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Evaluation of quality assurance in contractor contracts by multi-attribute decision-making methods

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ABSTRACT

The goal of this paper is to compare quality assurance in different contractor contracts by means of multi-attribute decision-making (MADM) and to select the best option. For this investigation, the authors have developed the complex of quality evaluation criteria. During experimental evaluation, the significance of criteria was determined and the expert evaluation of template construction contracts was performed. The complex comparison of contractor contracts was carried out by means of the following MADM methods: Simple Additive Weighting (SAW), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Complex Proportional Assessment (COPRAS) as well as the new Evaluation Based on Distance from Average Solution (EDAS). MADM. method. To determine the weights of criteria, with due consideration of uncertainty of expert evaluation, the Fuzzy Analytic Hierarchy Process (FAHP) method was applied. Evaluation of the data structure was performed by methods for the determination of objective weights: an entropy method and new criteria impact loss (CILOS) and integrated determination of objective criteria weights (IDOCRIW) methods. Expert subjective and objective weights were combined into aggregate weights. Based on the investigation performed, the authors make conclusions regarding possibilities for improving quality assurance in contractor contracts.

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1. Introduction

The contractor contract process is a multistage procedure involving a large number of stakeholders. This results in the formation of a contractual relationship network, which has to pass a large number of multistage decisions that affect the implementation of the contractor contract process and the economic success and behaviour of stakeholders seeking to avoid risks and possible losses.

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The contractor contract is a main legal document that sets forth a relationship between a customer and a contractor. It is one of principal documents regulating the contractor contract process.

That is exactly why many authors examine a contractor contract via different aspects. Liu, Huo, and Liao (2015) established an indicator system of contractor selection on large-scale construction projects, and two-stage partial least square path modelling combined with the maximisation of deviations principle was proposed as an aggregation approach for performance evaluation. Kirk (2009) focuses on standards for valuation of inventories and construct contracts; risk ranking and comparison of key risk factors on target cost contracts or guaranteed maximum price contracts was analysed by Chan, Chan, Lam, Yeung, and Chan (2011). Kei, On, Yiu, and Pang (2008) presented a study of how trust can be practised in construction contracting.

Notwithstanding the variety of stakeholder groups in the contracting process, regarding contractor contracts, contracts of this type are usually related to regulation of the relationship between the contractor and the customer. The due implementation of a contractor contract project significantly depends exactly on due regulation of the relationship between the customer and the contractor. In accordance with the provisions of law, the customer is engaged in a business activity, the purpose of which is to earn profit. The contractor should know entirely its rights and duties, and acts at its sole risk. There is no subordination or any other dependence relationship between the customer and the contractor, which means that the contractor selects the manner and time limits for performance of works at its own discretion and has no relationship with the organisational structure of the customer. Already at the stage of entering into a contract, the contractor who specialises in the specific field of works has to realistically evaluate its capacities, the specificity of a specific object and other actions required for due discharge of contractual obligations so that the customer will not be misled. Nevertheless, the right of the customer to give instructions to the contractor does not conflict with this provision. According to the contractor contract, the contractor shall perform works at its sole risk, and at its sole discretion shall determine the manner of implementation of the customer's task. Furthermore, the contractor shall perform contracting works by applying its own materials, facilities and capacities. However, in accordance with law, the customer is obliged to exactly define a task to the contractor. If the customer fails to perform this duty, the contractor may fail to follow the time limits set for performance of works.

Different authors indicate different reasons predetermining the successful relationship between the customer and the contractor, and examine different manners for the realisation of successful cooperation between the construction contractor and the customer. Chan et al. (2004) indicated essential cooperation factors; Meng (2012) examined the importance of relationship management for implementation of construction projects; Chen and Chen (2007) assessed the influence of 19 criteria on cooperation during the implementation of a project, while Merschbrock and Munkvold (2015) examined BIM application options for cooperation during the implementation of construction project.

The complex regulation of the relationship between the contractor and the customer, the different goals of stakeholders of the construction contract process, different assessment of the terms and conditions and liability of the contractor contract and other reasons mean that disputes regarding the quality of accomplished works constitute the type of dispute most often observed during the performance of contracting works. Legal evaluation of quality of contracting works and the issues of liability of the customer for possible defects continue to be topical problems both from a practical and scientific perspective. When entering into a contractor contract with the contractor, the customer is expecting a result that is technically qualitative and exactly complies with the customer's expectation. However, as works are often performed at a fast pace and problems regarding the funding of the contractual process arise, it is difficult to fully evaluate all circumstances, which, in turn, often results in the need for amendments to a contractor contract project during the performance of works. The inevitable result of these circumstances is incompliance of quality of works with mandatory technical regulations and the terms and conditions provided for in the contract. In this event, amendments to the specifications of the construction contract initiated by the customer have a direct relationship with the further defects of contractual works performed by the contractor, and as matter of fact grounds for judgement with regard to the occurrence of civil liability of the customer arise.

