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## UNCERTAINTY IN THE PROCESS OF RISK ANALYSIS

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### Abstract

*In the risk analysis we are often trying to describe and assess various quantities, which express the surrounding risk environment and in this way influence its existence and size. In connection with quantifying these risk factors we come across the problem of uncertainty, which rests in the fact that the values of these factors are unknown at the time of analysis and in this way they make the process of risk analysis complicated. In the presented article we deal with the interconnections of this uncertainty as well as with the possibilities of its interpretation and quantification in the risk analysis process.*

**Key words:** Risk, Risk Analysis, Uncertainty, Numerical Methods, Exact Methods

### 1. INTRODUCTION

The term security has been included among the most frequent terms of the humanities in recent years. In the complex understanding of security the departure from mostly military view of the security of the state and emphasising non-military risks and threats has become very important at the present time. The risks are integral parts of each society and each society perceives them on the basis of its own historical experiences. These risks do not exist isolated in the society, but they appear in various relations, interconnections and aspects. Knowledge of structures, interconnections of development and principles of how the risks act makes it possible for us to create effective prevention of appearance of phenomena of crisis.

It is not possible to assess the risks statically. Their objective assessment requires in particular monitoring the dynamics of development and changes, as well as relations and bonds to the whole number of other risks and social conditions. Understanding the risks from the point of view of security, their specificity and significance uncovers an opportunity for working out new approaches and techniques to these risks.

### 2. RISK ANALYSIS PROCESS

Risk analysis represents a basic process of risk management and creates supporting materials for a decision-taking process. Risk analysis is generally defined as a detailed risk identification process, determination of their sources and importance, investigation of their mutual relations and forecast of scope of negative impact on the system in case of appearance of crisis situation.

Risk analysis gives thus answers to the following questions: What can happen? What is the degree of probability? What are the consequences? The process of general risk analysis within the risk management process has been shown in the Fig. 1.

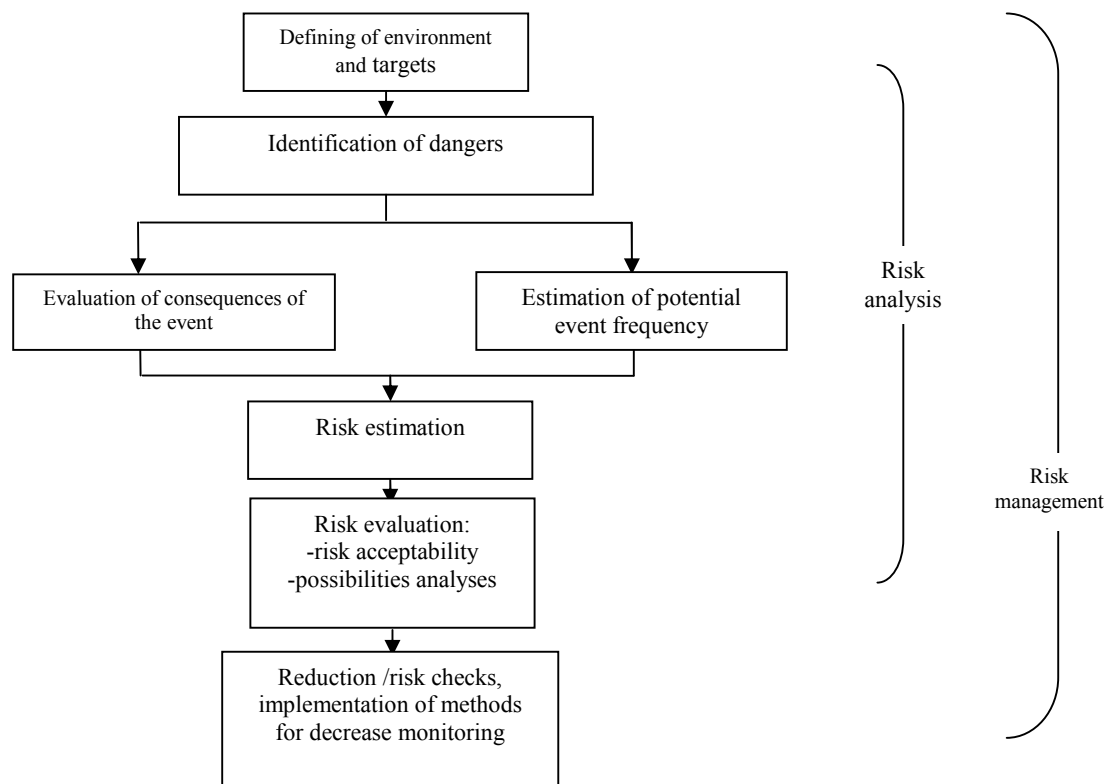


Fig. 1 Process of risk management and general risk analysis (source: authors)

