MULTI-ATTRIBUTE EVALUATION UNDER RISK

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Abstract

During the evaluation of the projects with requiring high investments is used the multi-attribute evaluation of discrete alternatives under risk. The paper briefly describes ways to integrate risk into the multi-attribute decision making (MADM). These approaches differ especially in their suitability and requirements on the decision maker. The paper proposes a model of the multi-attribute decision making under risk. This approach provides an integration of the risk decision making tools with the multi-attribute decision making methods under certainty. These methods include subjective probability distribution, probability trees, scenarios, the Monte Carlo simulation, and the rules of the decision making under risk. Each of these instruments is briefly described and characterized. The model is divided into three steps, which include: the construction of the model, the identification of key risk factors and the determination its probability; the determination of the probability distributions of the risk alternative consequences; the mono-attribute and multi-attribute evaluation.

Key words: multi-attribute evaluation, risk management, decision making

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Introduction

At present, the characteristic attributes of the environment are turbulence and continuing globalization, along with constant changes in input conditions. One of the significant competitive advantages is the overall quality of decision-making processes. The time when the environment was relatively stable, it is gone forever, and today's managers are faced with risk and uncertainty, that complicate their decisions. On the other hand, this environment is not only cause of threats, but also cause of of the new opportunities that the company can move from the position of an outsider in their field as one of the leading places.

It is possible to use a range of methods, procedures and tools for risky decisions, each of these methodological apparatus provides certain advantages and disadvantages, and their applicability in practice needs to be based at least from the environment in which the company moves, from the nature of the industry, from the chosen strategy and by way of management. A common feature of most methods is mono-attribute character, which means that these methods cannot work in assessing risk alternatives with several or more evaluation criteria. On the other hand, methods and tools for multi-attribute evaluation integrate risk and uncertainty difficult.

1 Approaches for Multi-attribute Evaluation under Risk

Multi-attribute evaluation under risk can be solved by several ways. It can be:

- **Integration of risk factors among the evaluation criteria** – in this procedure are specific risk factors included the evaluation criteria; for the qualitative criteria are usually partial evaluation provides by direct expert evaluation (Saaty & Vargas, 2010).
- **Assessment** of the two optimal **alternatives in terms of risk** – for each of the alternatives it should be considered questions seeking the assessment its risk, i.e. the question "What could happen?", "What if ...?", "If there is ... would this alternative acceptable?" (Kepner & Tregoe, 2006). It is good assumption for the early warning system (Fuld, 2003).
- Compensation uncertain impact of alternatives of **their mean values** (with respect to certain criteria) – mean values can be determined by experts, using scenarios or simulation Monte Carlo.
- Using **multi-attribute utility function** (Keeney & Raiffa, 1993).

Each of these approaches has its own advantages and limitations, which can be considered from the following aspects: simplicity and clarity for decision-makers, demands, level of simplification and suitability for different types of problems (Švecová et al., 2012).

These approaches can be extended with a combination of some of the tools of risk decision making (e.g., probability trees, decision matrix, scenarios and Monte Carlo simulation) with multi-attribute evaluation, which is the subject of further proposed model.

2 Methods and Tools Usable in the MADM under Risk

2.1 The Determination of the Probability Distributions of the Risk Factors

These distributions can be determined either on the basis of **subjective** or **objective probabilities**.

The **subjective probabilities** express an opinion, a belief or a persuasion of an expert in the field in which the factor is related. They are based on knowledge, intuition, former experiences or information. For discrete factors the probabilities may be determined by relative comparisons. For continuous factors the probabilities may be determined using estimation of the characteristics of the statistical distribution, such as median or quartiles or using suitable type of a theoretical distribution (Skinner, 2001).

The **objective probability** distributions can be determined by using the statistic methods if there are previous numeric data for certain risk factors. This approach is quite limited as the historical data are usually not available or due to the high changeability of the environment.

