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Attributes Weights Determining Peculiarities in Multiple Attribute Decision Making Methods

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Investment's risk management, the best feasible alternative's selection, alternatives ranking are usual practices of any project in construction. There is a set of attributes (parameters, factors, criteria) necessary for considering. Influence is noticed in environmental changes, cost reduction attributes in project's realization process, the effect of project's value on its realisation. Risk management is an essential part of project's life cycle. Management of investments risk means presence of all procedures control in any phase of the project. The estimation of risk must be carried out at various project stages. The investor work conditions changes continuously due to economic situation changes. Investment projects' quality estimation can be based only on the management's ingenuity of the investor and depend on its intuition and experience. The risk management attributes can have both qualitative and quantitative values. The biggest problem when making decisions is the estimation influence of different attributes. Given attributes significance values are based on experts' knowledge or new ways of its application. The article summarises the results of theoretical and empirical studies in the sphere of the multi-attribute decision making by focusing on the peculiarities of attributes weight determined by applying an expert method. The proposed method includes five stages: attributes significance measuring, values analysis, weights estimation, measures improving and improved weights estimation. According to the article, the authors' opinion is considered appropriate to limit experts given values to the attributes importance. The offered method of the attributes weights estimation is applied when there is a limited number of experts and it cannot be increased. The offered method was tested in the solution of the actual problem.

Keywords: *investment, project, risk, expert, attribute, weight, multiple attribute analysis, inquiry, limited interval.*

Introduction

The research problem. The attention attached to the creation of goods, services and technologies has already significantly increased (Neverauskas, Stankevicius, 2008). Environmental risk assessment and decision-making (Ciegis et al, 2009) strategies in construction over the last several decades have become increasingly more sophisticated, information-intensive, and complex, including such approaches as expert judgment, cost-benefit analysis, and investment risk assessment. The actuality of entrepreneurship in knowledge-based economy reveals the scientific problem showing interplay between economic sustainability and modernisation of entrepreneurship (Krisciunas, Greblikaite, 2007). All new ideas and possible variants of decisions must be compared according to many attributes (Turskis et al, 2009; Plebankiewicz, 2009). The effectiveness of activities is determined by many attributes (Domeika, 2008). One tool that has been used to support environmental decision-making is comparative risk assessment (CRA). CRA lacks a structured method for arriving at an optimal project alternative. Multi-attribute decision analysis (MADA) is a popular tool in many economic, managerial, constructional and other problems (Zavadskas et al, 2007a, b, 2008, 2009a; Kalibatas, Turskis, 2008; Selih et al, 2008) as it provides better-supported techniques for the comparison of project alternatives based on decision matrices, and it supplies with structured methods for the incorporation of project stakeholders' opinions in the ranking of alternatives (Turskis, 2008; Brauers et al, 2008a, b; Zavadskas et al, 2008a, b, c). Decision-making (Buoziute-Rafanaviciene et al, 2009; Sivilevicius et al, 2008; Turskis et al, 2009; Zavadskas et al, 2009b) in projects is a complex and confusing problem, characterized by trade-offs between socio-political, environmental, and economic impacts (Boguslauskas, Kvedaraviciene, 2009; Smaiziene, Jucevicius, 2009; Lakstutiene, 2008; Kaplinski, 2008; Juan et al, 2009; Ulubeyli, Kazaz, 2009; Ginevicius, Podvezko, 2008a, b; Zavadskas et al, 2009b). Cost-benefit analysis is often used, occasionally in the concept with comparative risk assessment, to choose between competing projects alternatives. The selection of appropriate policies involves multiple attributes such as cost, benefit, environmental impact, safety, and risk. Some of these attributes cannot be condensed into a monetary value, which complicates the integration problem inherent to making comparisons and trade-offs. Even if it were possible to convert attributes rankings into a common unit this approach would not always be desirable since stakeholder preferences may be lost in the process. Furthermore, projects often involve ethics and moral principles, which are not related to any economic use or value. Moreover, decisions typically draw upon multidisciplinary knowledge bases, incorporating natural, physical, and social sciences, medicine, politics, and ethics.

There is a set of attributes (parameters, factors, criteria) necessary for considering. It is feasible to limit expert's given attributes' importance values.

Newness of the research is a creative application of theoretical methods for investment risk research in construction. There is proposed a new approach to determine attribute weights, when experts' number is limited.

The research object is the concept of the multiple attribute risk management by applying weights of attributes determined by limited number of experts.

The aim of this research is to propose attributes weights determined by the limited experts' number.

The tasks. In order to fulfil objectives, the following research tasks had to be accomplished:

- to analyse the influence of attribute significance values given by experts on attributes weights;
- to determinate allowable interval of given attributes' significance values;
- to calculate attribute weights when attributes significance levels are determined in allowable intervals.

The method of the research was an analytic research method based on the case study.

Multi-attribute decision-making (MADM) methods and tools

In recent years, multi-criteria evaluation methods have been widely used in solving both theoretical and practical problems (Zavadskas, Turskis, 2008). Actually, these methods are universal. They allow us to quantitatively evaluate any complicated object described by a set of criteria. Another advantage of these methods is their ability to combine both maximizing and minimizing attributes expressed in various dimensions into one integrated criterion. The maximizing attributes imply that, if their values are growing, the situation is getting better, while for minimizing attributes this means a worsening situation. The integration is achieved by normalization. Normalization helps to convert all the attribute values into no dimensional, i.e. comparable quantities (Ginevicius, 2008; Turskis et al, 2009).