### 3. UNCERTAINTY IN THE RISK ANALYSIS

When analysing risks we come across the term uncertainty, which designates incomplete knowledge of the values of input and output parameters used in the model as well as abstraction of the model itself. This uncertainty is usually caused by insufficient knowledge, inaccurate information or by natural variability of parameters. In this way according to the source uncertainty can be divided into two groups. The first group consists of stochastic uncertainty and the second one of knowledge uncertainty (Tichý, 2006). A significant sign of stochastic uncertainty is that it displays a natural randomness of phenomena. On the other hand knowledge uncertainty is caused by insufficient knowledge or information about the investigated phenomenon or object. The difference between these two types of uncertainty is mainly in their removability. Stochastic uncertainty is irremovable type of uncertainty. Knowledge uncertainty is removable e.g. by means of expert methods.

Uncertainty, which appears in risk analysis, makes this process complicated. Correct understanding of this uncertainty can lead to its partial elimination or to the selection of suitable methods, which we can use when processing this kind of uncertainty. Therefore we have to know, where this uncertainty can be found in the process of risk analysis. A precondition for this finding is defining the risk analysis process. In case that we approach the risk analysis as to the created model (see Fig. 1), we will be able to determine three main groups of uncertainty, which we can see from three points of view:

- parametric uncertainty,
- model uncertainty,
- resulting risk uncertainty.

Parametric uncertainty in the risk analysis appears in case, when the values of considered risk factors are not sufficiently known. The reasons of uncertainty of these factors rest either in their natural variability or in shortage or inaccuracy of data. From this point of view parametric uncertainty can be considered to be a combination of stochastic as well as knowledge type of uncertainty. In case of stochastic uncertainty individual characteristics, which represent the parameters, are marked by a certain degree of randomness, which causes their uncertainty. On the other hand knowledge uncertainty is caused by an extended approach of use of historical data. These data can be inaccurate or inappropriate. For example it seldom happens that a sufficient volume of data has been collected in the areas, in which we plan to carry our analysis. For elimination of parametric uncertainty it is necessary to make an estimate of these parameters on the basis of probability divisions or by means of other divisions, which define the probable behaviour of parameters.

Model uncertainty is based on the fact that each model, whether it is an abstract model or a mathematical one, is a simplification of reality and does not cover all relations of model environment. In these models only those properties of the environment have been covered that serve for achieving of the specified target and abstractions are made from other properties of the environment and by doing this certain model uncertainty is created. It is generally not possible to determine a method by means of which we could eliminate uncertainty of a model; however a common approach to this uncertainty rests in creating of several parallel models. Using several models increases reliability of results and this happens in such a way that the output of this method is a certain interval, which is being created on the basis of the results of individual models. The pitfall of this approach is that parallel models can be based on the same data set, which will cause that their results will be more or less the same, which however does not mean that they are correct in reality.

The existence of uncertainty of the risk is a basic assumption of existence of risk and results also from risk definition, which uses the term probability for expression of this uncertainty. Also as Jelsovska (Jelsovska, 2007) mentioned conflict is a process of strategic interaction. If we are able to say which negative phenomenon takes place and where it takes place and what its consequences will be then we cannot speak about a risk. Uncertainty of risk expresses an unknown real risk value and in a similar way as in case of uncertainty of risk parameters, it can be caused by natural risk randomness or by insufficient information about the risk. In both cases it is possible to represent the degree of this uncertainty by means of probability. In order to be able to process this uncertainty in the risk analysis and to interpret it in a suitable way, it is necessary to determine in what way it is being influenced by input parameters. The effect of uncertainty of risk factors on the risk uncertainty is designated as a transmission of uncertainty and can be graphically represented as follows (see Fig. 2):

