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MULTIPLE CRITERIA DECISION SUPPORT SYSTEM FOR ASSESSMENT OF PROJECTS MANAGERS IN CONSTRUCTION

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Construction processes planning and effective management are extremely important for success in construction business. Head of a design must be well experienced in initiating, planning, and executing of construction projects. Therefore, proper assessment of design projects' managers is a vital part of construction process. The paper deals with an effective methodology that might serve as a decision support aid in assessing project managers. Project managers' different characteristics are considered to be more or less important for the effective management of the project. Qualifying of managers is based on laws in force and sustainability of project management involving determination of attributes value and weights by applying analytic hierarchy process (*AHP*) and expert judgement methods. For managers' assessment and decision supporting is used additive ratio assessment method (*ARAS*). The model, presented in this study, shows that the three different methods combined (ARAS method aggregated together with the AHP method and the expert judgement method) is an effective tool for multiple criteria decision aiding. As a tool for the assessment of the developed model, was developed multiple criteria decision support system (MCDSS) weighting and assessment of ratios (WEAR) software. The solution results show that the created model, selected methods and MCDSS WEAR can be applied in practice as an effective decision aid.

Keywords: Construction; project; manager; ranking; MCDM; model; ARAS; AHP; expert judgement; software.

1. Introduction

Selecting a project manager for a construction project is a very important decision for success in continuous monitoring and control. Successful project managers should

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have relevant experience and knowledge of the technology required by the project they manage. With a focus on different aspects of stakeholders, various sets and groups of success criteria have been suggested in the literature.[1] Decision support system (DSS) could be applied as an effective tool for many different problems solving of whole life cycle of projects.[2] Plaza and Turetken[3] created a model-based DSS for integrating the impact of knowledge in project control. The measure changes in the quality and accuracy of decision support information are resulting from the assimilation products. Van Leeuwen *et al.*[4] developed DSS a model for benchmarking that (a) promotes continuity and synergy within and between government agencies, (b) accommodates scientific, operational, and architectural dynamics, and (c) facilitates transfer of knowledge among research, management, and decision-making agencies. Kaklauskas *et al.*[5] presented integrated system of multiple criteria analysis for passive houses. Peng *et al.*[6] investigated empirical evaluation and presented software for risk management.

2. Multiple Criteria Assessment Model of Construction Projects Managers'

Selecting a design project manager is a complicated task in project management. It is very important to find well-grounded requirements and assess candidates. Dulaimi and Langford[7] developed a theoretical model for identifiyng different factors that may influence project managers' behavior and effectiveness. The results strongly suggested that construction firms can influence the direction and behavior of project managers.

Russell *et al.*[8] described principles of designing effective visual analytic solutions for various construction management functions and applications to the associated analytic reasoning tasks and visual representations including relevant interaction features. A detailed assessment of the images is presented in terms of strengths and weaknesses, and interaction features desired.

One of the leading reference sources for managers is the Guide to the Project Management Body of Knowledge (PMBOK) (2004) introducing a methodology to evaluate human resource management processes in construction projects. Many authors investigated the problems related to successful project management. The performance of each process was determined based on the importance weighting and the proposed efficiency of each criterion.[9] Russell *et al.*[10] showed that different criteria are predictors of success at different points. Cheng *et al.*[11] proposed to predict project success. Menches and Hanna[12] described a process for converting a project manager's qualitative evaluation of "successful performance" to a quantitative measurement. Chou *et al.*[13] presented a Web-based visualized architecture, design, and implementation for assessing project performance by integrating earned value analysis and database management system.

Aim of a construction project is to build effectively and safety qualitative building, which employs all project.

A DSS is a computer-based information system that supports business or organizational decision-making activities. DSSs serve the management, operations, and planning levels of an organization and help to make decisions, which may be rapidly changing and not easily specified in advance.

DSSs include knowledge-based systems. A properly designed DSS is an interactive software-based system intended to help decision makers compile useful information from a combination of raw data, documents, personal knowledge, or business models to identify and solve problems and make decisions.

Typical information that a decision support application might gather and present are: inventories of information assets (including legacy and relational data sources, cubes, data warehouses, and data marts), comparative sales figures between one period and the next, projected revenue figures based on product sales assumptions. Decision-making system could be applied in all stages of project life cycle: from cradle to candle.

The multiple criteria assessment model for project managers in construction is presented in Fig. 1. The procedure of applying the model consists of three stages:

(I) Identification;
(II) Appraisal;
(III) Assessment and decision.

In the first stage, stakeholders describe the micro, mezzo, and macro environment. Further, stakeholders' requirements for construction project managers are considered. Project managers must be assessed by a pre-determined set of criteria. The selected criteria could be grouped. Criteria sets are specific for each project.

The second stage is of two levels. The selection criteria describing the main conditions under which the selected projects manager will work are established.

The main stage is the third assessment and decision stage. First, the problem solution methods are to be selected. Investigation process of the problem under consideration is presented in part 3 of the article. The chosen methods are applied and solution results are presented. If the final solution is not accepted, new information is gathered and the next iteration of multi-attribute optimization is started. The general decision is made on the basis of the solution results.

3. Decision Making Model for Problem Solution based on Three Different Methods Combined: AHP, Expert Judgment, and ARAS

The assessment of design project managers is a decision-making procedure based on a multiple criteria set. Multiple criteria decision aid provides several powerful solutions[14–16] to sorting problems. There might be used highly simplified techniques for the ranking in decision making on suitability of a decision support methods such as the Simple Additive Weighting — SAW[16]; TOPSIS[14]; AHP.[18–22] There are a lot of peculiarities in determining criteria weights for MCDM methods.[17] Different problems were resolved by applying TOPSIS method. Lin *et al.*[23] described and

