Interpretation of the simulation and optimisation results is displayed through graphs and tables, and these graphical outputs need to be interpreted verbally. The individual outputs are archived so that they can be used in the future. They become part of the risk documentation of the enterprise and serve as a basis for establishing trends and forecasts and assessing the effectiveness of measures.

The Monte Carlo method is based on statistical calculations that are based on simulating random values from the point of view of random variables. The advantage of this method is the possibility to implement solutions for optimistic, pessimistic and realistic scenarios. Monte Carlo simulations use a stochastic approach based on probabilities. However, its application is also possible when solving problems based on a deterministic approach. The deterministic approach uses probability density [2, 3, 15-17].

The basic relationship for Monte Carlo simulation is [18-20]:

$$p = \frac{\frac{L}{d}}{\frac{\pi}{2}} \tag{1}$$

where:

p – probability of two lanes crossing,
L – needle length,

D – width of stripes.

The method creates pressure on managers and other management personnel to implement detailed monitoring of risk factors [21, 22].

When processing the proposal for the creation of a methodology for streamlining aviation management decisions through simulation, it was necessary to consider the following factors:

- The Present Value of the Investment (*PV*) is affected by the discount rate. For this reason, the variables in the simulation take into account the influence of time based on the discounting principle [23, 24].
- The basis of the mathematical apparatus of the input variables for the simulation is cash flow, while the main goal is to achieve positive cash flow [25-27].
- Cash flow updating in real time provides a real insight into the efficiency of the investment project, and its integration into the simulation creates space for more effective management decisions [26-28].

3. RESEARCH RESULTS AND INTERPRETATION

The introduction of software tools and new approaches and their integration into the decision-making processes of companies in aviation is a complex process that is vividly illustrated with the help of the algorithm (see Fig. 2). The output of a variable simulation is a series of graphically represented values. The Crystal Ball programming environment allows you to set arbitrary statistical indicators in each graph, which are integrated directly into the graphs. The simulation considers modelling different ratios of own and foreign resources. Monte Carlo simulation produces predictions represented by graphical diagrams based on the probability and frequency of repetition of the observed value. The diagrams have a distribution according to the distribution functions assigned in the Monte Carlo simulation preparation process. For example, representations of the distribution function are shown in Fig. 3. The basic output of the simulation is a histogram. This output provides data on the frequency of monitored values and their probability distribution. The Net Present Value (*NPV*) histogram is shown in Fig. 4.

The output graph of the simulation provides an overview of the probability distribution from the point of view of the monitored quantity, which is the *NPV* value. Such an output provides a sufficient amount of information for the needs of statistical analysis. Graphical representation of outputs through a histogram is essential for risk management and analysis. The benefit is a comprehensive overview of simulated parameters with a display of their probability and frequency. From the perspective of probability assessment, it is necessary to analyse the symmetry of the probability distribution of the *NPV* quantity. Outputs (Figs. 4 and 5) can be defined as follows in Table I.

Table I: Comparison of statistical data of the different versions of the *NPV* benchmark.

Statistical indicator	**Description**
Minimum	Highest possible loss.
Maximum	Highest possible profit.
Kurtosis	A value almost identical to the normal distribution whose value is equal to three.
Certainty	The probability of a criterial variable reaching a value lower than the deterministic value of that variable.
Standard deviation	Identifies the dissimilarity of typical scenarios and quantifies the dispersion of values from the mean.
Variance	Identifies the return per unit of risk. It gives the ratio of the mean value of the observed variable to its standard deviation.