Contracting works can be classified according to their nature and scope and other characteristics. Requirements for the performance and regulation of contracting works may partially depend on the nature of works. For instance, depending on the specificity of contracting parties, the following types of contractor contracts may be outlined: consumer contracts, construction contracts, design contracts and research contracts. Given that the range of contracting works is wide, the authors selected construction contracting works and the quality assurance of these works as a subject for detailed analysis. This selection will afford an opportunity to perform the analysis of contracts on the grounds of understandable practical examples rather than theoretical general situations. The decision model applied during the investigation may also be used for the evaluation of quality assurance in contractor contracts of other kinds.

The authors' analysis of disputes regarding the quality of construction works showed that such disputes mainly arise when the contractor and the customer do not agree about which quality requirements should be considered as the regular requirements to be applied to the works of this type. The law outlines the quality of construction works as 'to be fit for use as intended'.

With due consideration of the complexity of the relationship between the contractor and the customer of construction works and quality assurance of the construction works, it is worth selecting and applying multiple attribute decision making (MADM) methods. Mardani, Jusoh, and Zavadskas (2015a, 2015b) analysed the versatility of application of these methods.

When developing the method for evaluating the definition of quality in construction contracts, the following steps were performed: the feasibility of application of mathematical analysis methods with respect to quality assurance in construction contracts was taken into consideration; a set of evaluation criteria defining the quality of performance of works in a contract was developed; the significance of these criteria was determined; and a trial test was carried out.

MADM methods are widely used for comparison of different contracts and determination of the best alternative. The subjective and objective methods used for determination of criteria significance (weights) differ. Simple Additive Weighting (SAW), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Complex Proportional Assessment (COPRAS) MADM methods (Ginevičius & Podviezko, 2013; Hwang & Yoon, 1981; Podvezko, 2011; Podviezko & Podvezko, 2014; Vinogradova & Kliukas, 2015;

Zavadskas, Kaklauskas, & Šarka, 1994) as well as the new Evaluation Based on Distance from Average Solution (EDAS) method (Keshavarz Ghorabaee, Zavadskas, Olfat, & Turskis, 2015) were applied in this paper for comparison of different contracts and determination of the best alternative. The Fuzzy AHP (FAHP) method (Chang, 1992; Kurilovas, Vinogradova, & Kubilinskiene, 2016; Kurilov & Vinogradova, 2016) was used for determination of criteria weights with due consideration of uncertainty of expert evaluation. The entropy method and new criteria impact loss (CILOS) and integrated determination of objective criteria weights (IDOCRIW) methods (Zavadskas & Podvezko, 2016) were used for evaluation of the data structure. Expert subjective and objective weights were combined into aggregate weights.

2. Set of criteria for evaluation of a construction contract

In 2010, Podvezko, Mitkus, and Trinkūniene (2010) performed an analysis of the structure of construction contracts by selecting criteria that were used for comparison and evaluation of six construction contracts and by applying multi-criteria SAW and TOPSIS methods. In this paper, the system of contract terms was simulated with due consideration of the functions performed by the specific provisions of a contract. We selected nine criteria affecting the wording of a construction contract:

(1) Obligations of the customer;
(2) Obligations of the contractor;
(3) The right to alter a price for construction if the price increases in excess of 15 per cent for reasons beyond the control of a contractor;
(4) A warranty;
(5) Terms of payment;
(6) Subcontracting;
(7) Contract security;
(8) Suspension of a contract;
(9) Cancellation of a contract.

The previously performed investigation (Podvezko et al., 2010) developed the model of a construction contract based on the functions performed by the contract terms and determined the significance of the contract terms. Weights of contract terms criteria were determined by the analytic hierarchy process (AHP) method. This method was selected because it enables the solving of nondescript tasks that are likely to be resolved better by employing human experience and intuition. We evaluated construction contracts taken together without detailing the pattern of a dispute and without specifying a task.

Having examined the pattern of disputes in a construction contract, we noticed that most disputes arise with regard to the quality of construction works. Analysis of court practice showed that disputing parties – the customer and the contractor – differently understand quality and the requirements applied to quality, and have different expectations.

