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Monte Carlo Method in risk analysis for investment projects

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Abstract

Risk assessment for environmental projects consists of studying the probability that projects will achieve a satisfactory performance for threshold - values of internal rate of return (IRR) or net present value (NPV).
Risk analysis identifies and estimates risks and their level as well as measures considered to mitigate their negative impact.
Quantitative risk analysis is performed for estimating the risk of the project by numeric resources.
Monte Carlo simulation method can be widely applied in this area due to the advantages recognized both by practitioners and the academic community.
By using this method, the distribution of all possible outcomes of an event is generated by analyzing a model several times, each time using random input values selected from the probability distributions considered normal of the components that comprise the model.

Keywords: Risk assessement, Monte Carlo method, investment project, environmental investments.

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1.Introduction

Major investment projects (worth over € 50 million), financed with EU support must meet certain conditions, including criteria related to the size of the risk.

Article 40 of EC Regulation no. 1083/2006 of the European Council of 11 July 2006 laying down general provisions on the European Regional Development Fund, European Social Fund and the Cohesion Fund, outlines what information must be submitted to the Commission on major projects. This information includes the **requirement to present a cost-benefit analysis that includes a risk analysis**.

National legislation (HG 28/2008) for investment states in Annex 2, within the framework content of the feasibility study, the requirement to perform a risk analysis. Apart from this provision, there is no clear methodology and limits defining the calculation of risk associated with investment projects. In this context, the present study comes to propose a risk estimation method (Monte Carlo method) to be applied in a standardized way on investment projects.

The risk is a problem (situation, event, etc.) which has not yet appeared, but may occur in the future, in which case, obtaining the results previously set is threatened or enhanced. In the first case, the risk poses a threat, and in the second, the risk represents an opportunity. Risk represents the uncertainty in achieving the desired results and should be regarded as a combination of probability and impact.

For major projects, risk analysis indicate whether risks have been taken into account in estimating the costs, which are measures envisaged to mitigate the negative impact of major risks and the measures considered appropriate for risk minimization and prevention. The most important factors are related to the identification and measurement of the factors that can lead to deviation of the investment from the initial goals, or even to stop it.

2.Monte Carlo Method, concept and historic evolution

Monte Carlo simulation method[†] appearance is placed around the year 1944. This method has seen many interpretations, received various definitions, therefore we can state that this method has come a long and process of evolution and development. Initially, an important issue of the method (von Newman, 1951) was to generate large series of random numbers. In the first stage, there were used pseudo-random numbers, and then, with the development of computer technology, this barrier has been removed.

One of the most interesting works on the Monte Carlo method in selection of investment projects is Cost Estimating Uncertainty Using Monte Carlo Techniques edited by Paul F. Dienemann in 1966 as part of a research project conducted by the RAND Corporation for the U.S. military. In this paper discussions were on how to make a project selection based on their cost. The author emphasized that a single deterministic value is not a good selection indicator and that we need stochastic variables defined by the average, standard deviation, asymmetry etc. to take an optimal decision in choosing a project.

In Romania, the problem of using random numbers (Monte Carlo method) in engineering and economics has been exposed in the 70s (Sacuiu I., Zorilescu D. 1978). At that time, the generation of random numbers was difficult (they used tables, graph paper, etc.) and therefore the method has not gained a wide use.

Nowadays, the relatively low computational effort[‡] compared to the difficulty of the problems that could be solved, makes this method good to solve a variety of problems, with less effort.

Monte Carlo method generates artificial values of a probabilistic variable by using a random uniformly distributed number generator in the [0, 1] interval and also by using the cumulative distribution function

[†] The credit for discovering this method was assigned to mathematician Stanislaw Ulam, who collaborated during the Second World War on the Manhattan Project (Eckhardt, 1987). The first book published on the subject appeared in 1949, signed by authors Stanislaw Ulam and Nicholas Metropolis.

[‡] Currently generating random numbers is not a problem.

associated with these stochastic variable.

