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ELABORATION OF THE RISK ANALYSIS IN THE COST-BENEFIT ANALYSIS OF INVESTMENT PROJECTS FINANCED FROM ERDF AND CF

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This document has an informative character.

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CONTENT

1. INTRODUCTION

A risk assessment consists of studying the probability that a project will achieve a satisfactory performance. Probability should here be understood as an index that takes the value 1 under full certainty that a prediction will be confirmed, a zero value for certainty that the prediction will not be confirmed, and intermediate values for anything in between the two extremes.

Some of the most common risks:

- The risk of miscalculation of total costs of the project
- The risk of failure to follow the initial schedule of the project
- The risk of duration extension of the project
- The risk of failure to achieve the expected Internal Rate of Return and the Net Present Value
- The macroeconomic instability
- The ecological risk and unexpected damages

The following steps are carried out as part of the risk assessment:

- Sensitivity analysis

  Sensitivity analysis allows the determination of the 'critical' variables or parameters of the model. Such variables are those whose variations, positive or negative, have the greatest impact on a project's financial and/or economic performance. The analysis is carried out by varying one element at a time and determining the effect of that change on IRR or NPV.

- Probability distribution of critical variables

  This implies assigning a probability distribution to each of the critical variables, defined in a precise range of values around the best estimate, used as the base case, in order to calculate the expected values of financial and economic performance indicators.

- Risk analysis
- Assessment of acceptable levels of risk
- Risk prevention

Risk Analysis involves any method used to study and measure the risk inherent to a project and it usually occurs in CBA after Sensitivity analysis.

Sensitivity analysis simply determines the effect on the whole project of changing one of its risk variables. Its importance is that it often highlights how the effect of a single change in risk variables can produce a marked difference in the project outcome. A sensitivity analysis is performed in order to establish those variables which have a potentially high impact on the outcomes of the project and which will be included in quantitative risk analysis as input variables[1].

Risk analysis can be approached with qualitative or quantitative methods. Qualitative risk analysis aims at risk prioritization after identification of risks, being followed by quantitative risk analysis. One reason for this phasing is that it is important to include all main project risks in the risk model. Often high-priority risks are not included in the schedule, for instance, and activities have to be added before data gathering and simulation. If the quantitative risk analysis is conducted without performing the precursor processes, the risks identification and prioritization must be a part of this analysis.

Quantitative risk analysis is conducted for the evaluation of the amount of risk in a project by numerical means. Monte Carlo Simulation (MCS) is usually applied in this respect, due to its advantages recognized both by practitioners[2] and academics[3]. Therefore, this paper[4], due to MCS inherent advantages over other risk analysis methods, concentrates on the MCS method. By using this method, the distribution of all possible outcomes of an event (i.e. total time, total cost or NPV) is generated by analyzing a model many times, each time using input values randomly selected from the probability distributions of the components making up the model.

MCS allows project managers to incorporate uncertainty and risk in their project plans, while the other risk analysis methods cannot quantify the risk and uncertainty as acuratte as MCS. The results of simulation are quantifiable, allowing project managers to better communicate their arguments for project risks and project expectations.

The paper is structured as follows: section 2 provides a description of the principles of MCS, while the section three is focus on more specific and practical issues concerning the simulation tools and probability distributions that are provided. Section four is a case study of applying MCS in order to analyze the risk of project cost miscalculations, following three simulation scenarios. Conclusions are presented in section five and a glossary of statistical terms is provided as Annex A.

[1] A special working paper was devoted to Sensitivity analysis, namely WP9, *"Elaboration of the sensitivity analysis as part of the cost-benefit analysis".*
[2] See, for instance, Guiding Principles for Monte Carlo Analysis, Technical Panel, www.epa.gov/ncea/pdfs/montcarl.pdf
[3] See Vose, D. - *Risk Analysis: A Quantitative Guide*, 2nd Edition, Wiley, 2008
[4] See the section that consider the Relevance of the MCS, in the sext chapter.

2. THE CASE

2.1 THE PRINCIPLES OF MONTE CARLO ANALYSIS

Definition

Monte Carlo analysis, developed in the 1940's is a computer-based method of analysis that uses statistical sampling techniques in obtaining a probabilistic approximation to the solution of a model. In this context, simulation is the process of approximating the output of a model through repetitive random application of a model's algorithm.

Relevance

Monte Carlo simulation combines the distributions according to the relationships in the models by trying many combinations of input variables and storing the results for display. The relevance of the method is that the outputs are often graphs of probability distributions or cumulative probability distributions of output variables, such are, for instance, total cost or dates of completion. These outputs allow for an comprehensive and objective measurement of various risks.

Beside MCA, a number of statistical techniques can be used for project risk evaluation, such as PERT[5] (program evaluation and review technique), sensitivity analysis, decision tree analysis.

PERT analysis is used mostly to predict schedules, based on ranges of values and probability for the durations of the project tasks. Since the durations of the tasks can be a range of values, it is possible that the actual duration values will determine a critical path different than the one that is predicted by the most likely values. In such circumstance, MCA completes the PERT analysis of schedule estimation and evaluates these possibilities, providing statistical guidelines for the project schedule.