We developed the following set of quality assurance criteria:

(1) Time limits for performance of works;
(2) The obligation to act diligently and carefully;
(3) Deviations from normative documents and the contract terms;
(4) Delivery of materials and the quality of materials;

(5) Supplementary and unforeseen works;
(6) The obligation of the customer to notify to the contractor deviations from the contract terms if any;
(7) Cooperation obligation.

2.1. Time limits for performance of works

Times limits for completion of a contractor contract are set as may be agreed by the parties. The construction contract sets both the beginning and end of works. Based on an agreement between them, parties may set not only *deadlines* for completion of works but also *interim time limits* for completion of specific work stages. Once time limits are set, the contractor is obliged to promptly start performing works, while the customer is under an obligation to form due conditions for performance of works. Both law and a contract may provide for events when the customer is responsible for late performance.

In the construction process, the customer has duties, the non-performance or undue performance of which can entail a failure to follow interim time limits or deadlines for performance of works and may entail the civil liability of the customer.

Failures to follow time limits during the performance of construction contracts are often-seen problems. Głuszak and Leśniak (2015) analysed the main causes of late performance of construction contract works, among which the following were determined as the most important: errors in design documentation, personnel qualification, weather conditions, poor supervision of construction works, and lax control and monitoring of construction works. Most causes are evaluated in the set of criteria developed by the authors, which sets forth the builder's contractual civil liability for the quality of works.

2.2. Obligation to act diligently and carefully

Once construction works are completed, the customer shall have the obligation to examine and accept a work that has been executed. The works completed shall be accepted under a taking-over certificate, by which the customer either with or without reservations confirms that it has accepted, while the contractor confirms that it has handed over the works completed. While accepting the works completed, the customer should act carefully, which means that it should examine the object resulting from completion of works so that it would be sure whether the object has any apparent defects. In accordance with law, the customer is not requested to do more than a normal examination of the object. A technical construction supervisor supervises construction works, while all supervision procedures are actually carried out visually.

The visual detection of defects in construction is an important stage of the construction process which cannot usually be executed without participation of different stakeholders and professionals. In order to perform examination thoroughly, different engineering tools are often applied. Recently, 3D laser scanners, photogrammetric facilities and other tools have been used for this purpose. However, these tools require highly qualified specialists and specialised equipment (Kalyan, Zadeh, Staub-French, & Froese, 2016), therefore investigators regularly search for methods that can simplify and enhance the visual examination of an object.

2.3. Deviations from normative documents and the contract terms

The contractor shall perform construction works in accordance with the requirements set by normative construction documents and a contract (contract documents) that sets a price for works and the quality requirements applied to a structure (works). In all cases, the mandatory requirements applied to the quality of construction works and safety requirements set in technical construction regulations must be observed. The reasons for deviations from normative documents may differ, while the consequences of deviations may cause different undesirable results: late performance of construction works, increase in the price of construction works, occurrence of supplementary construction works, etc. Forteza, Sesé, and Carretero-Gómez (2016) performed an investigation during which they found that deviations from a construction process are amongst the important factors that predetermine a construction risk.

The customer shall have the right to refuse to accept the result of works if defects that prevent this result from using as intended in the construction contract are detected. However, the customer shall assume responsibility for minor deviations from the requirements of normative construction documents if they are admitted with consent of the customer, provided that such deviations do not affect the quality of the construction object and do not cause negative consequences. The model contracts of the International Federation of Consulting Engineers (FIDIC) have similar indications that the works completed must comply with the intended purpose as indicated in a contract. In accordance with FIDIC, if the customer detects deviations from the contract terms that may deteriorate the quality of works, or any other defects, it shall immediately notify this to the contractor and the engineer.

The contractor's liability for the quality of works continues to be valid after the expiration of the construction contract as well. Law provides for the warranty of quality of works completed: the contractor, unless the construction contract provides otherwise, shall guarantee that a construction object complies with the criteria set by normative construction documents and is fit for use according to the intended purpose set in the contract during the full warranty period.

2.4. Delivery of materials and the quality of materials

For the contractor contract, it is characteristic that one party, namely the contractor, is a professional, which presupposes that the contractor knows which materials, including the features and quality criteria of materials, are to be applied so that the final construction contract result would comply with the requirements of the contract. The contractor also evaluates the fitness of materials for use according to their certificates of conformity.

