MODEL OF MULTI-ATTRIBUTE EVALUATION UNDER RISK

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Abstract

The process of evaluation of strategic plans investments, development and innovation projects proceeds under conditions of risk and uncertainty. The assumption of an environment without risk and uncertainty for these strategic decisions is very simplistic. On the other hand, tools and approaches to support decision making under conditions of risk, usually offers only mono-attribute evaluation approach. This assumption (only one attribute/criterion for evaluation) is also simplistic. The paper will be illustrated a normative approach of multi-attribute decision making under risk. This approach combines the tools and approaches of multi-attribute evaluation under certainty with tools and approaches to decision making under risk. The model will be illustrated by a specific example. The model is based on a combination of tools for multi-attribute decision-making with the approaches of decision-making under risk; the model uses a subjective probability distribution of risk factors, decision matrices, scenarios and Monte Carlo simulation.

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

JEL Code: M10, M21, D01

Introduction

Decision making theory provides a relatively rich methodological apparatus to support multi-criteria evaluation. These approaches assume that the set of alternatives impacts will occur with certainty. On the other hand, a number of methods and tools to support risk decision-making exists, but most of them cannot work with more evaluation criteria. Usually, only one aspect of the advantages of the alternatives is then considered (one criterion) in respect of risk – more about these approaches (Švecová, et al., 2012; Fotr, et. al., 2013). Nowadays, when the vast majority of decisions is made under risk, both of the above approaches are quite simplistic.

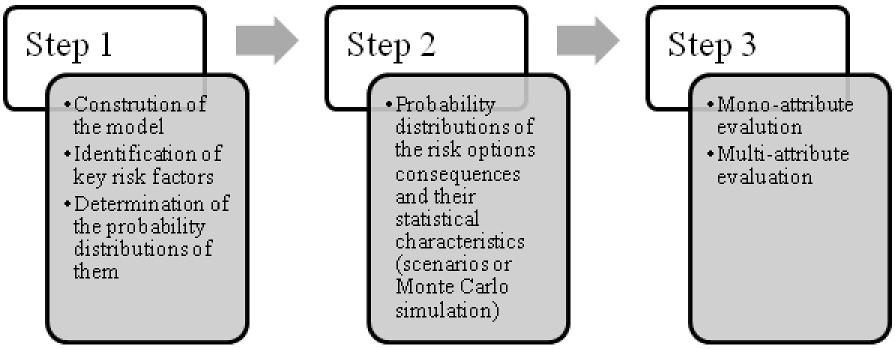
The following model provides connection methods and tools for multi-attribute decision-making methods with a risk management apparatus. The aim is not to increase the complexity of the decision-making process so that the difficulty for managers was acceptable. This model is designed primarily for strategic management level, because it is consuming to on the data base usable in the model, and requires knowledge of more complex methods and tools of risk decision-making. Using in the operational management would not be effective due to higher time-consuming. The model can also be applied to less structured problems solved at the tactical level (Švecová, 2014).

1 Model of Multi-attribute Evaluation under Risk

The new model of multi-attribute evaluation under risk was created (Švecová & Fotr, 2013). This model includes tree steps (see Figure 1) with this concern:

- Step 1: a) **construction of the model** – there it is possible to use cognitive maps or influences diagrams; b) **identification of key risk factors** – possible methods are check lists, risk registers, post-implementation analysis, catalogues group discussion, mind maps; and c) **determination of the probability distributions** of them – with using e.x. risk matrixes or probability trees;
- Step 2: **setting probability distributions of the risk alternatives consequences** and their statistical characteristic – scenarios are possible to use with small number of key risk factor (Cornelius, et al., 2005), (Foster, 1993), (Fuld, 2003), in other case is better to use the Monte Carlo simulation (Mun, 2006);
- Step 3: **mono- or multi-attribute evaluation**; of the mono-attribute evaluation is based on dominance principle and trade-off methods, the multi-attribute evaluation is based on MADM methods or multi-attribute utility function (Kepner & Tregoe, 2006), (Steward, 1998).

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



Source: authors (Švecová & Fotr, 2013)

2 Practical example of application of the model

The following example is illustrative of the application of the proposed model. This example is based on the real task, however, for the purposes of this work it is adapted and simplified[1].

A housing cooperative is before deciding whether to expand its activity in the form of purchase and subsequent construction of new properties or not. It considers these possible strategic alternatives:

- A1: purchase a building site, construction of 12 residential buildings in private ownership,
- A2: purchase a building site, construction of 12 residential buildings in housing cooperative ownership,
- B1: purchase a building site, construction of 4 private buildings in private ownership,
- B2: purchase a building site, construction of 12 private buildings in housing cooperative ownership,
- C1: combination of A1 and B1 (6 residential and 2 private buildings) – private ownership,
- C2: combination of A2 and B2 (6 residential and 2 private buildings) – housing cooperative ownership,
- D1: purchase a building site, its dividing to 4 smaller building site and their purchase.