Simulation of economic decisions can be applied to all grades of problems that include operating rules, policies and procedures, such as those concerning the decision adaptation, decision control and price policy. The action of simulation technique is not, in fact, a process of decision optimization. Solving problems using simulation techniques involves the use of interactive algorithms and the existence of well-determined steps in order to achieve the objective. The input data are usually random variables generated by a random number generator.

The method algorithm is shown in its succession interactive five steps:

Step 1: Creating a parametric model, $y = f(x_1, x_2, ..., x_q)$;

Step 2: Generation of random input set of data, $x_{i1}, x_{i2}, ..., x_{iq}$;

Step 3: Effective calculations and memorizing results as y_i;

Step 4: Repeating steps 2 and 3 for i = 1 to n ($n \geq 5000$);

Step 5: Analyzing the results using histograms, confidence intervals, other statistic indicators resulting from the simulation, etc.

The fundamental difference between deterministic and stochastic models is illustrated in Fig. 1. This figure represents the two models, deterministic and stochastic.

Parametric deterministic model establishes a set of input variables, reported to a set of output variables. In the stochastic model of propagation of uncertainty, the input variables are randomized (being described by a random distribution) and the result will be random as well, usually following the Normal Distribution. This is the basic principle of Monte Carlo simulation.

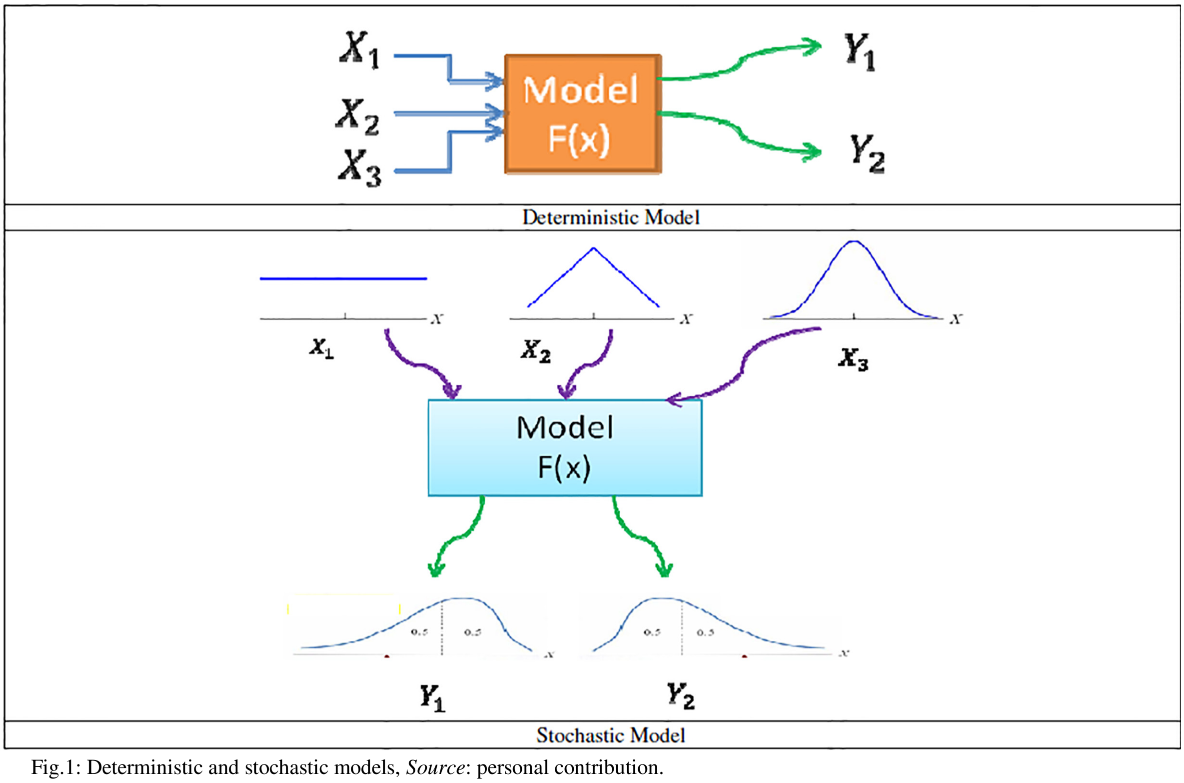

Fig.1: Deterministic and stochastic models, *Source*: personal contribution.