The success of a construction project depends on a large number of circumstances: a building site, personnel qualification, a construction project, the materials applied, weather conditions, etc. A number of uncertainties affect the success of the construction project. These and other reasons mean that, after implementing the construction project, satisfaction with the product obtained is often expected to be far less than in events when the number of factors predetermining the risk and their impact is small. Grout and Christy (1999) presented a model for supplier responses to *Just-In-Time* delivery requirements. The model shows a situation where the optimal action of the supplier is to hold more inventory.

When incentives for on-time delivery are increased, the supplier responds by decreasing the variance of flow time and by increasing the lead-time allowance.

Seeking to facilitate searching for construction materials, a large number of different databases have been developed recently. However, the information provided in databases should be evaluated with care. Martínez-Rocamora, Solís-Guzmán, and Marrero (2016) performed the evaluation of different databases of construction products by means of a specially developed criteria system.

2.5. Supplementary and unforeseen works

During the performance of the construction contract, unforeseen supplementary works may arise. In this event, the performance of some specific works needs to be postponed or some works need to be replaced by other ones. This reason leads to the need to revise a contracting price for the performance of construction works set by the contracting parties, possible alteration of the schedule for performance of works and the quality of works.

The calculation of a price for construction works and its adjustment is among the most important component parts of the construction contract. To determine a price, numerous methodologies based on different criteria affecting the price are applied. Azman, Abdul-Samad, and Ismail (2013) analysed price-determination principles based on different already implemented projects. It is evident that supplementary and unforeseen works directly affect the final price and quality of construction, and therefore they should be duly outlined in the contract.

2.6. Obligation of the customer to notify the contractor deviations from the contract terms if any

Once deviations from the contract terms that could deteriorate the quality of construction works or other defects are detected, the customer shall immediately notify this to the contractor. If the customer fails to inform of the defects detected, it shall lose the right to refer to them in the future.

The customer shall arrange for and execute the technical supervision of construction of a structure, which means that it shall appoint the technical supervisor of construction for supervision of compliance of the works performed by the contractor and their result with mandatory technical standards and the minimal quality requirements set by law (or the supplementary requirements set forth by the contractor contract).

If the decisions of the building project differ from existing ones, the problem of whether these deviations are substantial ones and whether they affect the conformity of the building with the essential requirements applied to buildings shall be dealt with. If deviations are determined as substantial ones, a new building permit shall be received. Deviations resulting from measurement errors, minor changes in the relief during construction and the impact of works attributable to routine repairs are considered as minor deviations.

The most frequent construction defects include the absence of specific component parts or undue functionality, damaged surfaces and undue installation. Aïssani, Chateauneuf, Fontaine, and Audebert (2016) investigated the impact of four common workmanship errors on the thermal performance of insulation panels.

2.7. Cooperation obligation

If during the performance of the contract any obstacles preventing due and prompt fulfilment of the contract arise, the contractor shall take all reasonable measures available to it to eliminate these obstacles.

Law does not itemise the wording of the cooperation obligation. The following attributes of the cooperation obligation may be indicated: the obligation to notify, give instructions and provide an assistance, form due conditions for the fulfilment of the contract and coordinate actions (Klimas, 2011). The cooperation obligation also is one of the expressions of the principle of good faith in contract law. A party that does not discharge this obligation shall lose the right to recover the losses caused by the failure to eliminate respective obstacles. When the cooperation obligation is breached and the issue regarding indemnification for losses to the other party to the contract is discussed, it is necessary to evaluate whether an aggrieved party by itself contributed to occurrence of a loss by its actions. In addition to this, it is necessary to evaluate whether the other party cooperated sufficiently and whether there are grounds to admit a fault, and whether there is a causal relation between insufficient cooperation and the incurred loss.

Cooperation between project stakeholders by sharing knowledge and information is critically important for the implementation of the contract. Abdull Rahman, Endut, Faisol, and Paydar (2014) investigated the importance of cooperation of stakeholders of the construction process.

The evaluation of quality assurance provisions of a construction contract is a complex procedure, and we suggest that seven different criteria should be applied during such evaluation. The significance of these criteria differs. Furthermore, seeking to make evaluation more versatile, it is worth hiring several experts of this field for evaluation. This complex attitude to quality assurance in construction contracts allows improving of the quality of the decision. However, due to its complexity such an evaluation requires the application of MADM methods. See the scheme for evaluation of quality of construction projects in Figure 1.