Decision tree analysis evaluates interdependent multiple risks and risks with multiple outcomes. This technique becomes useful because one chosen unplanned event can often result in multiple outcomes of various levels of severity. Due to its pictorial appearance and to the logical succession of decisions, the decision tree analysis is easier to understand compared to MCA, but there are several disadvantages, as well: risk estimates can be easily biased and difficult to estimate accurately; the model lacks flexibility; decision points occur continuously and not always at discrete junctions.

Monte Carlo simulation offers many **advantages** over the other techniques applied in risk analysis (Vose, 2008, pag. 45):

- The distributions of the model's variables do not have to be approximated in any way.
- The level of mathematics required to perform a MCS is quite basic.
- The computer does all of the work required in determining the outcome distribution.
- Software is commercially available to automate the tasks involved in the simulation[6].

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[5] Pprogram Evaluation and Review Technique
[6] see section 3 from present working paper for a more detailed approach of this issue.

- Monte Carlo simulation is widely recognized as a valid technique, so its results are more likely to be accepted.
- Changes to the model can be made very quickly and the results compared with previous models.

When could be applied

There may be a number of situations in which a Monte Carlo analysis may be useful. For example, a Monte Carlo analysis may be useful when screening calculations using conservative point estimates fall above the levels of concern. Other situations could include when the cost of regulatory or remedial action is high or when the consequences of simplistic risk estimates are unacceptable.

Considering such aspects, the MCS applied for risk analysis is recommended for major projects or for large investments. *We underline that within the framework of Working Paper No 2 („Role of performance indicators"), it has been recommended to use CBA only for the relevant[7] investments whose values exceeds 5 million Euro (for major projects, over 50 million Euro, the use of CBA is compulsory). In this sense, we recommend to apply MCS to all projects whose values are above 5 million Euro*.

Therefore, Monte Carlo Analysis is important in project management as it allows a project manager to calculate a probable total cost of a project as well as to find a range or a potential date of completion for the project. Other outputs could include lists of cost elements that contain the greatest risk (highest contribution to contingency to the mean of the total cost) or schedule activities (activities on the critical paths in the greatest number of iterations during simulation).

Often, a "tiered approach" may be helpful in deciding whether or not a Monte Carlo analysis can add value to the assessment and decision. In a tiered approach, one begins with a fairly simple screening level model and progresses to more sophisticated and realistic (and usually more complex) models only as warranted by the findings and value added to the decision[8].

Throughout each of the steps in a tiered approach, soliciting input from each of the interested parties is recommended. Ultimately, whether or not a Monte Carlo analysis should be conducted **is a matter of judgment**, based on consideration of the intended use, the importance of the exposure assessment and the value and insights it provides to the risk assessor, risk manager, and other affected individuals or groups.

In the same time, it is important to accept that not every assessment requires or warrants a quantitative characterization of variability and uncertainty. For example, it may be unnecessary to perform a Monte Carlo analysis when screening calculations show exposures or risks to be clearly below levels of concern (and the screening technique is known to significantly over-estimate exposure). As another example, it may be unnecessary to perform a Monte Carlo analysis when the costs of remediation are low.

[7] For some type of investments (e.g. social infrastructure investments), WP 2 recommended not to use CBA at all, no matter the value of the projects.

[8] Guiding Principles for Monte Carlo Analysis, Technical Panel, www.epa.gov/ncea/pdfs/montcarl.pdf

Steps of Monte Carlo analysis

The series of steps followed in the Monte Carlo analysis are listed below:

a. Define the problem to be solved.
b. Develop the model.
c. Define the project risk variables of the model.
d. Perform simulation runs based on the identified variables.
e. Statistically analyze the results of the simulation run.

Each of the above listed steps of the Monte Carlo simulation is detailed below.

a. Define the problem to be solved

Defining the problem to be solved is answering the question: Why the quantitative risk analysis is needed, what is the scope? The applicant might be interested in one type of risk exposure, such as risk to cost, schedule, resource levels, profitability or cashflow. In some cases an integrated view of overall exposure to several types of risk is needed. In any case, it is important that the questions to be answered should be clearly defined at the start.

b. Develop the model

The risk model is a mathematical relationship existing between input variables, in order to produce the risk variable that is analyzed. A risk variable is a parameter which is critical to the success of the project and a slight variation in its outcome might have a negative impact on the project. As noticed, the project risk variables are typically isolated using the sensitivity analysis. The risk model might be built starting from an existing baseline like a project plan or budget, with added risks or it might look only at the risks themselves.

c. **Define the project risk variables of the model**

The variables to go into the risk model must reflect relevant risks. Defining the project risk variables involves defining the maximum and minimum values for each variable identified. If there are historical data available this can be an easier task through frequency distribution. Otherwise, in the situation in which exhaustive historical data are not available, the project applicant needs to rely on expert judgement to determine the most likely values. More than that, the next step involves allocating the probability of occurrence for the project risk variable. To do so, multi-value probability distributions are deployed. Some commonly used probability distributions for analyzing risks are described in the next section.

In some cases, there is a need to identify dependencies between risks, using correlation between the project risk variables. Correlation is the relationship between two or more variables where in a change in one variable induces a simultaneous change in the other. In the Monte Carlo simulation, input values for the project risk variables are randomly selected to execute the simulation runs. Therefore, if certain risk variable inputs are generated that violate the correlation between the variables, the output is likely to be off the expected value. It is therefore very important to establish the correlation between variables and then accordingly apply constraints to the simulation runs to ensure that the random selection of the inputs does not violate the defined correlation. This is done by specifying a correlation coefficient that defines the relationship between two or more variables. When the simulation rounds are performed by the computer, the specification of a correlation coefficient ensures that the relationship specified is adhered to without any violations. The data availability and the identification of possible correlations between variables are considered to be the two major constraints when conducting a MCS[9].

d. Perform simulation runs based on the identified variables.