MADM methods evolved as a response to the observed inability of people. They effectively analyze multiple streams of dissimilar information. There are *many* different MADM methods (Guitouni, Martel, 1998; Lin et al, 2008; Shvechenko et al, 2008; Hui et al, 2009; Sarka et al, 2008; Thiel, 2008; Arslan, Aydin, 2009; Brauers, Zavadskas, 2009). They are based on different theoretical foundations such as optimization, goal aspiration, or outranking, or a combination of these (Jakimavicius, Burinskiene, 2009a,b; Ginevicius, Podvezko, 2009; Ginevicius et al, 2008a):

- **Optimization models** employ numerical scores to communicate the merit of one option in comparison to others on a single scale.
- **Goal aspiration,** reference level, or threshold models rely on establishing desirable or satisfactory levels of achievement for each attribute.
- **Outranking models** compare the performance of two (or more) alternatives at a time, initially in terms of each attribute, identify the extent to which a preference for one over the other can be asserted. Like most MADM methods, outranking models are *partially* compensatory (Kendall, 1970).

An overview of principal MADM approaches is provided in the remainder of this section.

Elementary methods intended to reduce complex problems to a singular basis for the selection of a preferred alternative. Competing decision attributes may be present, but inter-attributes weightings are not required.

Pros and Cons Analysis. A Pros and Cons Analysis is a qualitative comparison method in which experts identify the qualities and defects of each alternative (Turskis, 2008). Other methods are based on the Pros and Cons concept, including SWOT Analysis and Force Field Analysis

MaxMin and MaxMax Methods. The MaxMin method is based upon a strategy that seeks to avoid the worst possible performance – or "maximizing" the poorest ("minimal") performing attribute (Peldschus, 2008, Meszek, 2008; Chen, 2007).

Conjunctive and Disjunctive Methods. The conjunctive and disjunctive methods are non-compensatory, goal aspiration screening methods. They do not require attributes to be measured in commensurate units. These methods require satisfactory (in comparison with a predefined threshold) rather than best possible performance in each attribute - i.e. if an alternative passes the screening, it is acceptable.

Lexicographic Method. A lexicographic analysis of any problem involves a sequential elimination process that is continued until either a unique solution is found or all the problems are solved. In the lexicographic decision-making method attributes are first rank-ordered in terms of importance.

Decision Tree Analysis. Decision trees are useful tools for making decisions where a lot of complex quantitative information needs to be taken into account (e.g. deciding whether to take immediate action or to postpone action in treating a contaminated groundwater problem (Wang, McTernan, 2002). The principle behind decision tree analysis is link specific outcomes (or consequences) to specific decision nodes.

Influence Diagrams. An Influence Diagram is a graphic representation of a decision problem. This representation provides a framework for building decision analysis problems but does not provide a framework for quantitative evaluation (Morgan et al, 2002).

Multi-attribute utility/value theory **(MAUT/MAVT).** Multi-Attribute Utility Theory (MAUT/MAVT) is a technique for formally drawing multiple perspectives and evaluations into a decision-making process. The goal of MAUT/MAVT is to find a simple expression for the decision-maker's preferences. Concerns for the practical implement ability of MAUT/MAVT led to the development of the Simple Multi Attribute Rating Technique (SMART). SMART is a simplified multi-attribute rating approach, which utilizes *simple* utility relationships.

Similar to MAUT, AHP (Podvezko, 2009; Maskeliunaite et al, 2009; Morkvenas et al, 2008; Skibniewski, 1992) completely aggregates various facets of the decision problem into a single objective function. The goal is to select the alternative that results in the greatest value of the objective function. Like MAUT, AHP is a compensatory optimization approach. The AHP technique thus relies on the supposition that humans are more capable of making relative judgments than absolute judgments. The rationality assumption in AHP is more relaxed than in MAUT. Unlike MAUT and AHP, outranking is based on the principle that one alternative may have a degree of *dominance* over another (Kangas et al, 2001).

Common algorithm of weight establishment

To determine the significances of the attributes, the expert judgment method proposed by Kendall (1970) was used. Zavadskas and Vilutiene (2006), Zavadskas et al (2008c) discussed the application of this method in the construction field. This expert judgement method was implemented at the following stages:

- calculating values t_{jk};
- calculating weights q_j;
- calculating values S;
- calculating values T_k;
- calculating values W;
- calculating values χ^2;
- testing the statement $\chi^2 > \chi^2_{tbl}$.

The values t_{jk} for statistical processing were obtained by interviewing the respondents. The average attribute value $\bar{t}_j$ was calculated by the formula:

$$\bar{t}_j = \frac{\sum_{k=1}^{r} t_{jk}}{r}, \qquad (1)$$

where t_{jk} is the ranking of the j attribute by the k respondent and r is the number of respondents.

The weights of the attributes were calculated by dividing the sum of the attributes average values by the average value of each attribute:

$$q = \frac{\sum_{j=1}^{n} \bar{t}_j}{t_j}. \qquad (2)$$

The total weight of the attributes must be equal to one:

$$\sum_{j=1}^{n} \frac{\sum_{j=1}^{n} \bar{t}_j}{\bar{t}_j} = 1. \qquad (3)$$

Reliability of the data can be expressed by the coefficient of concordance (agreement) of the respondents' opinions by describing the extent to proximity of individual views. In cases with reiterated ranks for the same parameters, as in our case, the coefficient of concordance is:

$$W = \frac{12S}{r^2(n^3 - n) - r\sum_{k=1}^{r} T_k}, \quad W \in [0;1], \qquad (4)$$

where S is the total square deviation of the rankings of each attribute, T_k the index of reiterated ranks in the r rank, r the number of respondents and n the number of evaluation attributes.