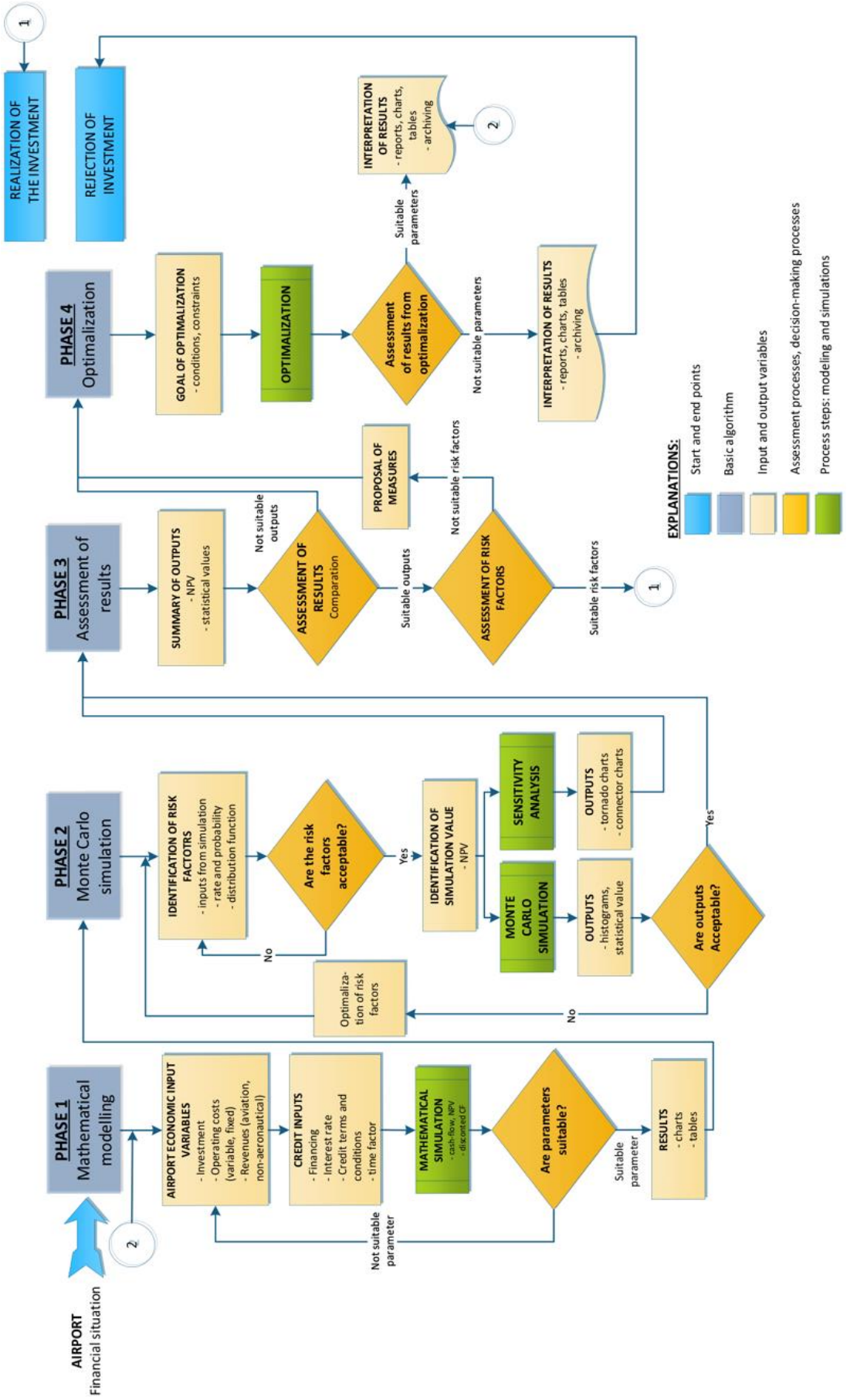

Figure 2: Algorithm of software tools for decision-making processes in aviation companies.

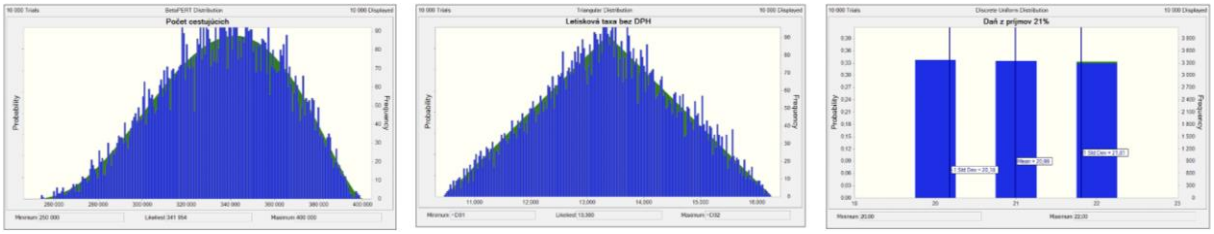

Figure 3: Selected outputs of assumptions from Monte Carlo simulation.