2.1 Step 1: Construction of the model, identification of key risk factors and determination of the probability distributions of them

As the key decision criteria was chosen: the net present value (influenced by different prices, expenditures and interest rates), the public attitude to the individual alternatives (public preference of less new residents), implementation difficulty and level of involvement required of the Board (involvement of specialists, negotiation with authorities etc.).

The main risk factors were identified on the basis of an expert assessment and probability distribution of risk factors that affect the net present value criterion (Table 1 and Figure 2). Factors not included in table 1: results of the negotiations with the authorities, obstruction of the public to any construction, and time consuming alternatives.

Tab. 1: Probability distributions of key risk factors

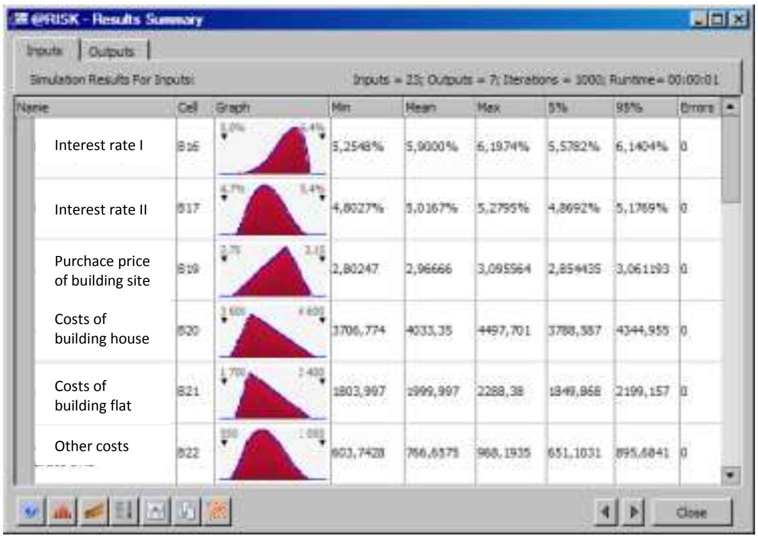
Factors	Lower limit	Upper limit	Mean	Distribution
Purchase price of build. site per m^2	2 800 CZK	3 100 CZK	3 000 CZK	triangle
Interest rate I	5,2 %	6,2 %	6 %	Pert

[1] Full version of this simple example was introduced in non-published habilitation thesis in Czech language (Švecová, 2014).

Factors	Lower limit	Upper limit	Mean	Distribution
Interest rate II	4,8 %	5,3 %	5 %	Pert
Costs of building a house	3.7 mil. CZK	4.5 mil. CZK	3.9 mil. CZK	triangle
Costs of building an apartment	1.8 mil. CZK	2.3 mil. CZK	1.9 mil. CZK	triangle
Other costs for alternatives A	0.6 mil. CZK	1 mil. CZK	0.75 mil. CZK	Pert
Other costs for alternatives B	1.05 mil. CZK	1.4 mil. CZK	1.25 mil. CZK	Pert
Other costs for alternatives C	0.95 mil. CZK	1.3 mil. CZK	1.1 mil. CZK	Pert
Other costs for alternative D	0.45 mil. CZK	0.8 mil. CZK	0.5 mil. CZK	Pert
Sale price of a house	4.5 mil. CZK	6.7 mil. CZK	6 mil. CZK	Pert
Sale price of an apartment	2.5 mil. CZK	3.5 mil. CZK	3 mil. CZK	Pert
Sale price of a building site per m^2	3 000 CZK	4 000 CZK	3 600 CZK	Pert
Interest rate on savings account	2 %	3,5 %	3 %	Pert
Rent (% of value of property)	5 %	15 %	10 %	discrete
Demand (priv. ownership, 1st year)	0 %	100 %	50 %	binomic
Demand (coop. own., 1st year)	0 %	80 %	50 %	binomic

Source: authors

Fig. 2: Probability distributions of key risk factors – input to the Monte Carlo simulation



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2.2 Step 2: Setting probability distributions of the risk alternatives consequences

Scenarios will be defined for all alternatives, but only for qualitative criteria. The probabilities of the scenarios will be different according to the selected alternative. The risk factors are related to each other. Expected impacts of the alternatives were scored on a scale of 0 to 10 for each quality evaluation criterion in the relation to possible developments (value 10 being the best score).