The deviation of the attribute ranking:

$$S = \sum_{j=1}^{n} \left[\sum_{k=1}^{r} t_{jk} - \frac{1}{n} \sum_{j=1}^{n} \sum_{k=1}^{r} t_{kj} \right]^2, \qquad (5)$$

where t_{jk} is the rank conferred by the k respondent to the j attribute.

However, the calculated value W is stochastic; and therefore, the significance of the concordance coefficient has to be calculated.

Kendall (1970) has shown that, when n>7, the value $\chi^2 = WR(N-1)$ has a distribution with the degrees of freedom v=n–1, where n is the number of attributes considered and r is the number of experts. It has been proved that if the calculated value χ^2 is larger than the critical tabular value χ^2_{tbl} for the pre-selected level of significance (e.g. α=0.05), then the hypothesis about the agreement of independent experts 'judgements' is not rejected. In our case, we have n=36, v=35 and the pre-selected level of significance is α=0.05, therefore, the above-mentioned conditions should be satisfied.

The significance χ^2 of the concordance coefficient is calculated as follows:

$$\chi^2_{a,v} = W \cdot r \cdot (n-1) = \frac{12S}{rn(n+1) - \frac{1}{n-1}\sum_{k=1}^{r} T_k}. \qquad (6)$$

If the $\chi^2_{a,v} > \chi^2_{tbl}$ the significance of concordance coefficient exists on α level, then the agreement of experts' opinions is satisfactory and group opinion is established. Otherwise, when $\chi^2_{a,v} > \chi^2_{tbl}$ is obtained, the respondents' opinions are not in agreement, which implies that they differ substantially and the hypothesis on the rank's correlation cannot be accepted.

Proposed algorithm

In the engineering environment, the data is almost always a sample that has been selected from some population. An effective data collection procedure can greatly simplify the analysis and lead to improved understanding of the population or process that is being studied. Decisions often need to be based on measurements from only a subset of objects selected in a sample. This process of reasoning from a sample of objects to conclusions for a population of objects was referred to as statistical inference.

To make good decisions, an analysis of how well a sample represents a population is clearly necessary. Furthermore, how should samples be selected to provide good decisions-ones with acceptable risks? Probability models help quantify the risks involved in statistical inference, that is, the risks involved in decisions made every day. Probability Density functions are commonly used in engineering to describe physical systems. Undoubtedly, the most widely used model for the distribution of a random variable is a normal distribution. Whenever a random experiment is replicated, the random variable that equals the average (or total) result over the replicates tends to have a normal distribution as the number of replicates becomes large.

Definition. Some useful results concerning a normal distribution are summarized below in Figure 1. For any normal random variable:

$$P(\mu - \sigma < X < \mu + \sigma) = 0.6827;$$
$$P(\mu - 2\sigma < X < \mu + 2\sigma) = 0.9545;$$
$$P(\mu - 3\sigma < X < \mu + 3\sigma) = 0.9973.$$

From the symmetry of $f(x), P(X > \mu) = P(X < \mu) = 0.5.$

Because $f(x)$ is positive for all x, this model assigns some probability to each interval of the real line. However, the probability density function decreases as x moves farther from μ. Consequently, the probability that a measurement falls far from μ is small, and at some distance from μ the probability of an interval can be approximated as zero. The area under a normal probability density function beyond 3σ from the mean is quite small. This fact is convenient for quick, rough sketches of a normal probability density function.

The sketches help us determine probabilities. Because more than 0.9973 of the probability of a normal distribution is within the interval, 6σ are often referred to as the width of a normal distribution. Advanced integration methods can be used to show that the area under the normal probability density function from $-\infty \le x \le \infty$ is 1.

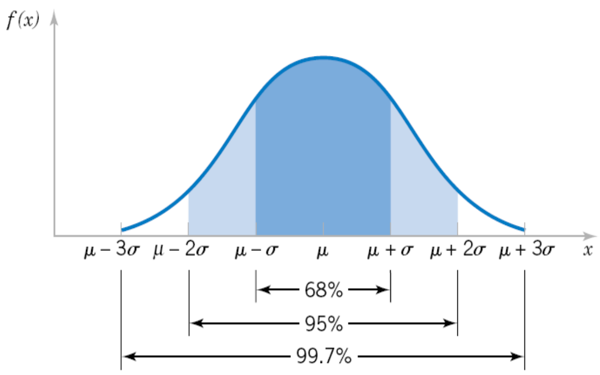


Figure 1. Probabilities associated with a normal distribution

In this research we suppose that all values, which differ from average value μ more than on 2σ, are rejected, also indicator weights are defined by applying the remained values.

Case study

Organizational and technological complexity of construction projects generates enormous risks. Investment risk managing theory allows planning investment problems. Managing the risk of investments means presence of an effective control for all procedures in any phase of the project, when varying factors are taking place, which influence the realization of the project. In most cases, any investment project possesses several attributes of efficiency. Conditions of investor works continuously change assessment. Investment project quality rules can be based only on the investor's leadership politics at this moment. The quality evaluation principle based on the intuition and experience of the decision maker. In the case study there is presented an investment problem in construction. The stakeholders must select the best alternative of investments. The alternatives are as follows:

– a_1 - to build a nine-storey 42 flat dwelling house;
– a_2 - to build a five-storey building for offices;
– a_3 - to build a three-storey building for offices and a five-storey building with 20 apartments.