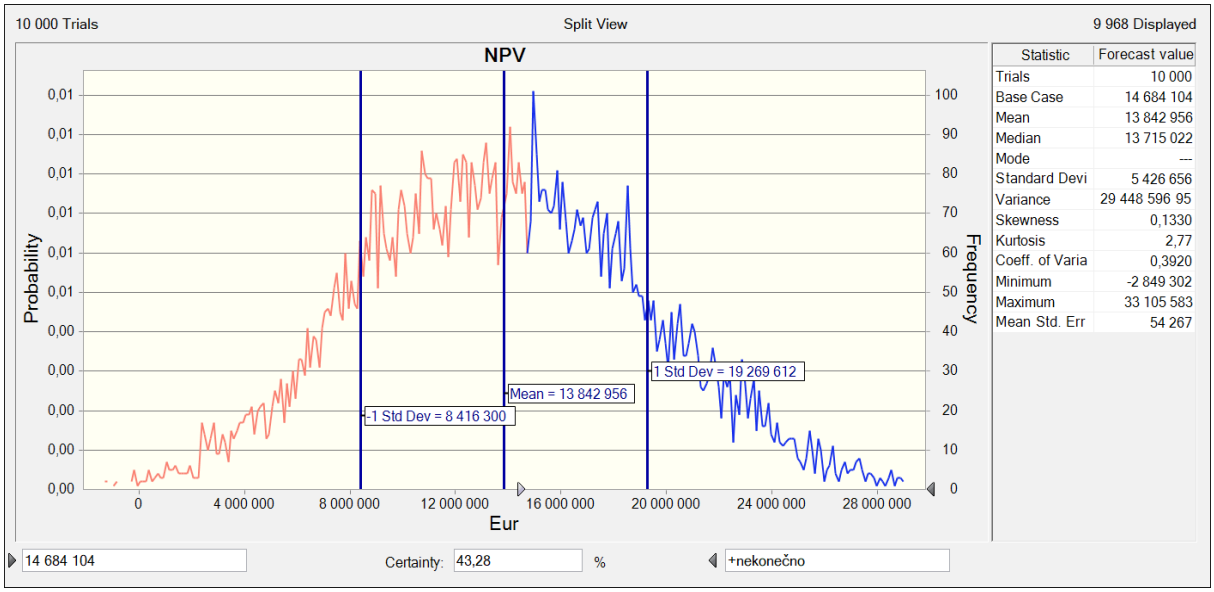

Figure 4: Probable *NPV* distribution.

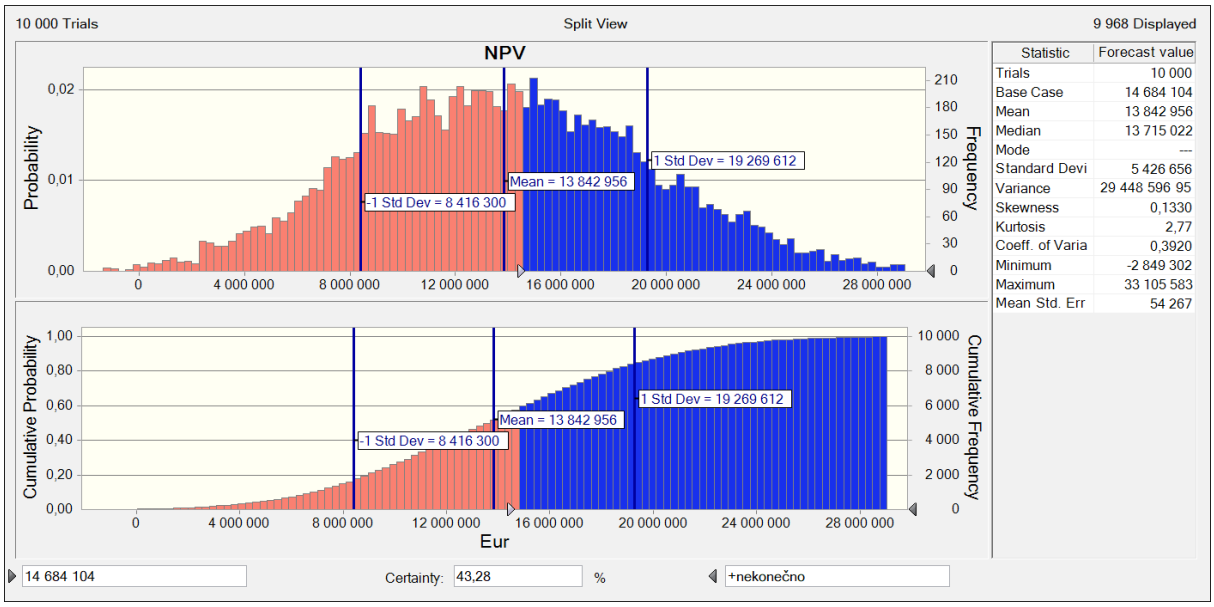

Figure 5: Normal and cumulative probability distribution of *NPV*.