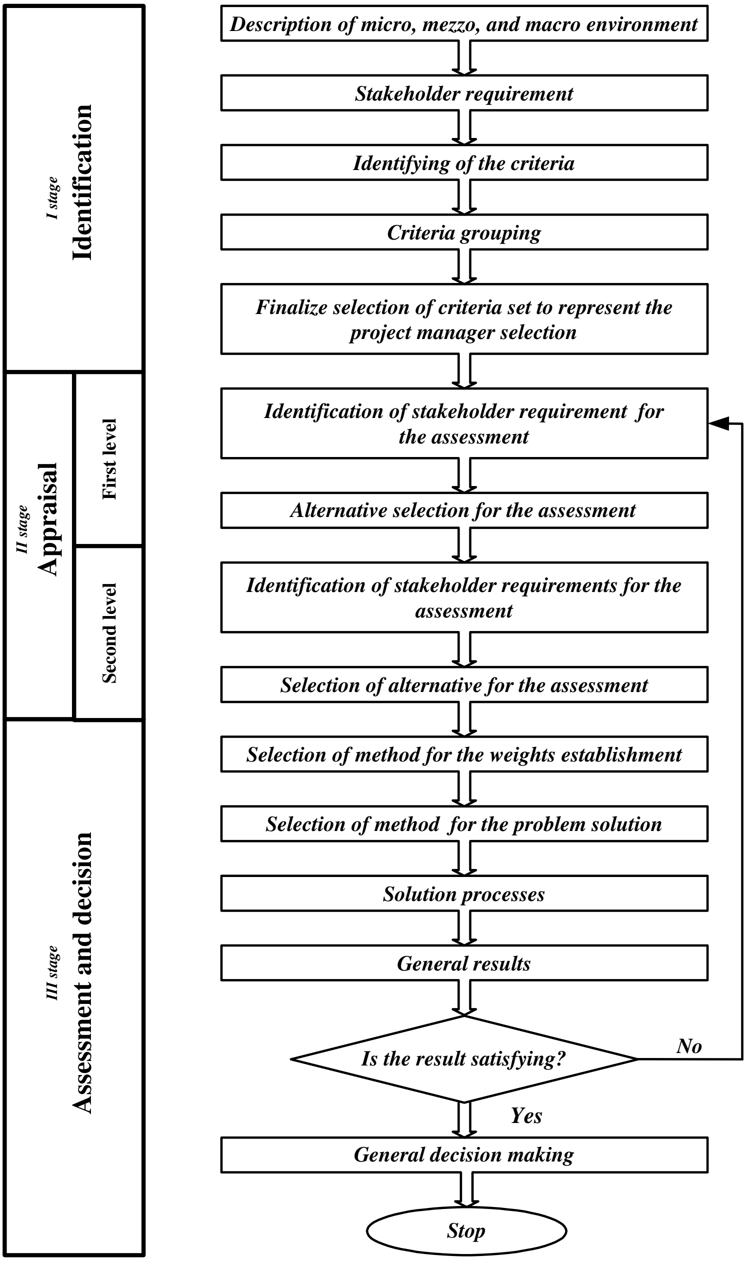

Fig. 1. Multiple criteria assessment model for project managers in construction.

applied TOPSIS method with grey number operations. Besides, the methods with new modifications fuzzy TOPSIS,[24] fuzzy AHP,[25–27] fuzzy Analytic Network Process,[28–30] COPRAS with grey relations,[31,32] and SAW-G[33] were described and practical examples provided.

The ranking of design project managers may be done by applying COPRAS method,[34] and ordering of solutions feasible alternatives in terms of preferability technique.[35]

The above-mentioned decision-making methods (MCDM or MADM) are employed to assign relative weights to different criteria. There are some different methods to determine weights of attributes. One of the most popular methods is the AHP method.[36,37] The AHP method was applied to solve a wide range of construction problems:

— Evaluation of construction technology[38];
— Assessment of strategy under uncertainty[39];
— Complex evaluation of contracts for construction[40];
— Qualifying of construction design projects managers[41,42];
— Ensemble of software defect predictors[22];
— Modeling the interaction of transport system elements[44];
— Determining the importance of operating asphalt mixing plant quality attributes[45];
— Selection of construction enterprises management[46];
— Integrated model for shaft sinking method selection[47];
— The e-banking website quality assessment[48];
— The fuzzy multiple criteria decision making for architect selection.[49]

Jaskowski *et al.*[50] newly presented selection of criteria weights technique based on a fuzzy AHP method application in group decision environment.

The expert judgment method may be used[17,51] to determine weights of the criteria.

In 2010, Zavadskas and Turskis[52] developed the ARAS method. The modifications of ARAS method such as ARAS-F[53] and ARAS-G with grey relations[54] have been developed. The considered method was applied for built and human environment renovation,[55] as well as multiple criteria analysis of foundation instalment alternatives.[56]

The model for problem solution is based on multiple criteria decision-making methods and is presented in Fig. 2.

The procedures of applying the model to rank and select construction project managers consist of the following steps:

(1) Determining initial value of education criteria (AHP method);
(2) Determining weights of criteria (expert judgment method);
(3) Assessing and ranking design heads (ARAS method).

The main steps of multiple criteria decision making are as follows:

(1) Establishing set of evaluation criteria describing a set of capabilities for attaining the goals;

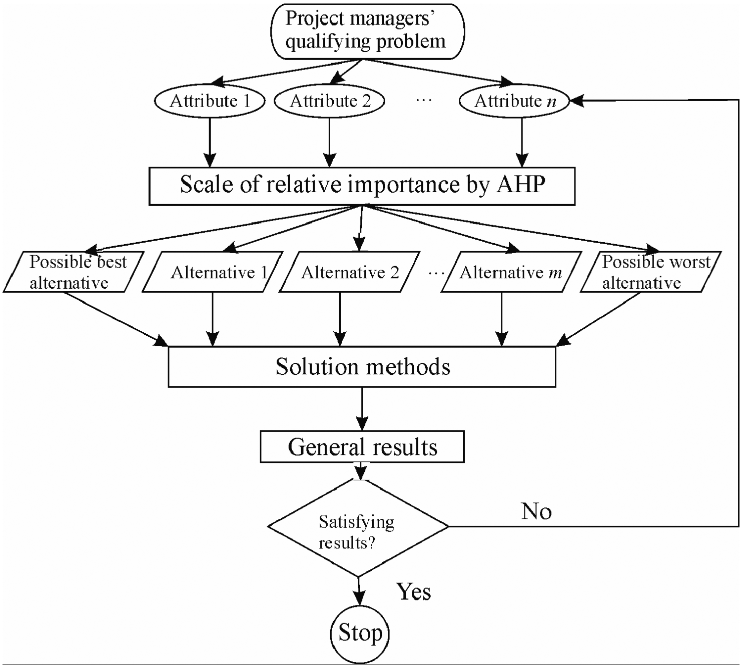

Fig. 2. Assessment algorithm of project manager consolidated of: AHP, expert judgement, and ARAS methods.

(2) Developing alternative systems for attaining the goals (generating alternatives);
(3) Evaluating alternatives in terms of criteria (the values of the attribute functions);
(4) Applying a normative multiple criteria analysis method;
(5) Accepting one alternative as "optimal" (preferred);
(6) If the final solution is not accepted, new information is gathered and the next iteration of multi-attribute optimization is started.

4. The Used Methods

Many methods can be used for the development of the multi-stage MCDM assessment model.[57] Three different consolidated MCDM methods such as AHP,[36,43] expert judgement,[51] and ARAS[52] were selected for problem solution.