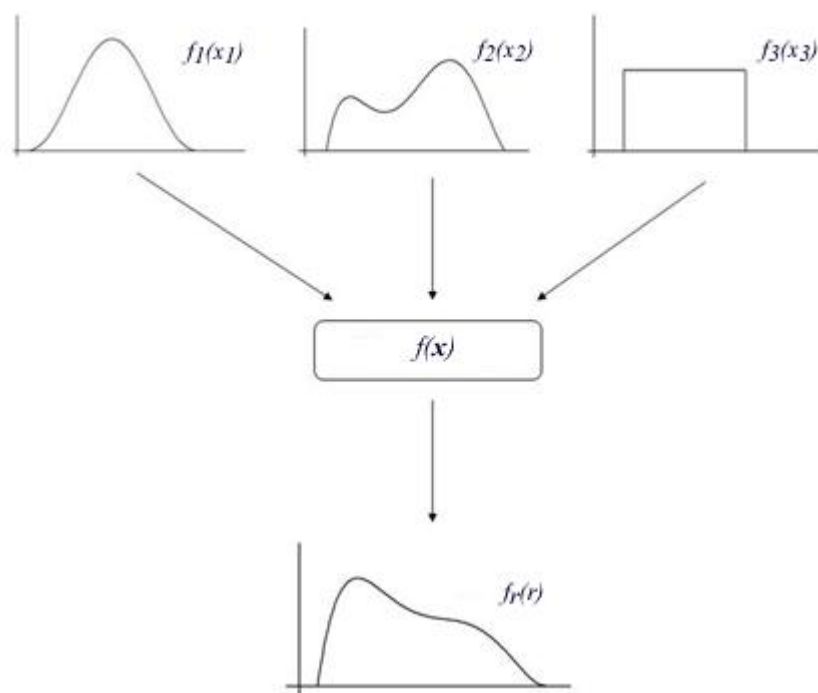


Fig. 2 Transmission of Uncertainty in the Risk Analysis

Uncertain parameter  $x_n$  can generally be perceived by us as a random variable  $X_n$ , the value of which  $P[X_n < x_n]$  is defined by the division of probability  $f_n(x_n)$ , which in this way expresses its stochastic behaviour. Uncertainty of risk  $r$  has been determined by the division of the probability  $f_r(r)$ . Functional relation  $f(x)$  models the transmission of uncertainty from input parameters into output risk. A group of methods on transmission of uncertainty is devoted to processing of transmission of uncertainty.

#### 4. METHODS OF UNCERTAINTY TRANSMISSION

Methods of uncertainty transmission are a key group of methods in the risk analysis. By means of these methods we are able to define the process of transmission of uncertainty of input parameters onto the output risk. We can generally speak about two types of methods, which are:

- exact methods,
- numeric methods.

The basic principle of exact methods is that they are trying to describe a problem by a certain functional relation or by its approximation, e. g. by approximation by Taylor order. Their usability in risk analysis is in particular narrowed to simple cases such as e.g. linear combination of variables with normal division. This subgroup of methods is often designated as moment methods and they are based on the mentioned approximation by Taylor order. The name moment methods is also indicated by the fact that in most cases in these methods the uncertainty is being transmitted and analysed by utilisation of medium value and dispersion of probable divisions, which create the first and the second central moment of these divisions.

The basic principle of moment methods is that they assume the best estimation of the value of input parameter  $X$  at the time  $i$  ( $x_i^0$ ), which equals to its central moment, most frequently to the medium value:  $x_i^0 = E[x_i]$ , where  $i = 1..n$ . The development by Taylor order provides then a manner of expression of deviations of output values of social risk  $y - y^0$  by means of deviations of estimated values of input parameter  $x_i - x_i^0$ :

$$y - y^0 = \sum_{i=1}^n (x_i - x_i^0) \left[ \frac{\partial y}{\partial x_i} \right]_{X^0} + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n (x_i - x_i^0)(x_j - x_j^0) \left[ \frac{\partial^2 y}{\partial x_i \partial x_j} \right]_{X^0} +$$

$$\frac{1}{3!} \sum_{i=1}^n \sum_{j=1}^n \sum_{k=1}^n (x_i - x_i^0)(x_j - x_j^0)(x_k - x_k^0) \left[ \frac{\partial^3 y}{\partial x_i \partial x_j \partial x_k} \right]_{X^0} + \dots$$

Approximation by Taylor development provides only an approximate estimate and therefore its application is not recommended in case of existence of bigger uncertainty. By means of use of higher orders of the development of Taylor development it is possible to increase accuracy of this approximation, however in this case the difficulty of algebraic computations significantly increases. In cases of more complicated models we come across in risk analysis is therefore the use analytical methods of transmission of uncertainty and in comparison with the numerical methods it is therefore more complicated and less advantageous.

The main idea of numerical methods is that from the point of view of the problem, it is not the function describing the given problem that is important (which in exact methods is approximated and it is more difficult to determine it in case of more complicated problems), but they are the functional values themselves that are significant. The basic principle of numerical methods rests in this way in the most accurate estimate of functional values of the function, which describes the specified problem.