3.The risk estimation of an environmental protection project using Monte Carlo method

3.1.Selection of an investment project

In order to select a project was used the database of the Managing Authority for the Sectoral Operational Projects (MA SOP Environment) for major projects to be financed by the Structural Funds. At the time of writing this material, were identified 23 waste management projects and a number of 40 water and wastewater projects, which have been contracted and are under implementation.

For these two types of projects following parameters were calculated: average, standard deviation and relative standard deviation (SD/m) (Table 1). It can be concluded that water supply projects are larger (average value of a project is 106.23 million €) compared to waste management projects (average of 31.7 million €) and takes, on average, 49 months (approximately 4 years). Waste management projects takes less than water projects (the average is 41.3 months/project).

Table 1. Parameters used to estimate the risk of investment projects

	23 waste management projects		**40 water and wastewater projects**	
	Project Value (mill. €)	Execution Period (month)	Project Value (mill. €)	Execution Period (month)
Average (m)	31.71	41.30	106.23	49.15
Standard Deviation (SD)	12.79	8.95	38.984	9.160
Relative SD	40.33%	21.67%	36.70%	18.64%

Source: processed data from MA POS Environment (www.amposmediu.ro).

With random choosing mechanism, one project was chosen, *Integrated Waste Management System in Suceava*, with a value of 51.76 million € and an implementation period of 45 months.

The key risk parameters to an investment project are: overcoming the initial value of the project and exceeding the execution period.

Next, we will analyze the two variables: the amount and duration of project implementation.

3.2 Estimating the risk of exceeding the project value

To estimate the risk of exceeding the contracted value of the project, the following analyze model was used:

1. Project value was split into six components (Table 2):
   a. Tradable goods, goods that may be traded in international trade markets (equipment, machinery, etc.)
   b. Non-Tradable goods, goods that may not be traded in international trade markets (rents, local raw materials, water and other items);
   c. Skilled labor: skilled labor wages;
   d. Unskilled labor: unskilled labor wages;
   e. Land Acquisition;
   f. Transfer Payments: Transfer payments to the state budget, such as excise duties.
2. A triangular distribution was used (minimum and maximum values in Table 2);
3. Random variable was introduced according to the Excel formula =RAND()*(Val. max-Val. min)+Val. min. in order to generate random values;
4. Calculations were done again for 1000 simulations;
5. Simulation indicators were calculated in the Table 3.

Table 2. Value structure of the investment project, according to the costs type

Costs by category of goods purchased for the project	Value	Minimum Value	Maximum Value
	Million €		
Tradable goods	15.53	12.50	17.20
Non-Tradable goods	5.18	4.20	6.70
Skilled labor	6.21	4.80	7.20
Unskilled labor	19.67	17.00	21.50
Land Acquisition	2.07	1.20	3.24
Transfer Payments	3.11	2.10	4.20
Total	**51.76**	**41.80**	**60.04**

Source: personal estimations.

Based on data obtained, the graph of distribution of frequencies and cumulative frequencies (probabilities) for variable value of the project was drawn (Fig. 2).

Table 3. Simulation Statistical indicators for value project (Variable I)

Indicators	Indicator Value
Average	50,75
Standard Error	0,07
Median	50,76
Standard Deviation	2,25
Flattening (Kurtosis)	-0,10
Asymmetry	0,05

Source: Processing of 1000 simulations.

According to the simulation results, we can draw the following conclusions (Fig. 2):

- The resulting average is 50.75 million€, slightly lower than the chosen project analysis, 51.76 mill. €;
- Asymmetry is 0.05 - which shows a slightly expanded distribution to the right;
- Flattening is -0.1 - indicating a slight flattening compared to normal distribution.