The AHP method was developed by Saaty in the early 1970s. The aim of AHP is to select the best from a number of alternatives evaluated with respect to several attributes. The scale of relative importance is presented in Table 1 (adapted from Saaty and Vargas (see Ref. 58)). The AHP algorithm is composed of four phases[37]:

(1) Construction of the hierarchical structure of the decision problem;
(2) Definition of the preferential information (relative weights) and calculation of the absolute weights;

Table 1. Scale of relative importance (adapted from Saaty and Vargas[58]).

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between adjacent scale values

(3) Coherence analysis;
(4) Construction of the final ranking.

The AHP method is designed to select the best result from a number of analyzed alternatives evaluated with respect to several criteria. Within each level of the hierarchy, the relative importance between each pair of criteria (or among pairs of sub-criteria relating to an upper single criterion) to the overall goal is evaluated. A nine-point scale is used for these evaluations. The desired weights to criteria are applied in the matrix below. Acceptable values range from 1/9 (absolutely less important) to 9 (absolutely more important).

The expert judgment method proposed by Kendall[51] was used to determine the weights of the criteria. This expert judgment method includes the following stages:

(1) Calculation of values t_{jk};
(2) Calculation of weights q_j;
(3) Calculation of values W;
(4) Calculation of values S;
(5) Calculation of values T_k;
(6) Calculation of values $\chi^2_{\alpha,v}$;
(7) Testing the statement $\chi^2_{\alpha,v} > \chi^2_{tbl}$.

According to the ARAS method,[52] a utility function value determining the complex relative efficiency of the feasible alternative is directly proportional to the relative effect of values and weights of the main criteria considered in a project.

In the first stage a decision-making matrix (DMM) is worked out. In the MCDM of the discrete optimization problem any problem to be solved is represented by the following DMM of preferences for m feasible alternatives (rows) rated on n signful criteria (columns):

$$X = \begin{bmatrix} x_{01} & \cdots & x_{0j} & \cdots & x_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}; \quad i = \overline{0,m}; \quad j = \overline{1,n}; \tag{1}$$

where m — number of alternatives, n — number of attributes describing each alternative, x_{ij} — the value representing the performance value of the i alternative in terms of the j criterion, and x_{0j} — the optimal value of j criterion.

If optimal value of j criterion is unknown, then:

$$\begin{aligned} x_{0j} &= \max_i x_{ij}, \quad \text{if } \max_i x_{ij} \text{ is } \textit{preferable}; \\ x_{0j} &= \min_i x^*_{ij}, \quad \text{if } \min_i x^*_{ij} \text{ is } \textit{preferable}. \end{aligned} \tag{2}$$

Usually, the performance values x_{ij} and the criteria weights w_j are viewed as the entries of a DMM. The system of criteria as well as the values and initial weights of criteria are determined by experts. The information can be corrected by the interested parties by taking into account their goals and opportunities.

Then the determination of the priorities of alternatives is carried out in several stages.

Usually, the criteria have different dimensions. The purpose of the next stage is to receive dimensionless weighted values from the comparative criteria. In order to avoid the difficulties caused by different dimensions of the criteria, the ratio to the optimal value is used. There are various theories describing the ratio to the optimal value. However, the values are mapped either on the interval [0; 1] or the interval $[0; \infty]$ by applying the normalization of a DMM.

In the second stage, the initial values of all the criteria are normalized — defining values $\bar{x}_{ij}$ of normalized DMM $\bar{X}$.

$$\bar{X} = \begin{bmatrix} \bar{x}_{01} & \cdots & \bar{x}_{0j} & \cdots & \bar{x}_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \bar{x}_{i1} & \cdots & \bar{x}_{ij} & \cdots & \bar{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \bar{x}_{m1} & \cdots & \bar{x}_{mj} & \cdots & \bar{x}_{mn} \end{bmatrix}; \quad i = \overline{0,m}; \quad j = \overline{1,n}. \tag{3}$$

The criteria, whose preferable values are maxima, are normalized as follows:

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}}. \tag{4}$$

The criteria, whose preferable values are minima, are normalized by applying the following two stage procedure:

$$x_{ij} = \frac{1}{x^*_{ij}};$$

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=0}^{m} x_{ij}}. \tag{5}$$

When the dimensionless values of the criteria are known, all the criteria, originally having different dimensions, can be compared.

In the third stage a normalized-weighted matrix — $\hat{X}$ is constructed. It is possible to evaluate the criteria with weights $0 < q_j < 1$. Only well-founded weights should be used because weights are always subjective and influence the solution. The values of weight w_j are usually determined by the expert evaluation method. The sum of weights w_j would be limited as follows:

$$\sum_{j=1}^{n} q_j = 1, \tag{6}$$

$$\hat{X} = \begin{bmatrix} \hat{x}_{01} & \cdots & \hat{x}_{0j} & \cdots & \hat{x}_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{i1} & \cdots & \hat{x}_{ij} & \cdots & \hat{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{m1} & \cdots & \hat{x}_{mj} & \cdots & \hat{x}_{mn} \end{bmatrix}; \quad i = \overline{0,m}; \quad j = \overline{1,n}. \tag{7}$$

Normalized-weighted values of all the criteria are calculated as follows:

$$\hat{x}_{ij} = \bar{x}_{ij} q_j; \quad i = \overline{0,m}, \tag{8}$$

where w_j is the weight (importance) of the j criteria and $\bar{x}_{ij}$ is the normalized rating of the j criteria.

In the following stage, the values of optimality function are determined as follows:

$$S_i = \sum_{j=1}^{n} \hat{x}_{ij}; \quad i = \overline{0,m}, \tag{9}$$

where S_i is the value of optimality function of i alternative.

The biggest value is the best, and the least one is the worst. Taking into account the calculation process, the optimality function S_i has a direct and proportional relationship with the values x_{ij} and weights w_j of the investigated criteria and their relative influence on the final result. Therefore, the greater the value of the optimality function S_i, the more effective the alternative. The priorities of alternatives can be determined according to the value S_i. Consequently, it is convenient to evaluate and rank alternatives when this method is used.

The degree of the variant utility is determined by comparing the analyzed variant with the ideally best one S_0. The equation used for the calculation of the utility degree K_i of an alternative a_i is given below:

$$K_i = \frac{S_i}{S_0}; \quad i = \overline{0,m}, \tag{10}$$

where S_i and S_0 are the optimality criterion values obtained from Eq. (9).

It is clear that the calculated values K_i are in the interval [0, 1] and can be ordered in an increasing sequence, which is the wanted order of precedence. The complex relative efficiency of a feasible alternative can be determined according to the utility function.