The simulation through the Crystal Ball software tool uses sensitivity analysis [29] as a superstructure, and the output is a Tornado sensitivity graph. The output of this sensitivity analysis is shown in Fig. 6. The graph also distinguishes the direction of influence. Roughly speaking, this analysis can be described as examining the effects of uncertainty (variability) of input variables on *NPV*.

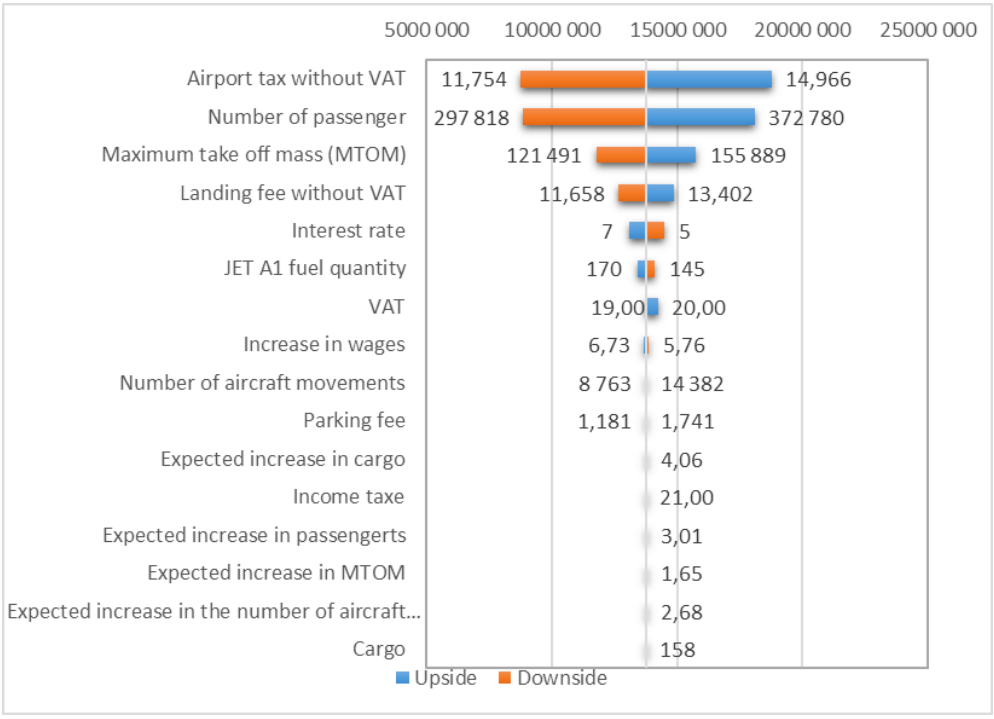

Figure 6: Percentage contribution of inputs to total output uncertainty of sensitivity analysis during Tornado graph.

The benefits of the Tornado chart are a descending order of the identified risk variables based on the assessment of their impact on the monitored quantity. The influence on the monitored quantity is determined based on the calculation of the values of the quantities at interval values of the risk variables.

During the implementation of the research, all outputs from the Monte Carlo simulation, as well as from the sensitivity analysis, were analysed and assessed. Crystal Ball software tool available comparison of all simulated scenarios through graphical outputs (see Fig. 7).