Simulation run is done using simulation software and ideally 500 – 1000 simulation runs constitute a good sample size. While executing the simulation runs, random values of risk variables are selected with the specified probability distribution and correlations.

e. **Statistically analyze the results of the simulation run**.

Monte Carlo analysis can tell us many useful things about risk exposure, including the range of possible outcomes, the likelihood of achieving our objectives and targets, the most influential risks, the main risk drivers, and the most effective actions. Each simulation run represents the probability of occurrence of a risk event. A cumulative probability distribution of all the simulation runs is plotted and it can be used to interpret the probability for the result of the project being above or below a specific value. This cumulative probability distribution can be used to assess the overall project risk.

2.2 SIMULATION TOOLS AND MAIN PROBABILITY DISTRIBUTIONS

Simulation tools

Simulation tools are required to conduct Monte Carlo simulation. There are simulation tools that add in to spreadsheets which are general and powerful, and can simulate any model that can be constructed in a spreadsheet. They allow different types of probability distributions and accommodate correlated variables and are generally used for quantitative risk analysis, such is cost risk analysis because cost estimates are usually expressed in a spreadsheet.

The spreadsheet used is often Microsoft Excel and there are at least two popular tools that can simulate Excel. Some major marketplace products, very popular (available for under $1,000) are follows:

- @Risk, which is an Microsoft Excel and MS Project Add in, developed by Palisade and available at www.palisade.com.
- Crystal Ball is an Microsoft Excel Add in, available at http://www.oracle.com/us/products/applications/crystalball/index.html

Palisade's @RISK has a formula based approach to Monte-Carlo Simulation, providing a robust, usable and efficient modeling package. Several advantages of this tool are:

- Comprehensive distribution gallery
- Good interface;
- Distribution logic is encapsulated in excel functions
- Automatic color coding when an @RISK function, helpful for graphic presentation of results.

[9] *Handbook for Integrating Risk Analysis in the Economic Analysis of Projects,* published by the Asian Development Bank, Manila, Philippines, 2002

Crystal Ball is an efficient modeling package that is also easy to use. The interface for Monte-Carlo simulation is very intuitive. Distributions are automatically defined as Inputs, but in the same time distribution logic is hidden; Automatic color coding is also provided.

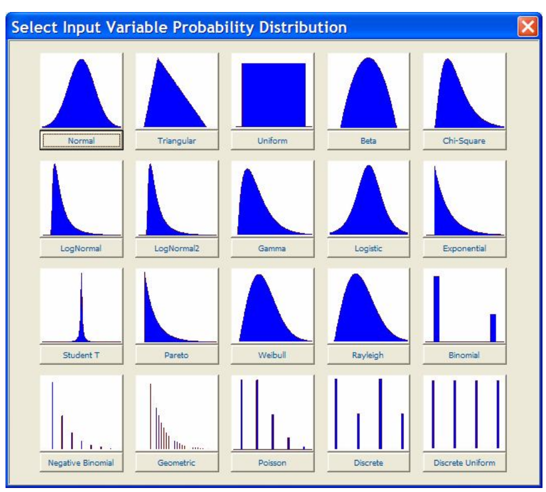
It is important to mention the fact that there are also available **free tools** that could be used in order to perform a Monte Carlo simulation. In the case of some small projects, the acquisition of an expensive soft that facilitate a risk analysis could be inefficient. Therefore, one possibility of solving this problem could be the use of some open source software; such is, for instance, SimulAr.

SimulAr is add-in for Microsoft Excel and it is distributed as "emailware". It was developed by Luciano Machain, from National University of Rosario, Argentina and is available at www.simularsoft.com.ar. It adds probability distribution functions in spreadsheets for performing Monte Carlo simulation and risk analysis under uncertainty conditions. It also provides the possibility of correlating variables and fitting distributions to data. Among its advantages is an easy user interface that makes the model-development really simple and the free availability through internet.

Main probability distributions used in MCS

A Monte Carlo Analysis shows the risk analysis involved in a project through a probability distribution that is a model of possible values. The range of the used probability distributions or curves for Monte Carlo Analysis as provided in Simular is presented in the figure 1. Other tools provide generally the same distributions.

Figure 1. Distributions gallery



Source: produced with SimulAr

Some of the commonly used probability distributions or curves for Monte Carlo Analysis include the normal distribution, the lognormal distribution, the triangular distribution, the beta distribution, the PERT distribution and the uniform distribution. These probability distributions are briefly described below.