5. Design Project Managers' Criteria of Requirements based on the Lithuanian Laws in Force

The competence of design project manager and their experience to design different buildings impacts the success of construction projects. Head of design projects must be selected considering supervisory experience,[59,60] and practical experience.[61] Arditi and Balci[62] evaluated the managerial competences of project managers. They were assessed in 20 different competences. Skipper and Bell[63] focused on two criteria enhancing the performance of construction project managers: (1) the differences in leadership behaviors between a top performing group and a control group of construction project managers; and (2) the causal influences for those leadership behavior differences. They found that the top performers had quantifiably better leadership behaviors than the controls.

A head of design determines the style of building design, the design strategy and the interaction with important stakeholders in a competitive environment. According to Technical Construction Regulation, head of design, applying technical construction regulation of a construction works, shall mean a civil engineer who, representing the interests of a builder, organizes the preparation of the design documentation of a construction works, coordinates solutions of parts of the design documentation of the construction works and the activities of the heads of a part of the design documentation of the construction works, supervises and is responsible for the implementation of the requirements of laws, other legislative acts, normative technical construction documents and normative documents pertaining to the safety and purpose of a construction works as well as mandatory documents related to the preparation of the design documentation of a construction works in accordance with the procedure established by the normative technical construction documents and head of a part of design of a construction works shall mean a civil engineer who prepares and manages a part of the design documentation of a construction works alone or supervises a group of specialists preparing a part of the design documentation and is responsible for the implementation of the requirements of laws, other legislation, normative technical construction documents and normative documents pertaining to the safety and purpose of a construction works as well as mandatory documents related to the preparation of the design documentation of a construction works. The Technical Construction Regulation establishes the requirements mandatory to those who seek to serve as heads in the main areas of technical construction activities.[64]

Assessment of the head of design is based on the three groups of the skills.[42] As presented in Fig. 3, the model of head of design criteria requirements is based on the Lithuania laws in force.

In the case concerned technical skills and experience serve as the basis for design project manager ranking and selecting. Technical skill implies an understanding of a

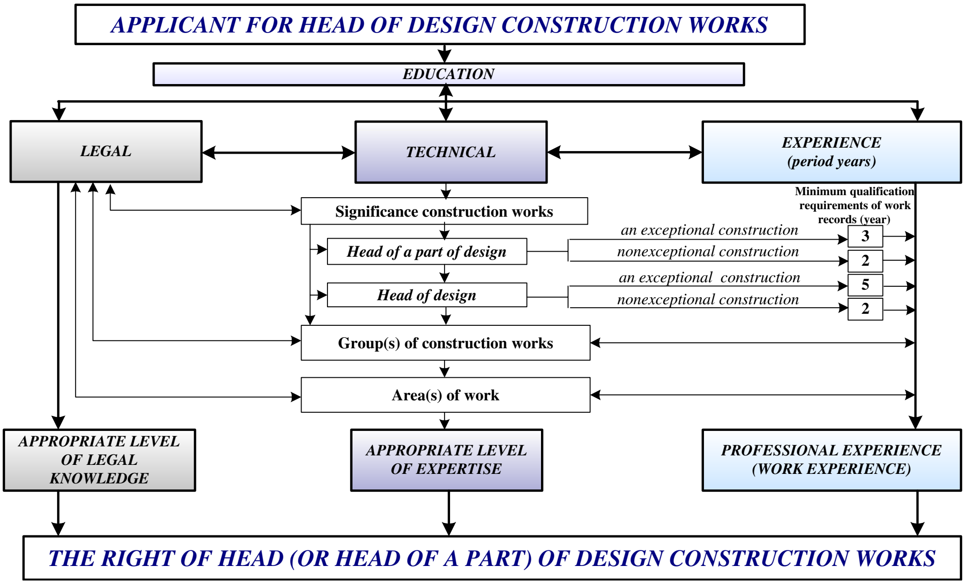

Fig. 3. Integrated assessment processes of skills of head of design construction works.

specific kind of activity, particularly one that involves methods, processes, procedures, or techniques. They involve specialized knowledge and analytical ability in the use of the tools and techniques of the specific discipline, e.g., construction engineering or information systems.[65]

Head of design must have some degree of technical skills, encompassing the technological discipline on which the project is based.

6. Case Study: Multiple Criteria Assessment of Design Project Managers' by Applying MCDSS WEAR

Many projects are based on the fundamental principles and knowledge of scope, time, cost, quality, human resource, communications, building site, building durability, procurement, project integration created value for clients by effectively scheduling and controls.

The case study presents testing of the described integrated model for assessment of projects managers in construction. The ARAS method assumes direct and proportional dependence of significance and priority of the investigated alternatives on a set of criteria that adequately describe the alternatives and is based on the criteria values and weights.

The complex decision problem is decomposed into a hierarchical tree and presented in Fig. 4.

The experts, involved in the procedure concerned, had to determine the set of criteria and calculate the initial values and weights of attributes. In the head of

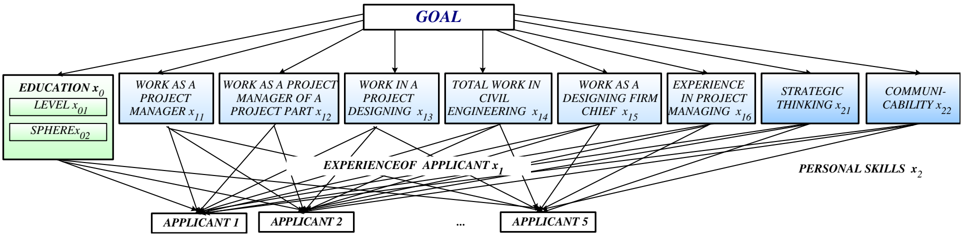

Fig. 4. Criteria hierarchy tree for the MCDSS WEAR.

design assessment processes the evaluation criteria were based on the Lithuanian laws in force. The three main groups of skills: education, experience, and personal, were taken into consideration. In the considered case the applicants' legal knowledge was sufficient. Further the applicants' technical and experience skills were assessed. For the problem solution the complex system of the following criteria was developed:

x_0 — Education:

x_{01} — Education sphere (sub-criterion of x_0);
x_{02} — Education level (sub-criterion of x_0);

x_1 — Criteria group of experience of applicant:

x_{11} — Experience of work as a project manager;
x_{12} — Experience of work as manager of a project part;
x_{13} — Experience of work in a project designing;
x_{14} — Total experience of work in civil engineering;
x_{15} — Experience of work as a designing firm chief;
x_{16} — Experience in projects managing;

x_2 — Criteria group of personal skills of applicant:

x_{21} — Strategic thinking;
x_{22} — Communicability.