3. MADM methods applied in the investigation

The background of MADM methods is formed from the decision matrix (for an estimator of alternatives of applied criteria) and the criteria weight vector. The intended purpose of MADM optimisation methods is determination of the best alternative out of several proposed ones. Each specific MADM method has its own specificity, logics, strengths and weaknesses. Therefore, for evaluation, several methods are applied in parallel, and the mean value of evaluations is used for ranking of alternatives. The methods applied in this paper reflect the unique features of MADM methods: data normalisation, combination of minimised and maximised criteria values and weights into a total evaluation, evaluation of versions according to their distances to the best, the least and average versions.

3.1. Methods for determining the weights of criteria

As has been mentioned, the weights of criteria mean one of two component parts in MADM methods. The effect of criteria on the results of evaluation differ, therefore determination of weights is very important.

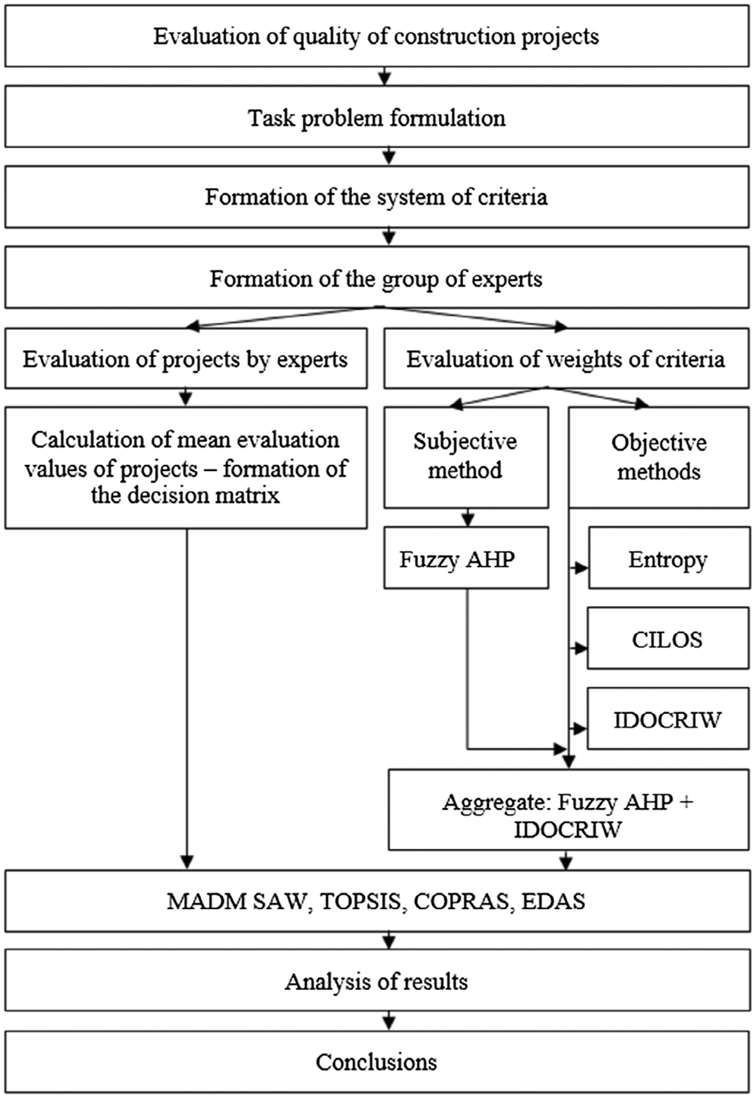

Figure 1. The scheme for evaluation of the quality of construction projects. Source: Created by the authors.

In practice, most often the subjective criteria weights determined by experts/specialists are applied (Gudienė, Banaitis, Podvezko, & Banaitienė, 2014; Hwang & Yoon, 1981; Keršuliene, Zavadskas, & Turskis, 2010; Podvezko & Sivilevičius, 2013; Saaty, 1980).

Subjective weights reflect the opinion of qualified experts who have vast theoretical and practical experience in the field under consideration, and are mainly applied in practice.

However, during evaluation, the data structure may be additionally evaluated and the real degree of dominance of each criterion may be determined. This is the objective weight of criteria. Compared with subjective weights, in practice objective weights are applied much more rarely (Hwang & Yoon, 1981; Kou, Lu, Peng, & Shi, 2012). Combination weighting is based on the integration of subjective weighting and objective weighting (Lazauskaitė, Burinskienė, & Podvezko, 2015; Ma, Fan, & Huang, 1999; Ustinovichius, Zavadskas, & Podvezko, 2007; Zavadskas & Podvezko, 2016).