As the next step consists of determining the probability distribution of the risk alternatives' consequences, the discrete risk factors are considered. In the first instance, when scenarios are used for the determination of the probability distribution of the consequences, it is necessary to approximate the continuous risk factors by the discrete risk factors (Fotr & Švecová et al., 2010). In the case of a mixed set of the risk factors, the use of the Monte Carlo simulation is necessary.

2.2 Decision Matrix

The decision matrix allows determining the effects of risk alternatives. Matrices cannot show effects of multiple criteria for evaluation, it is necessary to construct a several matrices. The decision matrix is essentially a table, which generally has a risk alternatives in rows and in columns there are scenarios. These may have the character of classic scenarios, i.e. combinations of risk factors, or the development of the values of one risk factor.

Decision matrix is constructed mostly for economic criteria such as net present value, profit, but also internal return rate, return on equity or cost savings. However, the decision matrix can be constructed for any evaluation criterion, as well as the criteria of a qualitative nature type of impact on the company image, environmental impact, etc. Then the matrix will include evaluation of a choice of the value of the selected scale.

2.3 Scenarios

Scenarios are images of the future, and these images are created by the elements and relations between them. Each of the images is based on a set of assumptions, characterized by their volatility. An important aspect is the internal consistency of all elements, relationships and assumptions on which the image (scenario) is based (Cornellius et al., 2005). Foster recommends four scenarios are more suitable: most likely, unsurprising, dreamlike and pessimistic (Foster, 1993).

Scenarios are possible to use for determination of the probability distribution of the consequences. Scenarios can be developed by combining discrete values of key risk factors. The graphical explanation of scenarios is probability trees.

When the set of the scenarios is the same for all alternatives and criteria, the situation is easier. But in many cases it is too simplifying assumption. This fact increases the difficulty in calculation of the determination of the consequences' probability distribution. It does not however change the essence of this approach.

2.4 Monte Carlo Simulation

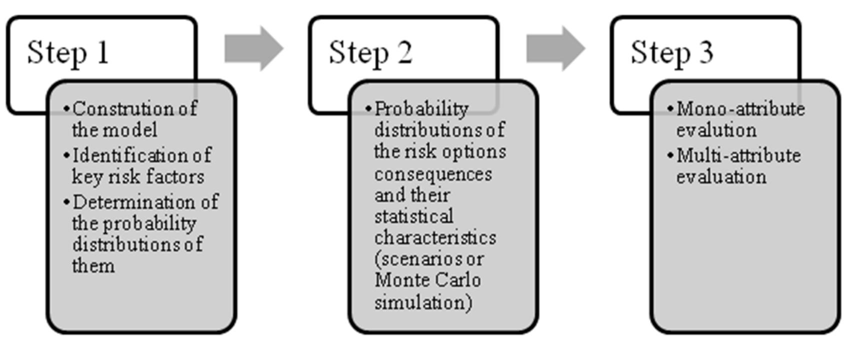
Monte Carlo simulations are among the **stochastic simulation**, i.e. simulation with random variables and the simulation allows continuous and discrete variables. The essence of simulation is to generate a large number (thousands or tens of thousands) of possible scenarios and calculate the selected criteria for each of these scenarios. It then allows building the probability distribution of these evaluation criteria and quantitative characteristics of the risks to the individual assessment risk alternatives there (Mun, 2006).

The simulation results are available in both graphical and numerical form, these are the graphs of the probability distribution for selected evaluation criteria, the statistical characteristics of position (mean, median) and a statistical measure of variability (variance, standard deviation, coefficient of variation, coefficient of skewness and kurtosis, variation range, percentiles, etc.).

3 Model of Multi-attribute Evaluation under Risk

This chapter presents certain recommendations, the own model, for the mono-attribute and especially, the multi-attribute evaluation of the risk options/alternatives. The approach is based on an integration of the decision making tools under risk with the MADM methods. The model has three steps (see Fig. 1). This model relates to the criteria that are stochastic.