In the following case study, there is highlighted the analysis and explanation methods of proposed solution algorithm that are particularly interesting for applications in construction. The problem was described by the system of attributes. The total list of attributes was designed after a rough analysis of similar problems solution. Highly qualified specialists left the most important five attributes:

– technological risk - x_1;
– period before termination construction works - x_2;
– period after termination construction works - x_3;
– financial risk - x_4;
– political and Legal risk - x_5.

The values for statistical processing t_{jk} were obtained by interviewing highly skilled construction specialists (Table 1).

Table 1

Attributes' significancy level determined by the experts

Expert $k = 1,...,25$	Efficiency attributes ranks values, t_{jk}; $j = 1,...,n$; $n = 5$.				
	x_1	x_2	x_3	x_4	x_5
1	2	5	3	1	4
2	4	1	2	5	3
3	5	4	3	2	1
4	5	3	4	2	1
5	5	4	3	1	2
6	5	3	4	1	2
7	5	4	2	3	1
8	4	5	1	3	2
9	5	3	4	1	2
10	5	4	1	2	3
11	5	4	1	3	2
12	3	5	4	1	2
13	4	2	1	3	5
14	5	3	4	1	2
15	5	4	2	3	1
16	5	4	3	2	1
17	2	4	3	5	1
18	4	3	5	2	1
19	5	3	4	1	2
20	4	5	1	2	3
21	5	4	2	3	1
22	1	4	3	2	5
23	5	4	3	2	1
24	3	5	1	5	2
25	1	4	3	5	2

The algorithm of attributes weight establishment and calculation process are presented in Table 2. After performed calculations, we established attributes weights.

Kendall (1970) has shown that, when $n > 7$, the value $\chi^2 = Wr(n-1)$ has a distribution with degrees of freedom $v = n-1$, where n is the number of attributes considered and r the number of experts. It has been proved that if the calculated value χ^2 is larger than the critical tabular value χ^2_{tbl} for the pre-selected level of significance is $\alpha = 0.01$, therefore, the above mentioned conditions should be satisfied. If the $\chi^2_{\alpha,v} > \chi^2_{tbl}$ is obtained, the respondents' opinions are not in agreement, which implies that they differ substantially and the hypothesis on the rank's correlation cannot be accepted. The concordance coefficient based on the attributes weights is $W = 0.66$. In this case, the tabular value was taken from Fisher and Yates statistical tables (Fisher, Yates, 1963). When the degrees of freedom is $v = n-1 = 5-1 = 4$ and pre-selected level of significance is $\alpha = 0.01$ (or error probability $P = 1\%$), in that case we have the value $\chi^2_{tbl} = 13.3$. Since $\chi^2_{\alpha,v} > \chi^2_{tbl}$, then, the assumption is made that the coefficient of concordance is significant and expert rankings are in concordance with 99% probability.

In Table 3 there are some values of attributes, whose difference from the mediocre values of each attribute are significant. The values that are less than mediocre value $\bar{t}_j - 2\sigma$ are marked by bold italic font and ones whose values are bigger than $\bar{t}_j + 2\sigma$ are marked by bold font. The values, whose difference from mediocre values are too big, eliminated as it is presented in Table 3.

Table 2

Algorithm of attributes weights establishment

Process of calculation	Efficiency attributes x_i; $j = 1,...,n$; $n = 5$.				
	x1	**x2**	**x3**	**x4**	**x5**
Sum of ranks $\bar{t}_j = \sum_{k=1}^{r=25} t_{jk}$	102	94	67	61	52
The average attribute rank value $\bar{t}_j = \frac{\sum_{k=1}^{r=25} t_{jk}}{r}$	4.08	3.76	2.68	2.44	2.08
Attribute rank	1	2	3	4	5
Attribute weight $q_j = \frac{\bar{t}_j}{\sum_{j=1}^{n=5} t_j}$	0.27	0.25	0.18	0.16	0.14
$\sum_{k=1}^{r=25} (t_{jk} - \bar{t}_j)^2$	11.42	14.81	47.46	22.81	25.60
Dispersion of experts ranking values $\sigma^2 = \frac{1}{r-1} \sum_{k=1}^{r=25} (t_{jk} - \bar{t}_j)^2$	0.34	0.44	1.40	0.67	0.75
Variation $\beta_j = \frac{\sigma}{\bar{t}_j}$	0.12	0.17	0.44	0.32	0.48
Ranking sum average	$V = \frac{1}{r} \sum_{j=1}^{n=5} \sum_{k=1}^{r=25} t_{jk} = 0.2(102 + 64 + 67 + 61 + 52) = 75.2$				
The total square ranking deviation	$S = \sum_{j=1}^{n=5} \left(\sum_{k=1}^{r=25} t_{jk} - V \right)^2 = (102-75.2)^2 + (94-75.2)^2 + (67-75.2)^2 + (61-75.2)^2 + (52-75.2)^2 = 1879$				
The coefficient of concordance	$W = \frac{12S}{r^2(n^3-n)} = \frac{12 \cdot 1879}{25^2(5^3-5)} = 0.30$				
The significance of the concordance coefficient (no related ranks) $\chi^2_{\alpha,v}$	$\chi^2_{\alpha,v} = \frac{12S}{rn(n+1) - \frac{1}{n-1}\sum_{k=1}^{r} T_k} = \frac{12 \cdot 1879}{25 \cdot 5(5+1)} = 3.01$, where $\frac{1}{n-1}\sum_{k=1}^{r} T_k = 0$				
Rank of table concordance χ^2_{tbl} when the importance equal to 1 %.	The freedom degrees value of a solved problem $v = n-1 = 5-1 = 4$; $\chi^2_{tbl} = 13.3$				
Compatibility of expert judgement (Kendall, 1970).	$\chi^2_{\alpha,v} = 3.01 \succ \chi^2_{tbl} = 13.3$ - The hypothesis about the consent of experts in rankings is not accepted				