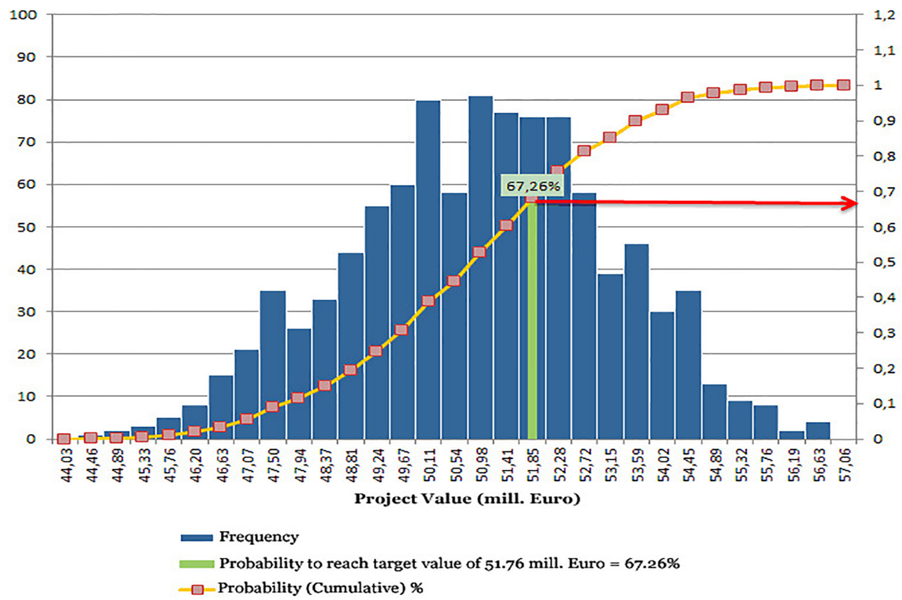

Fig. 2. Statistical distribution of the 1000 times simulation of the project value (Variable I), *Source:* personal processing.

To determine the probability that the project value will be reached, we used cumulative frequency diagram (Fig. 2). A value of 51.76 mil. RON was introduced and, on the cumulative probability) resulted a probability of 67.26% that the project value will be lower than the initially established project value. **The probability that the project value will be exceeded is 32.74% (=1-0.6726)**.

3.3.Estimating the risk of exceeding the project implementation period

In order to estimate the risk of exceeding the project execution period, we used the following model:

1. Project execution period was split into four stages (Table 4);
   a. Step 1 (Preparation);
   b. Step 2 (Tendering, choice of the constructor);
   c. Step 3 (Construction & Assembling);
   d. Step 4 (Completion, testing, commissioning operation). We calculated maximum and minimum values (Table 4);
2. It was introduced a random variable with triangular distribution according to the Excel formula
   = RAND()*(Max. Val. – Min. Val.)+ Minimum Value;
3. Calculations were done again over a period of 1000 simulations;
4. Simulation indicators were calculated (Table 5);
5. The graph of distribution of frequencies and cumulative frequencies (probabilities) for variable value of the project was drawn (Fig. 2).

Table 4. Spliting into 4 steps of Project Execution Period (Variable II)

Project steps	Estimated Execution Period	Optimistic Scenario	Pessimistic Scenario
		month	
Step 1 (Preparation)	6	5	9
Step 2 (Tendering, choice of manufacturer, other activities)	11	10	15
Step 3 (Construction & Assembling)	22	19	26
Step 4 (Completion, testing, commissioning operation)	6	6	10
Total Execution Period (month)	***45***	***40***	***60***

Source: personal estimations.

According to the result of the simulation (Table 5), some conclusions can be drawn:

- Average for the Execution Period Variable is 49.9 month, five month longer than execution period for the analyzed project (45 month);
- Asymmetry is 0.104 – which shows a slightly expanded distribution to the right;
- Flattening is - 0,48 - indicating a slight flattening compared to normal distribution.