- **The Normal distribution**

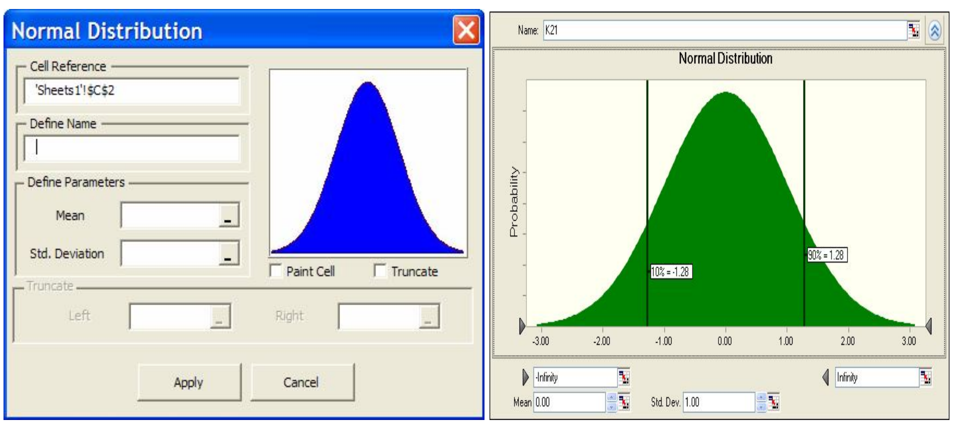
The normal distribution is an extremely important probability distribution in many fields, described by the mean and standard deviation. In this type of probability curve, the values in the middle are the likeliest to occur. The standard normal distribution is the normal distribution with a mean of zero and a standard deviation of one. Some of the most notable qualities of a normal distribution are that it is symmetric around the mean and the mean is also both the mode and median value.

- **The Lognormal distribution**

The Lognormal distribution is specified by mean and standard deviation. This is appropriate for a variable ranging from zero to infinity, with positive skewness and with normally distributed natural logarithm.

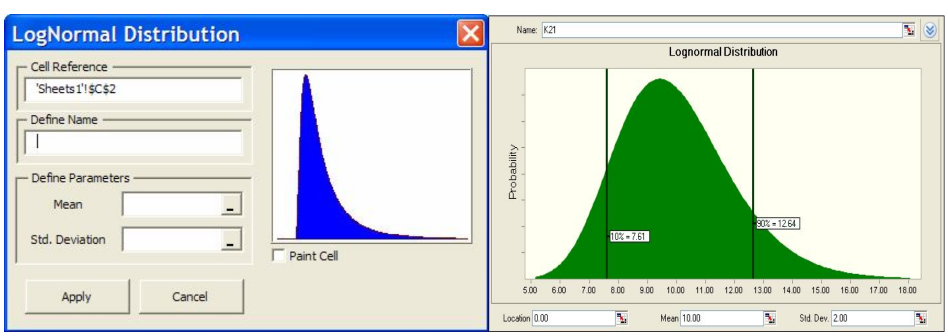
A Monte Carlo Analysis gives this type of probability distribution for project management in the real estate industry or oil industry.

Figure 2. Normal distribution



Source: produced with SimulAr and Crystall Ball

Figure 3. Lognormal distribution



Source: produced with SimulAr and Crystall Ball

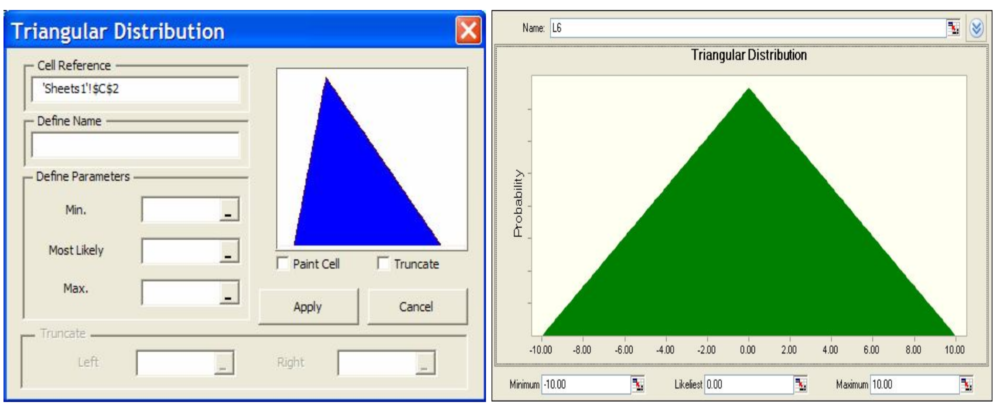
- **The Triangular distribution**

It is defined by its minimum, most likely and maximum values. The probability curve, a triangular one, will display values around the most likely option.

The mean and standard deviation of the Triangular distribution are equally sensitive to all three parameters. Many models involve variables for which it is fairly easy to estimate the minimum and most likely values. But for others the maximum is almost unbounded and could be enormous, for example, in estimations of cost and time to complete some task. In situations where the maximum is difficult to determine, the Triangular distribution is not usually appropriate since it will depend a great deal on how the estimation of the maximum is approached. For example, if the maximum is assumed to be the absolutely largest possible value, the risk analysis output will have a far larger mean and standard deviation than if the maximum is assumed to be a "practical" maximum by the estimating experts.

The Triangular distribution is often considered to be appropriate where little is known about the variable outside an approximate estimate of its minimum, most likely and maximum values. On the other hand, its sharp, very localized peak and straight lines produce a very definite and unusual (and very unnatural) shape, which conflicts with the assumption of little knowledge of the variable.