In this paper we apply the FAHP method, the entropy method, the CILOS method and the IDOCRIW method (Zavadskas & Podvezko, 2016).

3.1.1. Fuzzy AHP method

Quality assurance in a construction contract is evaluated by seven specified criteria, the importance of which is evaluated by experts. Expert evaluation features uncertainty that should be taken into account by a mathematical model. The application of the uncertainty approach to the evaluation task enables evaluation of a range of appropriate values rather than one point value. In this paper, to express the group expert opinion, fuzzy numbers were used, while weights were determined by the FAHP method. The fuzzy triangular numbers are three parameters *(l, m, u)*, which are formed as a general group estimator and which define the quality between 0 and 1 within the membership function (Zadeh, 1980).

The FAHP method is appropriate for determination of weights of criteria when evaluations are performed by a group of experts provided that the experts are independent, which means that this method provides an expert with an opportunity to carry out evaluations independently from the opinion of other experts of the group. The pairwise comparison matrix $\tilde{P}$ of the group of experts is formed by means of fuzzy triangular numbers. The weights of criteria are calculated by the Chang's extent analysis method (1992).

The weights of criteria by means of the FAHP (Kurilovas et al., 2016) method are determined at the following stages:

STAGE I: Experts evaluate the pairwise comparison by applying the AHP method scale. The consistency of the filled in matrix is checked by formula (3).

The principle of the pairwise comparison method is that an expert simultaneously compares only two criteria out of the total number of criteria. Pairwise comparison determines how much one criterion is more important than the other one. Saaty (1980) proposed a five-score 1–3-5–7-9 evaluation system. If criteria have the same importance, the result of evaluation is equal to one. If the difference between the weights of criteria is the biggest, the result of evaluation is equal to nine. Once evaluation is completed, an inverse unknown weight ratio symmetric pairwise comparison matrix P is formed. Matrix elements $p_{ij} = \frac{w_i}{w_j}, (i, j, = 1.2, \ldots, m), p_{ij} = \frac{1}{p_{ij}}, p_{ii} = 1,\ m-$ the number of criteria.

Each expert evaluates $m(m - 1)/2$ pairs, here m – the number of criteria. It is easy to check that

$$P\overline{\omega} = m\overline{\omega} \tag{1}$$

here, $\overline{\omega}$ - unknown weight eigenvector, which means that the problem of eigenvalues and eigenvectors (1) with the eigenvalue λ equal to matrix series m is being solved.

It was proved by Saaty (1980) that the weight vector $\overline{\omega}$ is the eigenvector of normalised values of the P matrix consisting with its maximal eigenvalue λ_{max}. The consistency (non-contradiction) of the expert's evaluation is determined by Consistency Index CI and Consistency Ratio CR:

$$CI = \frac{\lambda_{max} - m}{m - 1}, \tag{2}$$

$$CR = \frac{CI}{RI}, \tag{3}$$

here, RI is the random value of the Consistency Index (Saaty, 1980). The evaluation of the pairwise comparison is admitted if $CR < 0.1$.

STAGE II: Here, we are forming the expert group's pairwise comparison FAHP matrix $\tilde{P}$ out of individual elements p_{ij}^{t} of AHP pairwise comparison matrixes of experts, where $t = 1, 2, \ldots, T$, T - the number of experts.

The matrix of fuzzy triangular numbers $\tilde{P} = (\tilde{P}_{ij}) = (L_{ij}, M_{ij}, U_{ij})$of the pairwise comparison of the group of experts is formed as follows ($j > i$):

$$\begin{aligned} M_{ij} &= \frac{\sum_{t=1}^{T} p_{ij}^{t}}{T}; \\ L_{ij} &= \min_{t} p_{ij}^{t} \\ U_{ij} &= \max_{t} p_{ij}^{t}. \end{aligned} \tag{4}$$

As the matrix is an inverse symmetric one, then $\tilde{P}_{ij}^{-1} = \left(\frac{1}{U_{ij}}, \frac{1}{M_{ij}}, \frac{1}{L_{ij}}\right)$; $\tilde{P}_{ii} = (1, 1, 1)$:

$$\tilde{P} = \begin{pmatrix} (1,1,1) & (L_{12}, M_{12}, U_{12}) & \ldots & (L_{1m}, M_{1m}, U_{1m}) \\ (1/U_{12}, 1/M_{12}, 1/L_{12}) & (1,1,1) & \ldots & (L_{2m}, M_{2m}, U_{2m}) \\ \vdots & \vdots & \vdots & \vdots \\ (1/U_{1m}, 1/M_{1m}, 1/L_{1m}) & (1/U_{2m}, 1/M_{2m}, 1/L_{2m}) & \ldots & (1,1,1) \end{pmatrix}. \tag{5}$$