Numerical methods started to be used with the increasing growth of use of computer technology. These methods make it possible to reckon with the defined division of probability of input parameters, whereas they relatively precisely catch the transmission of their uncertainty on the resulting risk. One of the best known methods from this group, which we can use in the process of risk analysis, is Monte Carlo method.

Monte Carlo method is a numerical probability method, the basis of which is generating of random numbers with the division according to the probability, which has been determined in advance. By means of this method it is possible to simulate a whole number of problems and in this way to search for their solutions. One necessary condition of using this method is that we must be able to model this problem by means of relation of input quantity, which we are able to describe by means of the function of probability density and the output quantity, the values of which we are trying to estimate. The resulting solution is in this way a set of values of output parameter with a complicated division of probability, which is defined by a simulation model. The overall solution of the given problem can be then described by statistical characteristics of the obtained file.

Monte Carlo method can generally be divided into several main steps:

- selection of assessment criterion,
- determination of factors and specification of key factors,

- specification of dependence model of the selected criterion on the input criteria,
- simulation process itself.

On the basis of the general procedure it is held true that when using the Monte Carlo method in the risk analysis process before the simulation process itself we have first of all to identify the risk environment, specify the key determining risk factors, define their probable behaviour and finally to create a simulation model, which determines the functional dependence of the risk and its factors. Processing of these steps can be achieved by means of many mathematical-statistical, but also of qualitative methods, the selection and suitability of use of which is specific for concrete environment, object of investigation and the risk analysis target and also as Ristvej (Ristvej, 2008) mentioned with support of several software tools.

The simulation process consists of a great number of simulation steps, which are repeated until the result is obtained. In each simulation step a value of input uncertain factors with their probability division is generated, whereas in advance given dependencies between the input factors and output risk are respected and at the same time also the output risk value is recalculated. After sufficiently great number of simulation steps we obtain a set of values, which is controlled by division of probability of the investigated risk. On the basis of this set we know how to determine the necessary statistical characteristics such as e.g. the medium value or values of various percentiles. By the output of the model obtained in this way we have been able to determine in what way the uncertainty of input parameters is transmitted on the output of the model, i.e. on the given risk.

The disadvantage of this method is difficulty of processing, which can be removed by means of using the program support. Another disadvantage is connected with use of computer technology with the Monte Carlo method and it is generating random numbers on the basis of the so called pseudo-random generators, which can in some cases provide distorted results (Viega, 2003). However from the point of view of risk analysis the biggest disadvantage of this method can be considered that a simple division of probability of input parameters is assumed. However in the practical applications of risk analyses the factors influencing the risk have more complicated division of probability, which have to be estimated by means of approximation methods.

In addition to the method Monte Carlo we can also mention its modification, which is the method Latin Hypercube sampling. In comparison with the method Monte Carlo this modification makes it possible to decrease the number of simulations with preservation of estimation accuracy. Latin hypercube sampling preserves the functions of probability division of all simulated quantities and abides also by the required relations between the quantities. Latin hypercube makes it possible to construe an associated density of probability of vectors of random quantities, which enables to estimate an output parameter of the model with high accuracy, however with the use of a small number of simulations (Vořechovský, 2002).

## 5. CONCLUSION

The existence of uncertainty of the risk is a basic assumption of existence of the risk itself and results also from risk definition, which uses the term probability for expression of this uncertainty. Knowing of uncertainty, knowing of its causes and its factors or characteristics creates a basic precondition for achieving the targets of the risk analysis process and this happens through the correct assessment of risk extent. In the presented article we have described a possible approach to risk analysis on the basis of which we are able to work with uncertainty. On the basis of this approach it is possible to define various groups of uncertainty. In this article we describe three kinds of uncertainty resulting from the

assumed approach, i.e. parametric uncertainty, model uncertainty and the resulting risk uncertainty. Various kinds of uncertainty require various kinds of methods. We can generally speak about two groups of methods that work with uncertainty, i.e. about exact and numerical methods. Usability of exact methods in risk analysis is in particular narrowed to simple cases such as e.g. linear combination of variables with normal division. Numerical methods are capable of using the transmission of uncertainty in more complex cases. They are in particular the simulation methods of the Monte Carlo type that can be ranked among the most known numeric methods.

Uncertainty in the process of risk analysis is a significant factor, which influences the process of analysis itself as well as the correct interpretation of its results. For an efficient support of decision taking on the manners of decreasing the strength of risks down to the acceptable level it is necessary to know the possibilities of processing the uncertainty within risk analysis as well as methods that are capable of using it. An approach to uncertainty within the risk analysis as well as methods for its processing, which have been described in this article, provide a view on the important dimension of risk control, which makes its efficiency possible.

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