Table 5. Statistical Indicators of Simulation for Execution Periond (Variable II)

Indicators	Indicator value
Average	49,91422
Standard Error	0,093211
Median	49,82926
Standard Deviation	2,947584
Flattening (Aplatizarea Kurtosis)	-0,4857
Asymmetry	0,104802

Source: Processing of 1000 simulations.

To determine the probability that the project execution period will be shorter than the initially established period, we used cumulative frequency diagram (Figure 3). A value of 45 month was introduced and resulted a probability of 4.77% that project execution period will be shorter than initially forecasted.

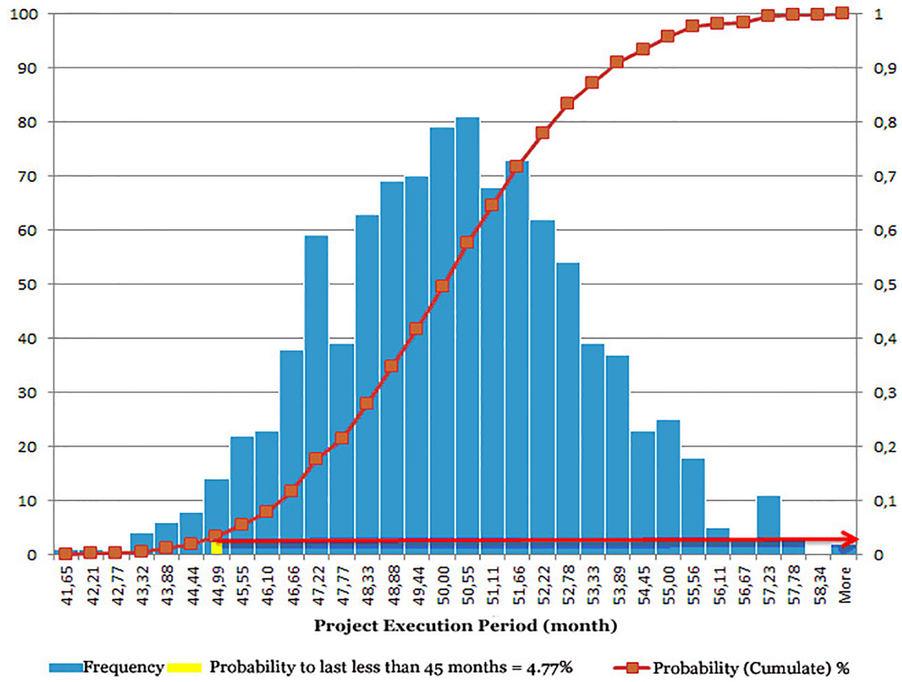

Fig. 3. Statistical Distribution of 1000 simulation of the Variable II (Project Execution Period), *Source:* personal processing.

Probability that the project duration will be larger than that forecasted is 95.23% (=1-0.477).

Cumulated probability that both value and execution period of the analyzed project will be higher than the estimated values (this two variables are considered independent) is 0.3274*0.9523 = 31.1%.

4.Conclusions

As pointed out, knowledge of risks is important as it helps us to find out how it affects investment in economic and financial terms.

The example analyzed show that there is a high probability that the project will record a lower value than originally scheduled. This is possible due to competitive bidding system that makes the offering price lower than the starting price.

As for the execution time, there are higher chances of exceeding the initially established period due to multiple situations occurring during implementation.

Monte Carlo method is relatively easy to perform and provides important information regarding the risks of investment projects.

After identification, analysis and evaluation of qualitative and quantitative economic and financial risk of investment projects, there may be different methods and approaches for managing and responding to risks.

Among the alternative strategies that can be used by project managers, in this regard, we recommend and propose the following:

- Risk acceptance (tolerance);
- Ongoing monitoring of risk;
- Risk avoidance strategy;

- Risk outsourcing;
- Risk mitigation.

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