Table 3

Attributes weights determined by the experts

Expert $k = 1,...,25$	Efficiency attributes ranks values, t_{jk}; $j = 1,...,n$; $n = 5$.				
	x_1	x_2	x_3	x_4	x_5
1	***2***	5	3	***1***	**4**
2	4	***1***	2	**5**	3
3	5	4	3	2	1
4	5	3	4	2	1
5	5	4	3	***1***	2
6	5	3	4	***1***	2
7	5	4	2	3	1
8	4	5	***1***	3	2
9	5	3	4	**1**	2
10	5	4	***1***	2	3
11	5	4	***1***	3	2
12	3	5	4	1	2
13	4	***2***	***1***	3	**5**
14	5	3	4	***1***	2
15	5	4	2	3	1
16	5	4	3	2	1
17	***2***	4	3	**5**	1
18	4	3	**5**	2	1
19	5	3	4	***1***	2
20	4	5	***1***	2	3
21	5	4	2	3	1
22	***1***	4	3	2	**5**
23	5	4	3	2	1
24	3	5	***1***	**5**	2
25	***1***	4	3	**5**	2
6σ=	4	4	3	**4**	**4**
σ=	0.67	0.67	0.50	0.67	0.67
μ-2σ=	***2.74***	***2.33***	***1.68***	***1.10***	***0.74***
μ +2σ=	**5.42**	**5.10**	**4.02**	**3.78**	**3.42**

The calculation of attributes weights performed as shown in table 4.

Table 4

Attributes weights determined by the experts

Expert $k = 1,...,25$	Efficiency attributes ranks values, t_{jk}; $j = 1,...,n$; $n = 5$.				
	x_1	x_2	x_3	x_4	x_5
1	**2.74**	5	3	**1.10**	***3.42***
2	4	**2.33**	2	***3.78***	3
3	5	4	3	2	1
4	5	3	4	2	1
5	5	4	3	**1.10**	2
6	5	3	4	**1.10**	2
7	5	4	2	3	1
8	4	5	**1.68**	3	2
9	5	3	4	**1.10**	2
10	5	4	**1.68**	2	3
11	5	4	**1.68**	3	2
12	3	5	4	1	2
13	4	**2.33**	**1.68**	3	***3.42***
14	5	3	4	**1.10**	2
15	5	4	2	3	1
16	5	4	3	2	1
17	**2.74**	4	3	***3.78***	1
18	4	3	***4.02***	2	1
19	5	3	4	**1.10**	2
20	4	5	**1.68**	2	3
21	5	4	2	3	1
22	**2.74**	4	3	2	***3.42***
23	5	4	3	2	1
24	3	5	**1.68**	***3.78***	2
25	**2.74**	4	3	***3.78***	2
6σ=	4	4	3	***3.78***	***3.42***
σ=	0.67	0.67	0.50	0.67	0.67
μ-2σ=	**2.74**	**2.33**	**1.68**	**1.10**	**0.74**
μ +2σ=	***5.42***	***5.10***	***4.02***	***3.78***	***3.42***

The calculation of attributes weights is performed as is shown in the table 5.

Table 5

New proposed algorithm of attributes weights establishment

Process of calculation	Efficiency attributes x_j; $j=1,...,n$; $n=5$.				
	x_1	x_2	x_3	x_4	x_5
Sum of ranks $\bar{t}_j = \sum_{k=1}^{r=25} t_{jk}$	106.96	95.66	70.1	56.82	48.26
The average attribute rank value $\bar{t}_j = \frac{\sum_{k=1}^{r=25} t_{jk}}{r}$	5.09	4.16	3.89	3.79	2.19
Attribute rank	1	2	3	4	5
Attribute weight $q_j = \frac{\bar{t}_j}{\sum_{j=1}^{n=5} t_j}$	0.27	0.22	0.20	0.20	0.11
$\sum_{k=1}^{r=25} (t_{jk} - \bar{t}_j)^2$	37.02	18.59	50.26	79.88	19.62
Dispersion of experts ranking values $\sigma^2 = \frac{1}{r-1} \sum_{k=1}^{r=25} (t_{jk} - \bar{t}_j)^2$	1.54	0.77	2.09	3.33	0.82
Variation $\beta_j = \frac{\sigma}{\bar{t}_j}$	0.24	0.21	3.89	0.48	0.41
Ranking sum average	$V = \frac{1}{r} \sum_{j=1}^{n=5} \sum_{k=1}^{r=25} t_{jk} = 0.2(106.96 + 95.66 + 70.1 + 56.82 + 48.26) = 75.56$				
The total square ranking deviation	$S = \sum_{j=1}^{n=5} \left(\sum_{k=1}^{r=25} t_{jk} - V \right)^2 = (106.96 - 75.56)^2 + (95.66 - 75.56)^2 + (70.1 - 75.56)^2 + (56.82 - 75.56)^2 + (48.26 - 75.56)^2 = 7261.43$				
The coefficient of concordance	$W = \frac{12S}{r^2(n^3 - n)} = \frac{12 \times 7261.43}{25^2(5^2 - 5)} = 1.16$				
The significance of the concordance coefficient (no related ranks) $\chi^2_{\alpha,v}$	$x^2_{a,v} = \frac{12S}{rn(n+1) - \frac{1}{n-1} \sum_{k=1}^{r} T_k} = \frac{12 \times 7261}{25 \times 5(5+1)} = \frac{87137.126}{750} = 116.18$, where $\frac{1}{n-1} \sum_{k=1}^{r} T_k = 0$				
Rank of table concordance χ^2_{tbl} when the importance equal to 1 %.	The freedom degrees value of a solved problem $v = n - 1 = 5 - 1 = 4$; $x^2_{tbl} = 13.3$				
Compatibility of expert judgement (Kendall, 1970).	$x^2_{a,v} = 116.18 > x^2_{tbl} = 13.3$ - The hypothesis about the consent of experts in rankings is accepted				