STAGE III: To determine the weights of criteria from the matrix of fuzzy numbers, the extent analysis method (Chang, 1992) is applied. The value $\tilde{S}_i$, referred to as the extension of the fuzzy synthesis (Chang, 1992; Kurilovas et al., 2016), is calculated for each criterion:

$$\tilde{S}_i = \sum_{j=1}^{m} \tilde{p}_{ij} \times \left\{ \sum_{i=1}^{m} \sum_{j=1}^{m} \tilde{p}_{ij} \right\}^{-1}; \quad i = 1, \ldots, m. \tag{6}$$

The criterion i is characterised by the value $\tilde{S}_i$, which is expressed as a fuzzy triangular number. Next, the degrees of their possibility are found by comparing criteria (which means fuzzy triangular numbers) with each other. The degree of possibility is calculated by the following formula:

$$V\left(\tilde{S}_j \geq \tilde{S}_i\right) = \begin{cases} 1, if\, M_j \geq M_i \\ \frac{L_i - U_j}{(M_j - U_j) - (M_i - L_i)}, if\, L_i \leq U_j \\ 0, in\ other\ cases \end{cases}, \quad i = 1, \ldots, m; \quad j = 1, \ldots, m. \tag{6a}$$

The least value of the degree of possibility is calculated as follows:

$$V_j = V\left(\tilde{S}_j \geq \tilde{S}_1, \tilde{S}_2, \ldots .\tilde{S}_{j-1}, \tilde{S}_{j+1}, \ldots, \tilde{S}_m\right) = \min_{i \in \{1,\ldots,m; i \neq j\}} V\left(\tilde{S}_j \geq \tilde{S}_i\right), i = 1, .., m. \tag{7}$$

The vector of priorities of the fuzzy matrix w_i is calculated as follows:

$$w_j = \frac{V_j}{\sum_{j=1}^{m} V_j}, j = 1, \ldots, m. \quad (8)$$

3.1.2. The method of entropy

Channon (1948) offered the method of entropy. The weights are determined by this method as follows (Hwang & Yoon, 1981):

Step 1: The values of criteria are normalised by the equation:

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}}. \quad (9)$$

Step 2: The entropy level of each criterion is calculated:

$$E_j = (-1/\ln n) \sum_{i=1}^{n} \tilde{r}_{ij} \cdot \ln \ \tilde{r}_{ij}; \quad (j = 1, 2, ..., m); \quad 0 \le E_j \le 1. \quad (10)$$

Step 3: The extent of variation of each criterion is determined:

$$d_j = 1 - E_j. \quad (11)$$

The normalised d_j values are taken for the weights obtained by the entropy method:

$$Wj = \frac{d_j}{\sum_{j=1}^{m} d_j}. \quad (12)$$

The method of entropy assesses the structure of the data array. The weights obtained by using this method reflect the structure of the data (i.e., the elements of the decision-making matrix) and their inhomogeneity. The weight of homogeneous data (when the values of the criteria do not differ considerably), which is obtained by the entropy method (12), is about zero and does not have a strong influence on evaluation.

The weights of the criteria obtained by using the entropy method do not depend on the criterion measuring units because normalised units are used in the evaluation. In this case, the criterion weight is associated with the dominance (significance) degree of a single criterion value. The largest weight of the criterion obtained by using the entropy method corresponds to the criterion with the highest weight ratio.

3.1.3. Method of criterion impact loss (CILOS)

Another promising method of determining the objective weights (by the group work) based on the criterion significance loss is offered in (Mirkin, 1974). In this work, the significance loss of each criterion, when one of the considered criteria obtains an optimal, the largest or the smallest value is evaluated. The logic and basic ideas behind this method, as well as its stages and calculation algorithm are described below (Zavadskas & Podvezko, 2016).

First, the minimised criterion values are maximised so that the largest criterion value can be optimal (the best), when, for example, the following expression is used:

$$\bar{r}_{ij} = \frac{\min_i r_{ij}}{r_{ij}}. \tag{13}$$

Maximised values of the criteria are not changed. Let a new matrix be $X = \|x_{ij}\|$. The largest values of each criterion in the matrix, i.e., the largest values of each column, are calculated:

$x_j = \max_i x_{ij} = x_{k_j j}$, where k_j is the number of the row with the largest element for j-th column.