Fig. 1: Model of Multi-attribute Evaluation under Risk



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3.1 Step 1

The basic information inputs during evaluation under risk are their consequences with regard to the one-dimensional attribute. It is necessary to **construct models of risk alternatives' consequences**. It will be depend on the risk factors and variables. The character of alternatives and their attributes influence this model. The suitable graphic tools, which support the development of these models, are the cognitive maps and influence diagrams.

The **identification of the risk factors** (RF) for each consequence's model is usually based on the expert assessment of the character of the partial input variables into these models. RF identification can be supported by suitable methods and tools, i. e. check lists, catalogues, risk registers, post-implementation analysis, group discussion, mind maps etc.

The set of the identified RF is very often too large and consists of tens or more RF. Therefore, it is necessary to focus on the **key risk factors** (KRF) that contribute the highest consequences on the attributes of the risk alternatives. Less important risk factors can be treated as deterministic variables. During this phase is possible to use the risk matrixes (see chapter 2.2) and the sensitivity. For these key risk factors is necessary to determine the probability distributions (see chapter 2.1).

3.2 Step 2

The second step is the determination of the probability distributions of the risk alternative consequences and their statistical characteristics. It is possible to use scenarios approaches (see chapter 2.3) or Monte Carlo simulation (see chapter 2.4).

If the number of KRFs is small (up to four RFs), it is possible to use scenarios for determination of the probability distribution of the consequences. If the number of KRFs is large or if the character of these factors is mostly continuous, it better to use Monte Carlo simulation.

3.2 Step 3

During this phase is possible to use mono-attribute or multi-attribute evaluation.

The first step of **mono-attribute evaluation** is **excluding the dominated alternatives**. It is possible to use the rule of the mean value and risk measure (variance, standard deviation or variation coefficient) or the rules of the stochastic dominance. After that, the evaluation is possible to do by using the **trade-off method** or using the **dimensionless value functions** for each criterion and by ordering the alternatives according to their decreasing utility values.

The multi-attribute evaluation of risk alternatives can be based on application **MADM methods** or on the **multi-attribute utility function** (MAUF).

- The process of the evaluation based on application MADM is similar to the mono-attribute evaluation approach. The first part is **excluding the dominated alternatives** (see mono-attribute approach). The second part is based on using the **trade-off method** for each pair of the sub-criteria (the mean value and the measure of risk) for all criteria. The last one is the application of the classical **multi-attribute decision-making methods**. The output is the order of the alternatives (Steward, 1998).
- During the using of the **additive multi-attribute utility function** the mean values of the dimensionless utilities will be determined and its total utility will be expressed as the weighted addition of the mean values of the dimensionless utilities. The output is the order of the alternatives which are ordered according to the decreasing mean values of the total utilities.

Conclusion

The economic crisis and prolonged recession pointed to the importance of risk decision making that fundamentally affects the economic prosperity of companies. Today, the focus only on operational risk management is insufficient. The multi-attribute decision making under risk and uncertainty is very timely. Standard instruments and methods using during multi-attribute decision making under risk have a number of limitations.

One option on risk integration into the multi-attribute decision making appears in the last phase of the evaluation wherein two most convenient options are **audited from the risk perspective**. This “audit” is convenient as a basis for a creation of the early warning system that should be included into the risk management. **Risk factors** are often included into the **criteria**. This approach is relatively simple while. Not respecting the dependencies of the alternatives’ consequences on the risk factors remains the fundamental disadvantage of this approach. The theoretical concept of the **multi-attribute utility function** is exact but its applicability is dependent on the compliance of many assumptions. It is often criticized from the view of the behavioral economics that questions the rationality of the decision maker as a basic premise of the utility function.

The convenient tools of the risk decision making is possible to connect with the methods and tools using by the multi-attribute decision making under certainty. This proposed concept, the model, can be divided into a three steps. The first step includes the construction of the model, the identification of the risk factors and the determining of the key risk factors and the determination the probability distributions of these factors. The second step is focusing on the determination of the probability distributions of the risk alternative consequences and their statistical characteristics. The third step is the actual evaluation of alternatives.

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