Figure 4. Triangular distribution



Source: produced with SimulAr and Crystall Ball

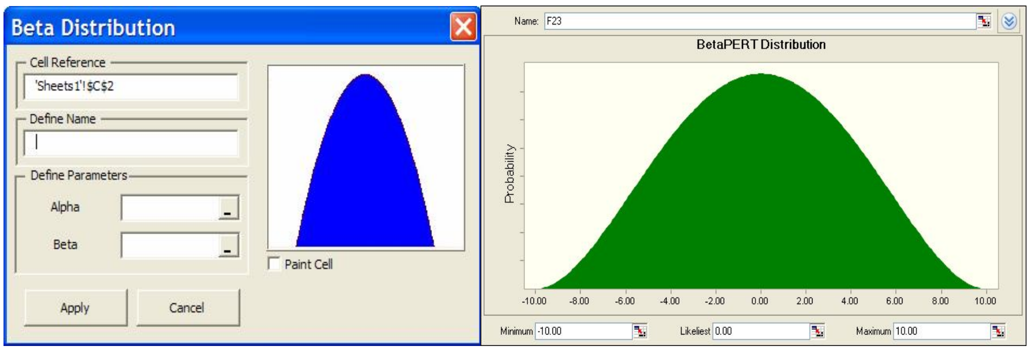
- **Beta distribution**

The Beta distribution is used as the description of uncertainty or random variation of a probability, fraction or prevalence. It can be rescaled and shifted to create distributions with a wide range of shapes and over any finite range. As such, it is sometimes used to model expert opinion, for example in the form of the PERT distribution. In a Monte Carlo simulation, the PERT distribution can be used to identify risks in project and cost models based on the likelihood of meeting targets and goals across any number of project components.

- **The Uniform distribution**

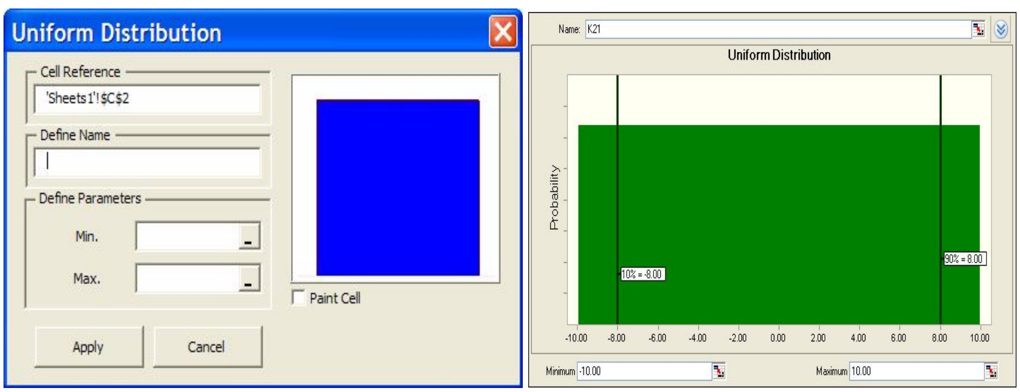
All instances have an equal chance of occurring. This type of probability distribution is common with manufacturing costs and future sales revenues for a new product. The Uniform distribution is generally a very poor model of risk, since all values within its range have equal probability density. The Uniform distribution is, however, used to highlight or exaggerate the fact that little is known about the variable;

Figure 5. Beta and Beta PERT distribution



Source: produced with SimulAr and Crystall Ball

Figure 6. Uniform distribution



Source: produced with SimulAr and Crystall Ball

2.3 CASE STUDY

2.3.1 BRIEF DESCRIPTION OF THE PROJECT

The case study chosen for this risk analysis is based on the project entitled **"Bucharest – Constanța Motorway, Sub-Section 6: CERNAVODA – CONSTANȚA Feasibility Study".** The study concerning the construction of a modern motorway between Bucharest and Constanța as part of the European Corridor IV, was elaborated by the *Louis Berger Group Inc*. in association with *SPT s.r.l and Consilier Construct* and was then proposed to the Romanian National Company of Motorways and National Roads. The Cernavoda – Constanța and Constanța By-pass motorways are sections of the Pan-European corridor IV: Berlin – Bucharest – Istanbul and in this perspective receive maximum support from the EU organizations and the

Romania Government (as expressed in the transport strategy of the National Development Plan 2004 - 2006).

Two main steps study were undertaken in this project. The **first step** concerned the *definition and analysis of motorway alternatives* from the technical, social and environmental point of view, while the **second step** consisted in the *preliminary engineering design and detailed feasibility study of the preferred alternatives of the project*.

2.3.2 MONTE CARLO SIMULATION OF COSTS USING CRYSTAL BALL SOFTWARE

As noticed, there are various risk factors that need to be taken into consideration when elaborating an investment proposal.

Out of these, the risk of miscalculation of the total costs of the project is considered to be one of the most important risk factors in an investment process. That is why, we will now focus upon the financial aspects of a project.

The purpose of this example is to provide a Monte Carlo approach for modelling the cost factors in order to quantify the risks of miscalculation of total costs of the project.

The main data used in the Monte Carlo analysis are summarised in table 1. Note that the estimated costs are expressed in real values. In case the available data is expressed in nominal values, in order to correctly forecast the data, one should first deflate the nominal values by taking into consideration the predicted inflation level for that period[10].