There are several mutually exclusive sub-criteria which deal with each of the three main groups of the criteria. They could significantly impact the selection and matching process: the education criterion x_0 which aggregates 2 sub-criteria: education level (x_{01}) and education sphere (x_{02}). The aggregated value of education criterion x_1 can be calculated as follows:

$$x_0 = x_{01} \cdot x_{02}. \tag{11}$$

Multi-stage assessment process aggregating three different methods is presented in Figs. 5–7. The process of the data input to the MCDSS WEAR for determining weights of criteria by applying the AHP method is presented in Fig. 6.

The calculation results criteria values for x_0 criterion education are shown in Tables 2 and 3.

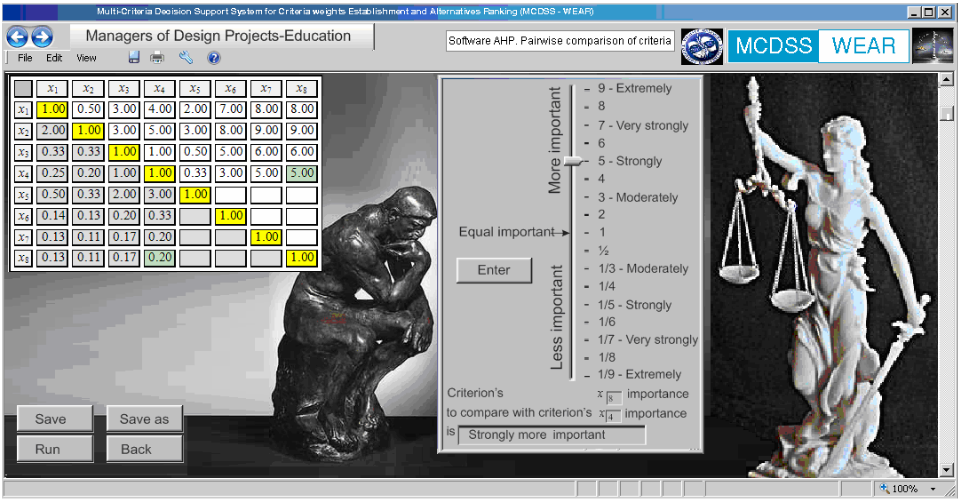

Fig. 5. The data input to the MCDSS WEAR for determining value of the x_{01} sub-criterion (education sphere).

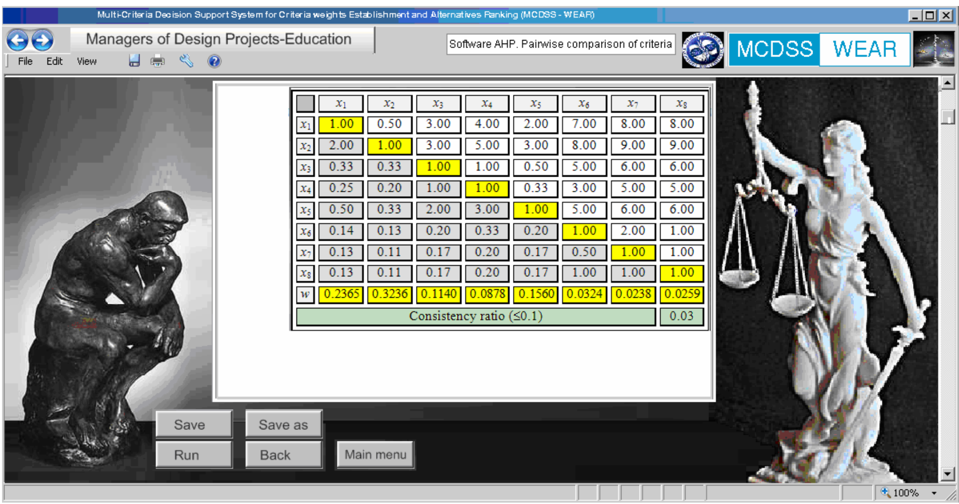

Fig. 6. The initial pairwise comparison matrix and determined criteria values of x_{01} sub-criterion (education sphere).

Criteria weights of x_0 — education, x_1 — experience of applicant, and x_2 — personal skills were established by applying expert questioning method. 20 high-skilled experts were asked to rank assessment skills according to the priority. The biggest priority is the most important. The criteria weights were established by applying expert judgment method.[17,51] Final ranking of the calculation results are presented in Table 4.

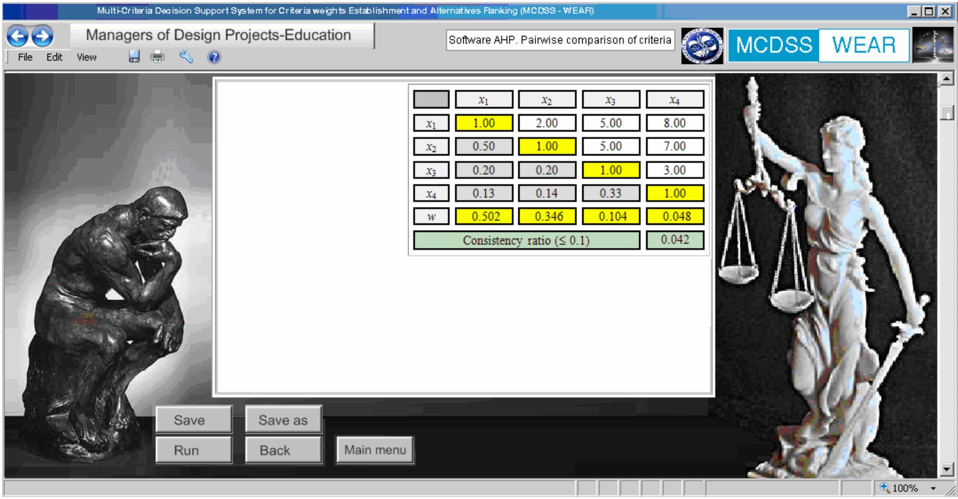

Fig. 7. Initial pairwise comparison matrix and determined criteria values for x_{02} sub-criterion — education level.

In Table 4 x_{ij} is rank of the criterion, where i group of the criteria, j criteria number in the groups:

$i = 1$ — experience criteria;
$i = 2$ — values of the applicant skills.

Table 2. The calculation results by applying AHP of x_{01} sub-criterion — education sphere.

	Criterion	Results
x_1	Civil engineer	0.2365
x_2	Architect	0.3236
x_3	City construction engineer	0.1140
x_4	Road engineer	0.0878
x_5	Engineer-sanitary technician	0.1560
x_6	Mechanic — energetic	0.0324
x_7	Distance communication engineer	0.0238
x_8	Electricity engineer	0.0259

Table 3. The calculation results by applying AHP method criteria values for x_{02} sub-criterion — education level.