Table 2 represents impact of all alternatives for criterion the public attitude. The values are determined subjectively (on a scale of 0 to 10). Analogically, the similar matrix was created for the second quantitative criterion (implementation difficulty and level of involvement required of the Board). The total evaluation of alternatives is calculated as the weighted average of the evaluation at the various scenarios where the weights are probabilities, e.g. total evaluation (A1) is calculated as 4 · 0.3 + 7 · 0.1 = 1.9 (see Table 3).

Tab. 2: Impacts of alternatives for criterion "the public attitude")

Alternative	Scenario 1 – negative attitude	Scenario 2 - attitude with minor reservations	Scenario 3 – neutral attitude
A1	0	4	7
probability	60 %	30 %	10 %
A2	2	5	9
probability	50 %	35 %	15 %
B1	3	5	9
probability	10 %	20 %	70 %
B2	3	6	10
probability	5 %	20 %	75 %
C1	0	4	8
probability	30 %	50 %	20 %
C2	1	5	9
probability	25 %	45 %	30 %
D1	4	7	10
probability	0 %	10 %	90 %

Source: authors

Tab. 3: Total evaluation of the qualitative criteria

Alternative	Public attitude	Implementation difficulty …
A1	1,9	3,4
A2	4,1	1,8
B1	7,6	7,2
B2	8,9	5,9
C1	3,6	4,6
C2	5,2	3,6
D1	9,7	9,8

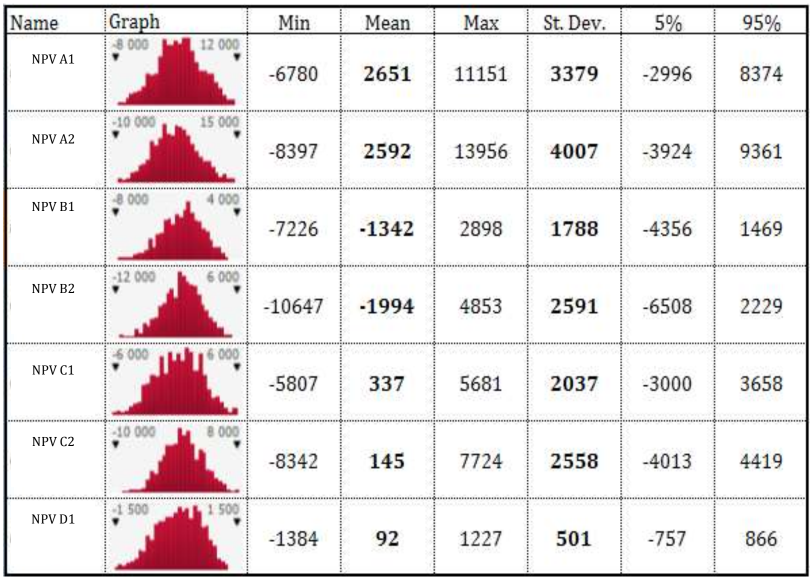
Source: authors

The Monte Carlo simulation was used to determine the impact of net present value. The inputs to the Monte Carlo simulation shows Figure 2. The result of the simulation (1000 iterations) shows Figure 3. The outputs are mean value, standard deviation, lower and upper limit, 5% a 95 % percentiles. The results show that all alternatives may end up losing, and from this point of view seems to be the least risky alternative D1. Alternatives group 2 (cooperative ownership) are generally more risky and perform worse.

Interestingly the differences between the expected value of net present value calculated at the most likely scenario (entering the mean of the distribution selected risk factors) and results from simulations, which arose at 1000 scenarios, are presented (see Table

4). From the table it is evident that the criticism of risk decision-making based on the most likely scenario is justified because the expected values calculated simulations usually have worse results.

Fig. 3: Outputs from the Monte Carlo simulation



Name	Graph	Min	Mean	Max	St. Dev.	5%	95%
NPV A1	-8 000 … 12 000	-6780	**2651**	11151	**3379**	-2996	8374
NPV A2	-10 000 … 15 000	-8397	**2592**	13956	**4007**	-3924	9361
NPV B1	-8 000 … 4 000	-7226	**-1342**	2898	**1788**	-4356	1469
NPV B2	-12 000 … 6 000	-10647	**-1994**	4853	**2591**	-6508	2229
NPV C1	-6 000 … 6 000	-5807	**337**	5681	**2037**	-3000	3658
NPV C2	-10 000 … 8 000	-8342	**145**	7724	**2558**	-4013	4419
NPV D1	-1 500 … 1 500	-1384	**92**	1227	**501**	-757	866

Source: authors

Tab. 4: Comparison of one scenario approach and simulation

Alternative	Expected value – one scenario approach	Expected value – simulation approach
A1	4161	2651
A2	4391	2592
B1	-316	-1342
B2	-471	-1994
C1	1742	337
C2	1812	145
D1	130	92

Source: authors

2.3 Step 3: Mono- or multi-attribute evaluation

Poor economic effect have alternatives B1 and B2. They will most certainly be realized (see Table 4). The output of step 2 of this model shows table 5, there are expected net present value, coefficient of variation of NPV, evaluation of qualitative criteria (public attitude and implementation difficulty).