The values of attribute weights are established as follows (Table 6):

w_1=0.27; w_2=0.22; w_3=0.20; w_4=0.20; w_5=0.11.

It can be stated that the biggest difference between established values is 22.5 percent (weight of attribute number 5). This algorithm allows excluding too big differences from mediocre values.

The case studies problem was solved by applying SAW method (with common defined attributes' weights and with modified weights (Zavadskas et al. 2007c) (Table 7).

It can be stated that solution results differ significantly. The third alternative was selected, which in the case of common defined attributes weights is the worst, but the third alternative with modified attributes weights is the best.

Table 6

Comparison of the established attributes weights calculated according to common and newly proposed approach

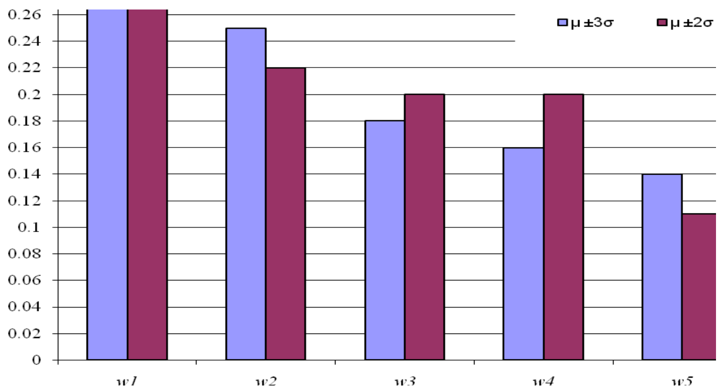
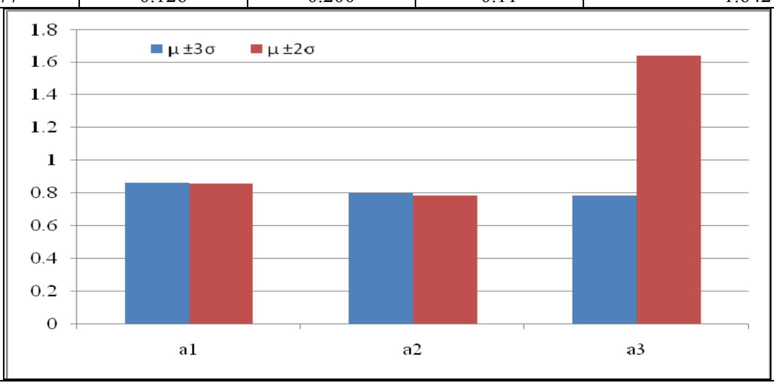
Allowable interval of attributes' significance values	*Determined attributes' weights*				
	w_1	w_2	w_3	w_4	w_5
$\mu \pm 3\sigma$	0.27	0.25	0.18	0.16	0.14
$\mu \pm 2\sigma$	0.27	0.22	0.20	0.20	0.11
Graphic view					

Table 7

Comparison of solution results by applying SAW method and attributes weights calculated according to common and newly proposed approach

Solution with common defined attributes' weights						
	Initial decision-making matrix					
Alternatives	*Criteria*					
	x_1	x_2	x_3	x_4	x_5	
Preferable	*min*	*min*	*min*	*min*	*min*	
w	0.27	0.25	0.18	0.16	0.14	
a_1	34	51	12	51	56	
a_2	39	49	23	38	48	
a_3	55	61	19	27	36	
	Normalised decision-making matrix					
a_1	1	0.961	1	0.529	0.643	
a_2	0.872	1	0.522	0.711	0.75	
a_3	0.618	0.803	0.632	1	1	
	Weighted-normalised decision-making matrix					Results
a_1	0.27	0.240	0.18	0.085	0.090	0.865
a_2	0.235	0.25	0.094	0.114	0.105	0.798
a_3	0.167	0.201	0.114	0.160	0.140	0.781
Solution with modified attributes' weights						
	Initial decision-making matrix					
w	0.27	0.22	0.20	0.20	0.11	
	Weighted-normalised decision-making matrix					Results
a_1	0.27	0.211	0.2	0.106	0.071	0.858
a_2	0.235	0.22	0.104	0.142	0.083	0.784
a_3	0.167	0.177	0.126	0.200	0.11	1.642
Graphic view of solution results						

Conclusions

Solving many multi-attribute problems, we have to identify weights of attributes. The expert inquiry method can be applied for this purpose.