Table 1. Cost estimation

	***Estimated Costs (**RON)*
Land acquisition	62638505.56
Land arrangements	361750.00
Environmental protection works	36865189.01
Subtotal 1	***99865444.57***
Sewerage, gas supply, electricity supply, telephone, radio-tv, etc.	141663396.34
Access roads, industrial railways	0.00
Subtotal 2	***141663396.34***
Land surveying	6610351.22
Obtaining approval, agreements and permits	6804773.31
Design and Engineering	33395502.21
Tendering for public acquisition procedures	651150.00
Consultancy	25274872.31
Technical Assistance	1840764.69
Subtotal 3	***74577413.75***
Permanent works	972110473.47
Subtotal 4	***972110473.47***
Site mobilization cost	23020016.18

[10] The issue of real and nominal prices is aproached in a specific Working Paper No 4 “Costs used in cost-benefit analysis for the investment projects financed through ERDF and CF”.

Commissions, taxes, legal charges, financing costs:	61495511.62
Contigency: 5% din [Cap1.2+Cap1.3+Cap.2+Cap.3+Cap.4]	63308328.62
Subtotal 5	***147823856.41***
TOTAL	**1436040584.55**

The Monte Carlo simulation was elaborate based on three distinct scenarios that will be further on described. First, a moderate scenario was considered, in which each type of costs varies between -10% and + 10%. It was then followed by an optimistic and a pessimistic scenario.

- **The first scenario** (***the moderate scenario):*** was built by considering that the main types of project costs follow a triangular distribution, where the minimum values represent 90% of the estimated costs of the base year, while the maximum values correspond to a 110% of the initial estimated costs. The most likely values are considered to be the exact estimated costs of the base year.

The results of the Monte Carlo simulation after 2000 iterations are presented in fig. 7. After applying the simulation technique, we notice that the simulated costs tend to be slightly higher than the initial estimation, suggesting that the risk of miscalculation of total costs of the project is indeed present.

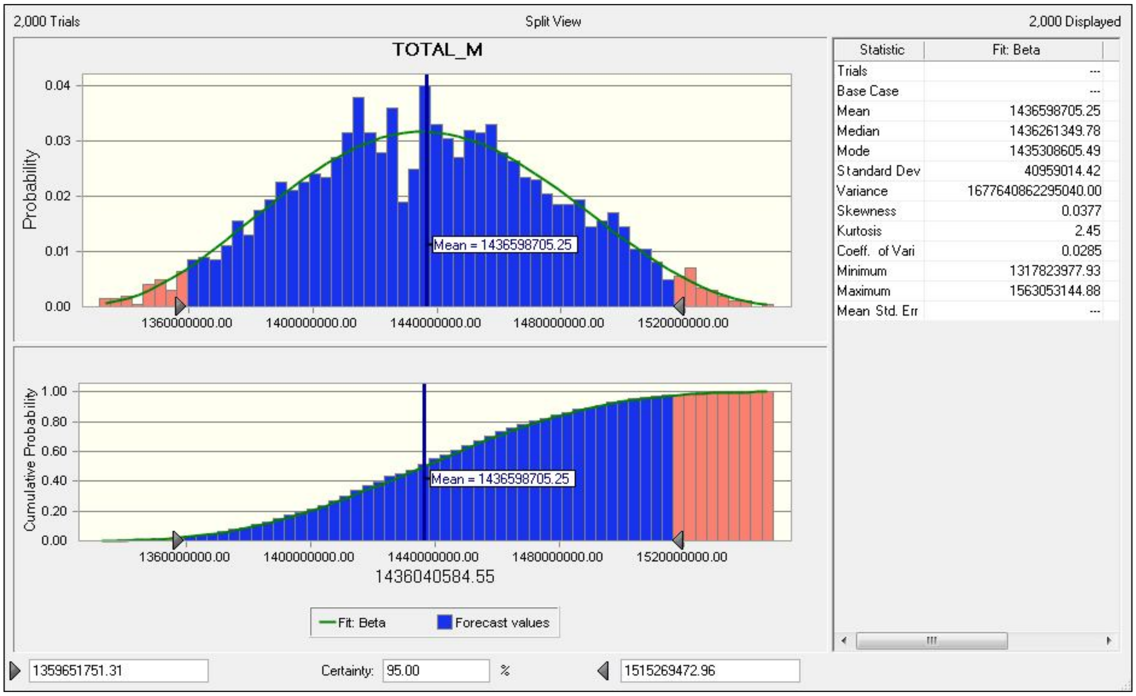
The simulated total cost is now 1436598705,25 RON, being with 558120,70 RON higher than expected. The 0,04% increase of costs as compared to the initial cost estimation can be understood as a cost estimation error.

The maximum value is of 1563053144,88 RON, while the minimum cost level registers a value of 1317823977,93 RON.

The simulation indicates that there is a 95% chance that the project costs are between 1359651751,31 RON and 1515269472,96 RON.

Based on these results, one can better avoid cost risks.

Figure 7. The moderate scenario simulation of total costs



Source: produced with Crystall Ball

- **<u>The second scenario</u>** (***the optimistic scenario):*** assumed that the main types of costs follow a triangular distribution, where the minimum values represent between 70% to 80% of the estimated costs of the base year, while the maximum values represent between 105% to 110% of the initial estimated costs (see table 2). The most likely values are considered to be around 90% to 98% of the estimated costs of the base year.