By now, the final evaluation would be depended on the preferences of decision makers (Board) and their attitude to risk. This would be reflected in the weights of individual criteria, in particular between economic criteria (NPV, and coefficient of variation of NPV) and other criteria. Due to the significant differences in the economic benefits of the alternatives A1 and A2 from other alternatives, would have been chosen one of these two alternatives (likely).

Tab. 4: Impacts of risky alternatives for all criteria

Alternative	NPV (thousands CZK)	Coefficient of variation of NPV	Public attitude (score)	Implementation difficulty … (score)
A1	2651	1,27	1,9	3,4
A2	2592	1,55	4,1	1,8
C1	337	6,05	3,6	4,6
C2	145	17,63	5,2	3,6
D1	92	5,42	9,7	9,8

Source: authors

One of the simulation output is sensitivity NPV on the risk factors. The most important factors are: sale price of the apartment, cost of construction of one apartment, purchase price of a building site, interest rate on a savings account, additional costs of alternatives group A, and interest rate on the loan in the event of alternatives in group 1.

Given that the sale price of an apartment is the most important risk factor, it is appropriate to perform the additional analysis, e.g. what would happen if there was a decline in the sale prices of apartments by 10%? In this case, the result are very interesting. Expect alternative D1, every alternative shows negative net present value. Strong risk aversion would therefore lead to the implementation of alternatives D1.

Conclusion

The economic crisis and the current turbulent environment significantly affect management companies. A prerequisite for success is high quality risk decision-making. Good risk decision-making means that this decision making is given adequate attention and that is based on the undistorted input data. Unfortunately, standard multi-attribute evaluation instruments are inadequate. These tools and methods do not work with risk. On the other hand, risk decision making instruments cannot work with multiple criteria.

Described model provides connection of the two approaches. The model is divided into three steps: 1) construction of the model, identification risk factors and determining their probabilities; 2) determination of the probability distributions of the risk alternative consequences and their statistical characteristics; and 3) mono- or multi-attribute evaluation. The described example clearly illustrates this model and advantage of this model in comparison with usual one scenario approach.

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References

Cornelius, P; Van De Putte, A; Romani, M. (2005). Three Decades of Scenario Planning in Shell. *California Management Review*, 48(1), 92-109.

Foster, M. J. (1993). Scenario Planning for Small Business. *Long Range Planning*, 26(1), 123-129.

Fotr, J.; Plevný, M.; Švecová, L.; Vacík, E. (2013): Multi-criteria project portfolio optimalization under risk and specific limitations. *E+M. Ekonomie a Management*, 16 (4), 71–88.

Fuld, L. M. (2003). Be Prepared. *Harvard Business Review*, 11, 20-21.

Kepner, Ch. H.; Tregoe, B. B. (2006). *The New Rational Manager: An Updated Edition For A New World*. Princenton: Princenton Research Press.

Mun, J. (2006). *Modelling Risk: Applying Monte Carlo Simulation, Real Options Analysis, Forecasting, and Optimization Techniques*. New York: John Wiley & Sons.

Steward, T. (1998). Robustness of Additive Value Function Methods in MCDM. *Journal of Multi-Criteria Decision Analysis,* 5 (4).

Švecová, L. (2014). Multi-attribute Evaluation of Alternatives under Risk (habilitation’s thesis).

Švecová, L; Fotr, J. (2013). Multi-criteria Evaluation under Risk. Prague 19.09.2013 – 21.09.2012. In: PAVELKA, T., LÖSTER, T. (ed.). *International Days of Statistics and Economics*. Slaný, Melandrium, 1411-1418. URL: http://msed.vse.cz/files/2013/131-Svecova-Lenka-paper.pdf.

Švecová, L; Fotr, J.; Vrbová, L. (2012). A Multi-criteria Evaluation of Alternatives under Risk. Prague 13.09.2012 – 15.09.2012. In: PAVELKA, T., LÖSTER, T. (ed.). *International Days of Statistics and Economics*. Slaný: Melandrium, 1090–1100.

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