Qualification, experience and knowledge of experts generally vary and are unequal in different fields. Having not enough knowledge in a particular field of science or business is the reason why experts give most attributes prominence or, to the contrary, understate them.

Thus, divergent rating values of some attributes must be eliminated. An algorithm, presented in this article, can be used for this purpose. Attributes rating values, which differ more than per 2σ from an average value, could be eliminated.

This is the way to have a concerted experts' opinion and to get more precise calculation results.

Based on the results the most reasonable decisions could be made, without increasing the number of experts.

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Daugiatikslių apsisprendimo metodų rodiklių svorio nustatymo ypatumai

Santrauka

Investicijų rizikos vadyba, geriausios galimos alternatyvos parinkimas, alternatyvų pateikimas – tai visų statybos projektų uždaviniai. Pateikta būtinų nagrinėti rodiklių (parametrų, kriterijų) aibė. Veikia išorinės aplinkos pokyčiai, išlaidų sumažinimas, projektų realizavimo rodikliai ir projekto realizavimo vertės efektas. Rizikos vadyba yra svarbi visų projektų gyvavimo ciklų dalis. Investicinių projektų vadybos kokybės nustatymas gali remtis tik projekto investuotojo vadybos sumanumu, jo patirtimi ir intuicija. Rizikos vadybos rodikliai gali būti apibrėžiami kokybine ir kiekybine informacija. Vienas iš sunkiausių uždavinių - nustatyti įvairių rodiklių įtaką. Nustatytos rodiklių svarbumo reikšmės yra pagrįstos ekspertų žiniomis arba nauju jų pritaikymu. Straipsnyje apibendrinti teorinių ir empirinių tyrimų daugiatikslio apsisprendimo rezultatai. Dėmesys skiriamas rodiklių svorių reikšmių nustatymo ekspertiniu metodu ypatumams. Anot straipsnio autorių galima apriboti suteikiamas rodikliams svarbumo lygio reikšmes leistinuose intervaluose. Pasiūlytą rodiklių svorio nustatymo metodą sudaro penki etapai:

– rodiklių svarbumo matavimo,
– rodiklių svorio nustatymo,
– rodiklių svarbumo matavimo pataisymo ir
– pataisytų rodiklių svorių nustatymo.

Siūlomas rodiklių svorių nustatymo metodas yra taikomas tada kai ekspertų yra ribotai ir jų negali būti daugiau. Šis metodas buvo išbandytas sprendžiant svarbų uždavinį.

Tyrimo uždavinys. Prekių, paslaugų ir technologijų kūrimas yra viena iš svarbiausių žmonijos veiklos sričių. Ši sritis nuolatos yra plėtojama ir tobulinama. Supančios aplinkos rizikos vertinimas ir apsisprendimo strategijos statyboje per paskutinius dešimtmečius tapo sudėtingos ir painios, informacijos požiūriu labai dinamiškos ir komplikuotos, kurios jungia tokias sritis: ekspertinės sprendimų paramos sistemas, išlaidų ir gautos naudos analizę ir investicijų rizikos analizę. Verslo realijos žiniomis grįstoje ekonomikoje rodo mokslinius uždavinius, atskleisdamos sąryšį tarp ekonominio darnumo ir naujovių diegimo versle. Visos naujos idėjos ir galimi sprendimų variantai turi būti lyginami pagal daugelį rodiklių. Viena iš priemonių, tinkančių pagrįsti darnius aplinkos sprendimus, yra lyginamoji rizikos analizė (LRA). LRA trūksta gerai struktūrizuoto optimalaus projekto nustatymo metodo. Daugiatikslio apsisprendimo analizė (DAA) yra populiarių metodų grupė spręsti daugelį ekonominių, vadybos, statybinių ir kitokių uždavinių. Jos yra tinkamos tikslingoms projektinėms alternatyvoms palyginti. Šių metodų pagrindas yra sprendimų priėmimo matricos. Jos pateikia gerai struktūrizuotus metodus projekto gyvavimo ciklo dalyvių nuomonėms įvertinti tam, kad būtų sudarytos sprendimų priėmimo matricos ir pateiktos tikslingos alternatyvos.

Apsisprendimas projektų gyvavimo ciklo metu yra sudėtingas ir painus uždavinys, apibrėžiamas suderinamumu ir įvairių socialinių, politinių, aplinkos ir ekonominių poveikių nuolaidomis tam, kad būtų galima pasirinkti vieną iš alternatyvių sprendinių, dažnai taikoma išlaidų ir gautos naudos analizė, retkarčiais gali būti taikoma ir lyginamoji rizikos analizė.

Tinkamos strategijos pasirinkimas susieja kainą, naudą, aplinkos poveikį, saugumą ir riziką. Dalis iš šių rodiklių negali būti išreiškiami pinigine verte. Tai uždavinio sprendimas tampa neatsiejamas nuo palyginimų ir naudos siekimo. Net ir tuo atveju, kai įmanoma rodiklius rūšiuoti į vienodus mato vienetus, šie metodai nėra visuomet tinkami, nes projekto gyvavimo ciklo dalyvių suteikiami ir siekiami prioritetai gali pradingti sprendžiant uždavinį. Be to, projektuose labai svarbu atsižvelgti į etinius ir moralinius elementus, kurie nesiejami su jokia ekonomine nauda. Dar daugiau, paprastai sprendimai išrenkami pagal tarpdisciplininių duomenų bazių duomenis, sujungiančius gamtos, fizikos ir socialinius mokslus, mediciną, politiką ir etiką.