Table 2. Cost triangular distribution for the optimistic scenario

	Minim (% of initial cost)	Most likely (% of initial cost)	Maxim (% of initial cost)	Minim (RON)	Most likely (RON)	Maxim (RON)
Subtotal 1	70%	90%	110%	69905811.2	89878900.1	109851989
Subtotal 2	75%	90%	105%	106247547.3	127497057	148746566
Subtotal 3	75%	98%	110%	55933060.3	73085865.5	82035155.1
Subtotal 4	80%	95%	105%	777688378.8	923504950	1020715997
Subtotal 5	80%	96%	110%	118259085.1	141910902	162606242

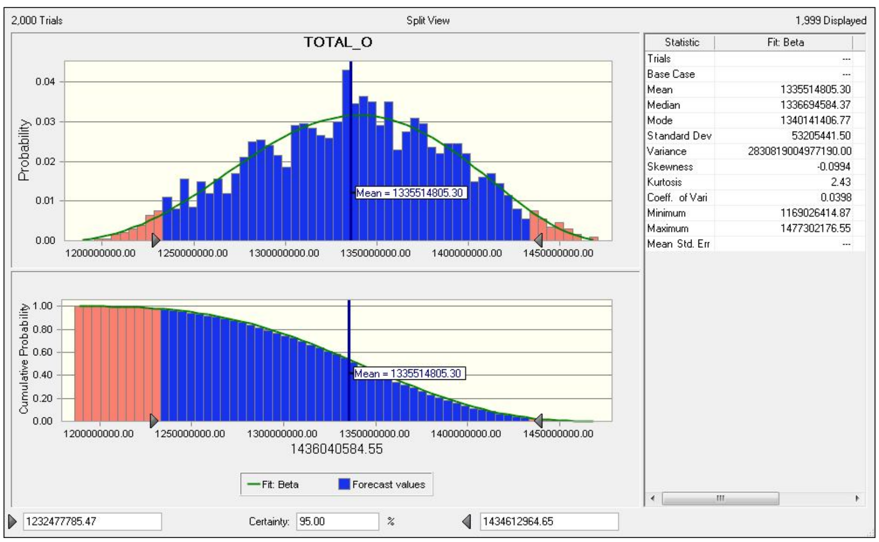
The results of the Monte Carlo simulation after 2000 iterations are presented in fig. 8. After applying the simulation technique for the second scenario, we notice that the simulated costs are significantly less than the initial estimation.

The simulated total cost is now 1335.514.805,3 RON, being with 100.525.779,25 RON less than initially estimated. This means that there is a 7% decrease of costs as compared to the initial cost estimation, being explained by the fact that the decision maker is in this scenario considered to be risk lover.

The maximum value is of 1477.302.176,55 RON, while the minimum cost level is 1169.026.414,87 RON.

The simulation indicates that there is a 95% chance that the project costs are between 1232.477.785,47 RON and 1434.612.964,65 RON.

Figure 8. The optimistic scenario simulation of total costs



Source: produced with Crystall Ball

- **<u>The third scenario</u>** (***the pessimistic scenario):*** assumed that the main types of costs follow a triangular distribution, where the minimum values represent between 90% to 95% of the estimated costs of the base year, while the maximum values represent between 120% to 130% of the initial estimated costs (see table 3). The most likely values are considered to be exactly the estimated costs of the base year.

The results of the Monte Carlo simulation after 2000 iterations are presented in fig. 3. After applying the simulation technique for the third scenario, we notice that the simulated costs are in this case significantly higher than the initial cost estimation.

Table 3. Cost triangular distribution for the pessimistic scenario

	Minim (% of initial cost)	Most likely (% of initial cost)	Maxim (% of initial cost)	Minim (RON)	Most likely (RON)	Maxim (RON)

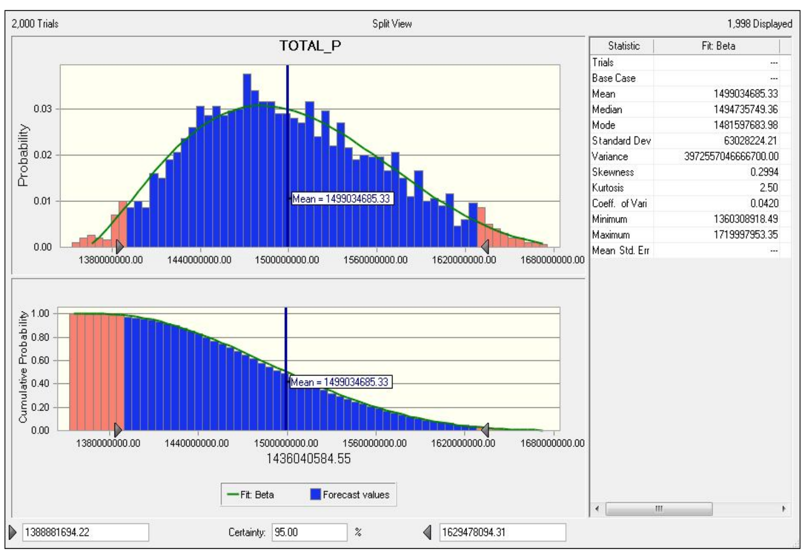
Subtotal 1	90%	100%	130%	89878900.11	99865444.6	129825078
Subtotal 2	95%	100%	125%	134580226.5	141663396	177079245
Subtotal 3	90%	100%	127%	67119672.38	74577413.8	94713315.5
Subtotal 4	90%	100%	120%	874899426.1	972110473	1166532568
Subtotal 5	92%	100%	128%	135997947.9	147823856	189214536

The simulated total cost is now 1499.034.685,33 RON, being with 62.994.100,78 RON higher than initially estimated. This means that there is a 4,4% increase of costs as compared to the initial cost estimation, being explained by the fact that the decision maker is in this scenario considered to be risk adverse.