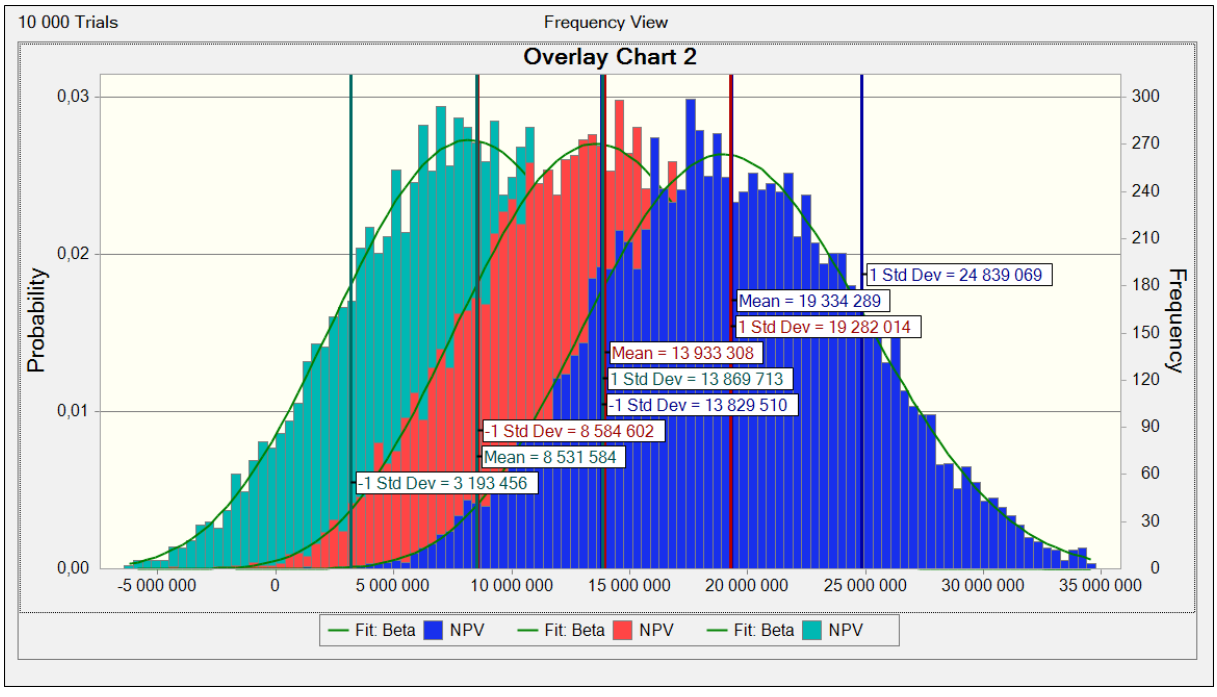

Figure 7: Comparison Network diagram of sensitivity analysis.

Applying the mean and variance rule to the selection of risk scenarios required the processing of comparisons of the output data from the different scenarios of the observed *NPV* (see Table II).

Table II: Comparison of statistical data of the different versions of the *NPV* benchmark.

Statistics	**Version 1 Financing form 30/70**	**Version 2 Financing form 50/50**	**Version 3 Financing form 70/30**
Number of steps	10,000	10,000	10,000
NPV baseline	19,894,053	14,684,104	9,474,155
Mean	19,334,289	13,933,308	8,531,584
Median	19,133,184	13,840,374	8,412,910
Standard deviation	5,504,779	5,348,706	5,338,129
Variations	30,302,596,789,250	28,608,654,462,361	28,495,616,720,221
Skewness	0.1101	0.1087	0.0974
Pointedness	2.74	2.72	2.76
Coefficient of variation	0.2847	0.3839	0.6257
Minimum	1,460,442	-4,428,408	-8,458,543
Maximum	39,992,700	32,979,230	26,277,639

According to the decision rule of average and variance used in assessing different scenarios of investment activities of companies, it is clear from the outputs in Table II that the most advantageous scenario is version 1. The calculation in this scenario showed the highest mean value of the *NPV* value compared to the other scenarios. For the company, the most advantageous financing of investment activities is through 30 % of own resources and 70 % of foreign resources.

4. CONCLUSION

The aim of the article was to create a new approach through a methodological manual for assessing risk areas in the implementation of investment activities of companies. Many methods are used to predict the development of investment activities of companies in aviation. The most frequently used methods are Regression Analysis, Capital Asset Pricing Model, Portfolio Theory, Markowitz Theory Model, and other.

Monte Carlo simulation was used in the research of the solved problem, which, despite different opinions on its use, provides fairly extensive and accurate statistical and graphic outputs when the input parameters are correctly set and the limits are identified. Its advantage is primarily the possibility to combine deterministic and stochastic modelling into the simulation. The limits of this method lie in the exact estimation of variables, depending on the probability, in the accuracy of the calculation based on multiple repetitions of the simulation, in the limited knowledge and digital skills of managers (statistics, mathematics, information technology, economics, etc.). The analysis showed that the current aviation companies are based on traditional methods of evaluating investment activities. As stated in the article, the simplicity and clarity of the framework methodology for introducing modern approaches to management decision-making processes in the area of investment activities of companies in aviation does not reduce its applicability in practice, but on the contrary creates space for its wide application through minimalist interventions. The rapid development of aviation and in the field of digitization of companies creates space for future research in the field of applying sophisticated software tools to processes in companies in various industries. Our future research

will be addressed in two lines. We will prioritise research to verify the methodology and its modification for the needs of companies in an international context, especially in the current turbulent and unstable period in the world. Research was also carried out aimed at solving the problems of business financing using various sources. Foreign companies largely use not only bank credit financing (BCF) but also trade credit financing (TCF). Research has shown that TCF is a balanced choice of financing for companies with limited capital [29]. Our intention will be to modify the algorithm for the needs of TCF. The second line of research will be focused on investigating the possibilities of digitizing decision-making processes with the aim of increasing the digital skills of managers, which can lead to better efficiency and sustainability in business management.

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