Yra daugybė būtinų įvertinti rodiklių (parametrų, faktorių, kriterijų), kurie skirtingai svarbūs pagal daugelį dalykų. Tikslinga riboti ekspertų suteikiamus rodiklių svarbumo reikšmių intervalus.

Tyrimo naujumas – teorinių metodų kūrybiškas pritaikymas realiems investicinės rizikos uždaviniams spręsti ir tirti statyboje. Pasiūlytas naujas būdas, kaip nustatyti rodiklių svorius ekspertų apklausos metodu, kai ekspertų yra ribotai.

Tyrimo objektas – daugiatikslis rizikos vadybos statyboje vertinimo pasiūlymas taikant rodiklių reikšmes, nustatytas apklausiant nedaug ekspertų.

Šio tyrimo tikslas – pasiūlyti rodiklių svorių nustatymo būdą, kai yra ribotai ekspertų.

Tyrimo uždaviniai. Siekiant straipsnio tikslų, sprendžiami tokie uždaviniai:

– rodiklių svarbumo lygių, kurie suteikti ekspertų, įtakos rodiklių svoriams analizė;
– rodiklių svarbumo lygių leistinų intervalų nustatymas;
– rodiklių svorių nustatymas, kai rodiklių svarbumo lygiai, suteikti ekspertų, yra leistini.

Tyrimo metodas – analitinis tyrimas, grįstas tiriamuoju uždaviniu.

Tyrimo pavyzdys. Statybos projektų organizacinis ir technologinis sudėtingumas sukuria didelę riziką. Investicinės rizikos vadybos teorija leidžia planuoti investicinius uždavinius. Investicijų rizikos vadyba reiškia efektyvią visų procedūrų, vykdant visus projekto etapus taikymą, kai yra kintamieji projekto realizacijos poveikiai. Daugeliu atvejų kiekvienas ivesticinis projektas turi keletą efektyvumo rodiklių. Investuotojo darbo sąlygos nuolatos keičia įvertinimą. Investicinio projekto kokybės taisyklės gali būti pagrįstos tik investuotojo vadovavimo strategija. Kokybės vertinimo principas yra pagrįstas sprendimų priėmėjo patirtimi ir intuicija. Šiame straipsnyje pateiktas investavimo į statybos projektą uždavinys. Suinteresuotos projekto gyvavimo ciklu grupės turi parinkti geriausią alternatyvą iš šių galimų tikslingų alternatyvų:

– a_1–statyti devynaukštį 42 butų gyvenamąjį namą;
– a_2–pastatyti penkiaaukštį biurų pastatą;
– a_3–pastatyti triaukštį biurų pastatą ir penkiaaukštį 20 apartamentų namą.

Alternatyvoms aprašyti aukštos kvalifikacijos ekspertai išskiria penkis svarbiausius rodiklius:

– Technologinę riziką – x_1;
– Laikotarpį prieš statybos darbų užbaigimą – x_2;
– Laikotarpį po statybos darbų užbaigimo – x_3;
– Finansinę riziką – x_4;
– Politinę ir teisinę riziką – x_5.

Pavyzdyje pateikiama sudaryta uždavinio sprendimo priėmimo matrica, ekspertų pirminės apklausos matrica, nustatyti rodiklių svoriai pagal įprastinį rodiklių svorių nustatymo ekspertų apklausos metodą ir pagal naujai siūlomą rodiklių svorių nustatymo metodą, taikant rodiklių svarbumo lygio apribojimą intervaluose. Parinktas pirmasis variantas, kuris, taikant įprastiniu būdu nustatytus svorius, buvo geriausias, ir, pritaikius pakeistus svorius, liko geriausias.

Išvados. Reikia nustatyti daugelio daugiatikslių apsisprendimo metodų rodiklių svorius. Šiam tikslui gali būti taikomas ekspertų apklausos metodas. Ekspertų dažniausiai yra ribotai ir prireikus jų negali būti daugiau, nes tinkamų ekspertų daugiau nėra arba jų neįmanoma greitai rasti.

Ekspertų kvalifikacija ir jų žinios yra nevienodos. Žinios ir patirtis nėra vienodos skirtingose srityse. Neturėdami pakankamų žinių ar patirties konkrečioje siauroje mokslo ar verslo srityje ir turėdami išskirtinius poreikius ar nuostatas, ekspertai kai kuriuos rodiklius ypač sureikšmina, o kai kuriuos visai nuvertina.

Todėl gerokai išsiskiriantis rodiklių svarbumo sureikšminimas ar sumenkinimas turi būti pašalinamas.

Šiame straipsnyje pateiktas algoritmas siūlo rodiklių svarbumo lygio reikšmes, kurios skiriasi daugiau nei 2σ nuo ekspertų apklausos metu nustatytos vidutinės reikšmės prilyginti ribinei leidžiamai reikšmei.

Taip gaunama glaudesnė ekspertų apibendrinta nuomonė ir tikslesni skaičiavimo rezultatai.

Taigi negausinant ekspertų gali būti nustatyti rodiklių svoriai ir parinkti pagrįsti tikslingi sprendiniai.

Raktažodžiai: *investicijos, projektas, ekspertas, rodiklis, svoris, daugiatikslė analizė, apklausa, rizika, apribotas intervalas.*

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