	Criterion	Results
x_1	PhD	0.502
x_2	Master degree	0.346
x_3	Bachelor	0.104
x_4	College	0.048

Table 4. The criteria weights establishment by applying expert judgment method for complex criteria system.

$\text{Expert}_{k=1,\ldots,20}$	Values of efficiency criteria ranks t_{jk}; $j = 1, \ldots, n$; $n = 9$.								
	x_0	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{21}	x_{22}
1	1	9	8	2	4	6	3	5	7
2	1	8	9	2	3	5	4	7	9
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
20	1	9	8	3	4	5	3	4	6
The sum of the rank, t_k	25	171	155	44	73	110	68	108	140
Average of the rank	1.25	8.55	7.75	2.20	3.65	5.50	3.40	5.40	7.00
Priority line	*1*	*9*	*8*	*2*	*4*	*6*	*3*	*5*	*7*
Weight, q_j	0.121	0.101	0.103	0.119	0.115	0.110	0.116	0.110	0.105
The reliability of the expertise, β	0.355	0.080	0.083	0.583	0.285	0.240	0.350	0.203	0.123
The average quadratic scattering, δ	0.444	0.686	0.639	1.281	1.040	1.318	1.188	1.095	0.858
The coefficient of concordance, W					0.86				
Deviation of the quadratic sum, S					20340				
The ratio of associate rank, T_k					264				
Ratio of the concordance significant, $\chi^2_{\alpha,v}$					136.65				
Ratio of the concordance significant, χ^2_{tbl}					34.81				

The data of measurement is presented in Fig. 8 (initial DMM X). The weighted-normalized values (weighted-normalized DMM $\hat{X}$) and solution results using the ARAS method are shown in Fig. 9.

According to the problem solution results, the alternatives rank as follows: $a_1 \succ a_3 \succ a_2 \succ a_4 \succ a_5$. Consequently, the first project manager is the best and the fifth one is the worst. In this case, the first applicant was selected as a project design manager. The solution results indicate that the proposed model, applying MCDSS WEAR, can be successfully applied for project manager's assessment.

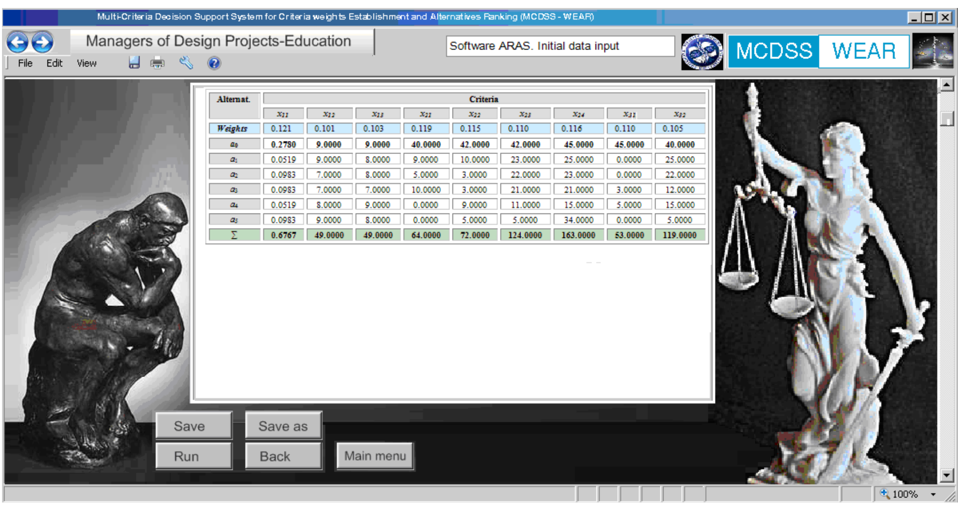

Fig. 8. Initial data input to the DMM (complex assessment of applicants).

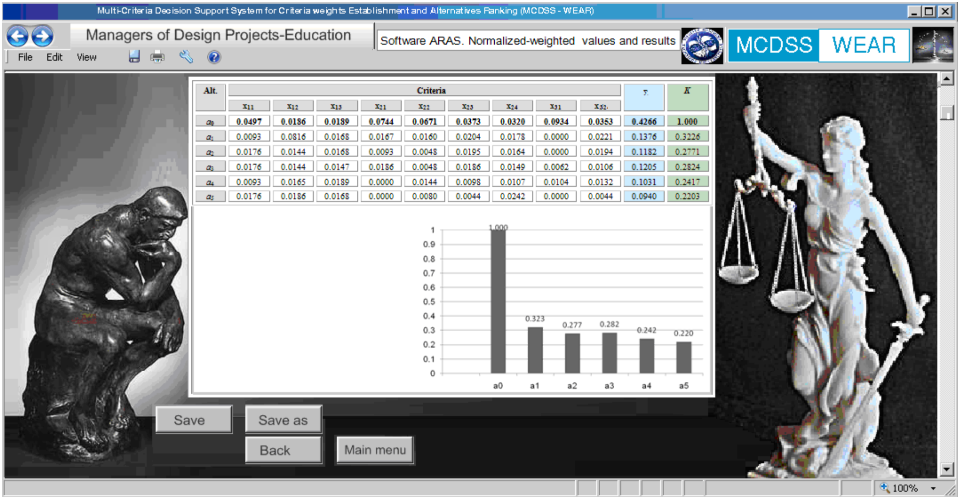

Fig. 9. Normalized-weighted DMM and calculation results (complex assessment of applicants).

7. Conclusion

The case study shows that combining of different multiple criteria methods to solve personel selection, ranking of feasible alternatives is useful tool. The multiple criteria assessment model to assess design project managers' competence level and their experience to design different buildings was developed. A set of criteria weights is determined. The AHP, expert judgement and ARAS methods were employed. The priorities of alternatives were determined according to the utility function value. The application of different consolidated MCDM methods has proved convenient for evaluating and ranking decision alternatives in construction.

The model and solution results are of practical as scientific interest. It allows investor to assess applicants on the multiple criteria basis. Similar to the model developed can be applied in assessing other discrete alternatives in construction. For the achieving goal, which is presented above, a decision support aid MCDSS WEAR software was developed. The solution results show that the created model, selected methods and MCDSS WEAR software can be applied in praxis as an effective decision support aid.

References

1. J. Yang, G. Q. Shen, M. Ho, D. S. Drew and A. P. C. Chan, Exploring critical success factors for stakeholder management in construction projects, *Journal of Civil Engineering and Management* **15**(4) (2009) 337–348.
2. G. Kou, Y. Shi and S. Wang, Multiple criteria decision making and decision support systems — Guest editor's introduction, *Decision Support Systems* **51**(2) (2011) 247–249.
3. M. Plaza and O. Turetken, A model-based DSS for integrating the impact of learning in project control, *Decision Support Systems* **47**(4) (2009) 488–499.