The maximum value is of 1719.997.953,35 RON, while the minimum cost level is 1360.308.918,49 RON.

The simulation indicates that there is a 95% chance that the project costs are between 1388.881.694,22 RON and 1629.478.094,31 RON.

Figure 9. The pessimistic scenario simulation of total costs



Source: produced with Crystall Ball

The final cost levels resulted from the Monte Carlo simulations, when considering all of the three distinct scenarios, are summarised in table 4.

Table 4. Simulated costs

	Cost Estimation	Simulated costs Moderate Scenario	Simulated costs Optimistic Scenario	Simulated costs Pessimistic Scenario
	RON	RON	RON	RON
Land acquisition	62638505.56			
Land arrangements	361750.00			
Environmental protection works	36865189.01			
Subtotal I	***99865444.57***	***99899832.01***	***89670260.40***	***106327406.12***
Sewerage, gas supply, electricity supply, telephone, radio-tv, etc.	141663396.34			
Access roads, industrial railways	0.00			
Subtotal II	***141663396.34***	***141636683.14***	***127494115.15***	***151228774.59***
Land surveying	6610351.22			
Obtaining approval, agreements and permits	6804773.31			
Design and Engineering	33395502.21			
Tendering for public acquisition procedures	651150.00			
Consultancy	25274872.31			
Technical Assistance	1840764.69			
Subtotal III	***74577413.75***	***74684202.30***	***70214375.61***	***78801897.15***
Permanent works	972110473.47			
Subtotal IV	***972110473.47***	***973018998.85***	***907344590.62***	***1004638560.19***
Site mobilization cost	23020016.18			
Commissions, taxes, legal charges, financing costs:	61495511.62			
Contigency: 5% din [Cap1.2+Cap1.3+Cap.2+Cap.3+Cap.4]	63308328.62			
Subtotal V	***147823856.41***	***147358988.94***	***140791463.53***	***158038047.3***
TOTAL	**1436040584.55**	**1436598705.25**	**1335514805.30**	**1499034685.33**

From the Monte Carlo Simulation, one can conclude that the risk of miscalculation of total costs of the project is correlated to the risk aversion of the decision maker. Based on the numerical simulation we were able to quantify the risk of miscalculation of total costs.

3. CONCLUSIONS

Based on the first sections of the present paper, in which he priciples of the MCS are described, one can conclude that MCS is a valuable technique for analyzing risks, specifically those related to cost and schedule.

The fact that it is based on numeric data gathered by running multiple simulations adds even greater value to this technique, as it is emphasized in the first sections of the working paper. It also helps in removing any kind of project bias regarding the selection of alternatives while planning for risks. Though there are numerous benefits of the Monte Carlo simulation, the reliability of the outputs depends on the accuracy of the range values and the correlation patterns, if any, that you have specified during the simulation. Therefore, extreme caution should be taken while specifying the range values and the selecting the adequate distribution. Else, the results will not be accurate. It is important to specify that these require a **strong knowledge** of the domain in which the project is elabotared.

A case study on analysing the risk of project cost miscalculation is included in the working paper. The risk model consists in summarysing the simulated costs, in order to provide estimates for total cost. We considered three simulation scenarios acording to which the simulated costs are following a triangular distribution under different hypothesis. The simulations indicate that there is a 95% chance that the project costs are ranging between a minimum and a maximum value and mean values are provied for each scenario. Therefore, project applicant is aware about the project cost variability under different circumstances and the possible loss that should be expected in these cases.

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5. ANNEXES

Annex A: Glossary of statistical terms

Correlation coefficient	A measure of the interdependence of two random variables that ranges in value from −1 to +1, indicating perfect negative correlation at −1, absence of correlation at zero, and perfect positive correlation at +1.
Cumulative Distribution Function	A plot of cumulative probability values as a smooth curve
Cumulative Frequency	The number of data points falling in all classes up to the current class
Cumulative Probability for any particular "k" value of a parameter	The probability that all values will be less than "k".
Frequency	Number of data points in each class, or the number of times an event occurs per unit time
Histogram	A plot of the variable magnitude in the form of blocks representing each variable class
Mean for sampled data	The sum of all sample values divided by the number of values
Median for sampled data	Re-arranging data from smallest to largest and selecting the middle the 50th percentile
Mode	The value of a variable that has the highest probability level
the 10th Percentile	The value that separates the smallest 10% of all values from the largest 90%
the 90th Percentile	The value that separates the smallest 90% of all values from the largest 10%
Probability	A number in a scale from 0 to 1 which expresses the likelihood that an event will occur.
Probability Density Function	A plot of probability values as a smooth curve
Random Variable	Any parameter that has a PDF or a CDF defined for it. Typically, random variables are used to describe future events whose outcomes are uncertain
Relative Frequency	Relative number of data points in each class, expressed as a % of the total number, or the fraction of times an event occurs
Standard Deviation	The square root of the variance.
Variance	The square of the difference between all values and the mean.

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