4. W. van Leeuwen, C. Hutchinson, S. Drake, B. Doorn, V. Kaupp, T. Haithcoat, V. Likholetov, E. Sheffner and D. Tralli, Benchmarking enhancements to a decision support system for global crop production assessments, *Expert Systems with Applications* **38**(7) (2011) 8054–8065.
5. A. Kaklauskas, J. Rute, R. Gudauskas and A. Banaitis, Integrated model and system for passive houses multiple criteria analysis, *International Journal of Strategic Property Management* **15**(1) (2011) 74–90.
6. Y. Peng, G. Kou, G. Wang, H. G. Wang and F. Ko, Empirical evaluation of classifiers for software risk management, *International Journal of Information Technology & Decision Making* **8**(4) (2009) 749–767.
7. M. F. Dulaimi and D. Langford, Job behavior of construction project managers: Determinants and assessment, *Journal of Construction Engineering and Management* **125**(4) (1999) 256–264.
8. J. S. Russell, E. J. Jaselskis and S. P. Lawrence, Continuous assessment of project performance, *Journal of Construction Engineering and Management* **123**(1) (1997) 64–71.
9. K. El-Dash, Assessing human resource management in construction projects in Kuwait, *Journal of Asian Architecture and Building Engineering* **6**(1) (2007) 65–71.
10. A. D. Russell, C.-Y. Chiu and T. Korde, Visual representation of construction management data, *Automation in Construction* **18**(8) (2009) 1045–1062.
11. M.-Y. Cheng, Y.-W. Wu and C.-F. Wu, Project success prediction using an evolutionary support vector machine inference model, *Automation in Construction* **19**(3) (2010) 302–307.
12. C. L. Menches and A. S. Hanna, Quantitative measurement of successful performance from the project manager's perspective, *Journal of Construction Engineering and Management* **132**(12) (2006) 1284–1293.
13. J.-S. Chou, H.-M. Chen, C.-C. Hou and C.-W. Lin, Visualized EVM system for assessing project performance, *Automation in Construction* **19**(5) (2010) 596–607.
14. C. L. Hwang and K. Yoon, *Multiple Attribute Decision Making*, Lecture Notes in Economics and Mathematical Systems, Vol. 186 (Springer-Verlag, Berlin, 1981).
15. J. Figueira, S. Greco and M. Ehrgott (eds.), *Multiple Criteria Decision Analysis: State of the Art Surveys* (Springer, 2005).
16. K. R. MacCrimon, Decision making among multiple attribute alternatives: A survey and consolidated approach, Rand Memorandum, RM-4823-ARPA (1968).
17. E. K. Zavadskas, Z. Turskis, L. Ustinovichius and G. Shevchenko, Attributes weights determining peculiarities in multiple attribute decision making methods, *Inzinerine Ekonomika-Engineering Economics* **21**(1) (2010) 32–43.
18. T. L. Saaty and J. S. Shang, An innovative orders-of-magnitude approach to AHP-based mutli-criteria decision making: Prioritizing divergent intangible humane acts, *European Journal of Operational Research* **214**(3) (2011) 703–715.
19. H. Sivilevicius and L. Maskeliunaite, The criteria for identifying the quality of passengers' transportation by railway and their ranking using AHP method, *Transport* **25**(4) (2010) 368–381.
20. L. Chen, Z. G. Zhou, Y. Peng and G. Kou, Structural model for determining enterprise group's integrated lines of credit, *International Journal of Information Technology & Decision Making* **10**(2) (2011) 269–285.
21. K. Yuen and F. Kam, The primitive cognitive network process: Comparisons with the analytic hierarchy process, *International Journal of Information Technology & Decision Making* **10**(4) (2011) 659–680.
22. Y. Peng, G. Kou, G. Wang, W. S. Wu and Y. Shi, Ensemble of software defect predictors: An AHP-based evaluation method, *International Journal of Information Technology & Decision Making* **10**(1) (2011) 187–206.

23. Y.-H. Lin, P.-C. Lee, T.-P. Chang and H.-I. Ting, Multi-attribute group decision making model under the condition of uncertain information, *Automation in Construction* **17**(6) (2008) 792–797.
24. M. Celik, S. Cebi, C. Kahraman and I. D. Er, Application of axiomatic design and TOPSIS methodologies under fuzzy environment for proposing competitive strategies on Turkish container ports in maritime transportation network, *Expert Systems with Applications* **36**(3) (2009) 4541–4557.
25. U. Cebeci, Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard, *Expert Systems with Applications* **36**(5) (2009) 8900–8909.
26. L. Mikhailov, H. Didehkhani and S. Sadi-Nezhad, Weighted prioritization models in the fuzzy analytic hierarchy process, *International Journal of Information Technology & Decision Making* **10**(4) (2011) 681–694.
27. A. Nieto-Morote and F. Ruz-Vila, A fuzzy AHP multi-criteria decision-making approach applied to combined cooling, heating, and power production systems, *International Journal of Information Technology & Decision Making* **10**(3) (2011) 497–517.
28. M. Dağdeviren and İ. Yüksel, A fuzzy analytic network process (ANP) model for measurement of the sectoral competition level (SCL), *Expert Systems with Applications* **37**(2) (2010) 1005–1014.
29. A. H. I. Lee, H.-Y. Kang and C.-C. Chang, An integrated interpretive structural modeling-fuzzy analytic network process-benefits, opportunities, costs and risks model for selecting technologies, *International Journal of Information Technology & Decision Making* **10**(5) (2011) 843–871.
30. D. Ergu, G. Kou, Y. Peng and Y. Shi, A simple method to improve the consistency ratio of the pair-wise comparison matrix in ANP, *European Journal of Operational Research* **213**(1) (2011) 246–259.
31. E. K. Zavadskas, A. Kaklauskas, Z. Turskis and J. Tamosaitiene, Multi-attribute decision-making model by applying grey numbers, *Informatica* **20**(2) (2009) 305–320.
32. E. K. Zavadskas, Z. Turskis and J. Tamosaitiene, Risk assessment of construction projects, *Journal of Civil Engineering and Management* **16**(1) (2010) 33–46.
33. E. K. Zavadskas, T. Vilutiene, Z. Turskis and J. Tamosaitiene, Contractor selection for construction works by applying SAW-G and TOPSIS grey techniques, *Journal of Business Economics and Management* **11**(1) (2010) 34–55.
34. E. K. Zavadskas, Z. Turskis, J. Tamošaitienė and V. Marina, Multicriteria selection of project managers by applying grey criteria, *Technological and Economic Development of Economy* **14**(4) (2008) 462–477.
35. Z. Turskis, Multi-attribute contractors ranking method by applying ordering of feasible alternatives of solutions in terms of preferability technique, *Technological and Economic Development of Economy* **14**(2) (2008) 224–239.
36. T. L. Saaty, *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation* (McGraw-Hill, USA, 1980).
37. T. L. Saaty and H.-S. Shih, Structures in decision making: On the subjective geometry of hierarchies and networks, *European Journal of Operational Research* **199** (2009) 867–872.
38. M. J. Skibniewski and L.-C. Chao, Evaluation of advanced construction technology with AHP method, *Journal of Construction Engineering and Management* **118**(3) (1992) 577–593.
39. S. Li and J. Z. Li, Hybridising human judgment, AHP, simulation and a fuzzy expert system for strategy formulation under uncertainty, *Expert Systems with Applications* **36**(3) (2009) 5557–5564.

40. V. Podvezko, S. Mitkus and E. Trinkūniene, Complex evaluation of contracts for construction, *Journal of Civil Engineering and Management* **16**(2) (2010) 287–297.
41. P. Vainiunas, E. K. Zavadskas, F. Peldschus, Z. Turskis and J. Tamosaitiene, Model of construction design projects' managers qualifying by applying analytic hierarchy process and Bayes rule, 5th International Vilnius Conf. EURO Mini Conf. "Knowledge-Based Technologies and OR Methodologies for Strategic Decisions of Sustainable Development", eds. M. Grasserbauer, L. Sakalauskas and E. K. Zavadskas, Technika, Vilnius, 2009, pp. 154–158.
42. P. Vainiunas, E. K. Zavadskas, Z. Turskis and J. Tamosaitiene, Design projects' managers ranking based on their multiple experience and technical skills, 10th Int. Conf. "Modern Building Materials, Structures and Techniques", eds. P. Vainiunas and E. K. Zavadskas, Technika, Vilnius, 2010, pp. 544–548.
43. T. L. Saaty and H. J. Zoffer, Negotiating the Israeli-Palestinian controversy from a new perspective, *International Journal of Information Technology & Decision Making* **10**(1) (2011) 5–64.
44. H. Sivilevicius, Modelling the interaction of transport system elements, *Transport* **26**(1) (2011) 20–34.
45. H. Sivilevičius, Application of expert evaluation method to determine the importance of operating asphalt mixing plant quality criteria and rank correlation, *The Baltic Journal of Road and Bridge Engineering* **6**(1) (2011) 48–58.
46. K. Zavadskas, Z. Turskis and J. Tamosaitiene, Selection of construction enterprises management, *Archives of Civil and Mechanical Engineering* **11**(4) (2011) 1063–1082.
47. A. Lashgari, M. M. Fouladgar, A. Yazdani-Chamzini and M. J. Skibniewski, Using an integrated model for shaft sinking method selection, *Journal of Civil Engineering and Management* **17**(4) (2011) 569–580.
48. T. Kaya and C. Kahraman, A fuzzy approach to e-banking website quality assessment based on an integrated AHP-ELECTRE method, *Technological and Economic Development of Economy* **17**(2) (2011) 313–334.
49. V. Kersuliene and Z. Turskis, Integrated fuzzy multiple criteria decision making model for architect assessment, *Technological and Economic Development of Economy* **17**(4) (2011) 645–666.
50. P. Jaskowski, S. Biruk and R. Bucon, Assessing contractor selection criteria weights with fuzzy AHP method application in group decision environment, *Automation in Construction* **19**(2) (2010) 120–126.
51. M. G. Kendall, *Rank Correlation Methods*, 4th edn. (London Griffin, 1970).
52. E. K. Zavadskas and Z. Turskis, A new additive ratio assessment (ARAS) method in multicriteria decision-making, *Technological and Economic Development of Economy* **16**(2) (2010) 159–172.
53. Z. Turskis and E. K. Zavadskas, A new fuzzy additive ratio assessment method (ARAS-F). Case study: The analysis of fuzzy multiple criteria in order to select the logistic centers location, *Transport* **25**(4) (2010) 423–432.
54. Z. Turskis and E. K. Zavadskas, A novel method for multiple criteria analysis: Grey additive ratio assessment (ARAS-G) method, *Informatica* **21**(4) (2010) 597–610.
55. L. Tupenaite, E. K. Zavadskas, A. Kaklauskas, Z. Turskis and M. Seniut, Multiple criteria assessment of alternatives for built and human environment renovation, *Journal of Civil Engineering and Management* **16**(2) (2010) 257–266.
56. E. K. Zavadskas, Z. Turskis and T. Vilutiene, Multiple criteria analysis of foundation instalment alternatives by applying additive ratio assessment (ARAS) method, *Archives of Civil and Mechanical Engineering* **10**(3) (2010) 123–141.

57. Z. Turskis and E. K. Zavadskas, Multiple criteria decision making (MCDM) methods in economics: An overview, *Technological and Economic Development of Economy* **17**(2) (2011) 397–427.
58. T. L. Saaty and L. G. Vargas, *Decision Making with the Analytic Network Process* (Springer, 2006).
59. E. Bendoly, D. G. Bachrach and B. Powell, The role of operational interdependence and supervisory experience on management assessments of resource planning systems, *Production and Operations Management* **17**(1) (2009) 93–106.
60. E. Bendoly, D. Thomas and M. Capra, Multilevel social dynamics considerations for project management decision makers: Antecedents and implications of group member tie development, *Decision Sciences* **41**(3) (2010) 459–490.
61. A. D. Ibrahim, A. D. F. Price and A. R. J. Dainty, Evaluation of key practices under the Local Improvement Finance Trust (LIFT) initiative for UK healthcare facilities Engineering, *Construction and Architectural Management* **16**(5) (2009) 504–518.
62. D. Arditi and G. Balci, Managerial competencies of female and male construction managers, *Journal of Construction Engineering and Management* **135**(11) (2009) 1275–1278.
63. C. O. Skipper and L. C. Bell, Assessment with 360° evaluations of leadership behavior in construction project managers, *Journal of Management in Engineering* **22**(2) (2006) 75–80.
64. STR 1.02.06: 2007 "The description of the procedure to qualify for the right of the designer of a construction works, contractor of construction, manager of design or construction and contractor of expert examination of design documentation or construction works. The rules of recognising in the Republic of Lithuania the documents issued in a foreign state submitted by natural persons, legal persons or other foreign organisations confirming the right to work in the main areas of technical construction activities in the country of origin", Technical Construction Regulation, Lithuania 2007.
65. C. B. Daniels, Improving leadership in a technical environment: A case example of the ConITS leadership institute, *EMJ-Engineering Management Journal* **21**(1) (2009) 47–52.