The square matrix $A = \|a_{ij}\|$ is constructed of the k_j-th rows' values $x_{k_j j}$ of matrix X, corresponding to the maximum of the j-th criterion maximum: $a_{jj} = x_j$, $a_{ij} = x_{k_j j}$ $(i,j = 1,2,...,m$; m denotes the number of criteria), which means that the largest values of all the criteria will be found in the main diagonal of the matrix. The i-th row of matrix A represents the elements of the row k_i of matrix X. It should be noted that matrix A can have the same rows as matrix X because when the largest values of various criteria are found in the same row, they belong to one alternative.

The matrix $P = \|p_{ij}\|$ of the relative loss of criterion significance is formed as follows:

$$p_{ij} = \frac{x_j - a_{ij}}{x_j} \quad (p_i i = 0) \quad (i, j = 1, 2, \dots, m). \tag{14}$$

The above matrix shows how much of the significance should be lost by each criterion of the alternative for it to be evaluated the best based on all the criteria (the optimum according to the Pareto principle). The elements p_{ij} of matrix P show how much the significance of the j-th criterion of the alternative decreased when the i-th criterion was chosen to be the best.

The weights $q=(q_1, q_2, ...,q_m)$ can be found from the system of equations:

$$Fq = 0. \tag{15}$$

Here, matrix F is as follows:

$$F = \begin{pmatrix} -\sum_{i=1}^{m} p_{i1} & p_{12} & \cdots p_{1m} \\ p_{21} & -\sum_{i=1}^{m} p_{i2} & \cdots p_{2m} \\ & \cdots & \\ p_{m1} & p_{m2} \cdots & -\sum_{i=1}^{m} p_{im} \end{pmatrix}. \tag{16}$$

The method based on the criterion significance loss offsets the drawback of the entropy method. Thus, when the values of a criterion do not considerably differ, the elements p_{ij} of the matrix P of relative loss of criterion significance (14) approach zero, while the respective criterion weight increases and has a strong influence on the evaluation. In the case of homogeneity, when the values of one of the criteria are the same in all the alternatives, all relative losses of the criterion, as well as its total loss, are equal to zero. Therefore, the linear system of equations (15) has no sense because one column of elements in matrix P is equal to zero.

3.1.4. Integrated Determination of Objective CRIteria Weights (IDOCRIW) method

The idea of integrating various weights into an aggregate weight (Hwang & Yoon, 1981; Ustinovichius et al., 2007; Ma et al., 1999; Zavadskas & Podvezko, 2016) allows us to combine the weights W_j obtained by the method of entropy with the weights q_j obtained using the method of the criterion significance loss and obtain the aggregate weights for objective evaluation of the data array structure:

$$\omega_j = \frac{q_j Wj}{\sum_{j=1}^{m} q_j Wj}. \tag{17}$$

These weights will emphasise the entropy of the values of particular criteria; however, the significance (influence) of these criteria will decrease due to their higher losses compared with those of other criteria.

The next step is to combine the weights calculated by the entropy method with those calculated by the criterion significance loss approach, aiming to obtain the aggregate weights and to use them for multiple criteria evaluation, ranking the alternatives and determining the best one.

The expert subjective weights and the IDOCRIW (Zavadskas & Podvezko, 2016) objective weights may, analogously to formula (17), be combined into aggregate weights $\propto_j$:

$$\propto_j = \frac{\omega_j w_j}{\sum_{j=1}^{m} \omega_j w_j}. \tag{17a}$$

Aggregate weights $\propto_j$ reflect both the knowledge of experts and the data structure as of the moment of evaluation.

4. Applied MADM methods

4.1. The SAW method

The basic idea behind the MADM methods is to combine the criteria values and weights to obtain a single point of reference for evaluation, i.e. the method's criterion. A common example is SAW, where the method's evaluation criterion S_i is calculated by Eq.(18) (Hwang & Yoon, 1981; Podvezko, 2011):

$$S_i = \sum_{j=1}^{m} \omega_j \tilde{r}_{ij} \tag{18}$$

where ω_j is the weight of the j_{th} criterion and $\tilde{r}_{ij}$ is the normalised (dimensionless) value of the j_{th} criterion for the i_{th} alternative:

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sum_{i=1}^{n} r_{ij}} \tag{19}$$

4.2. The TOPSIS method

The TOPSIS method is based on vector normalisation (Hwang & Yoon, 1981; Podviezko & Podvezko, 2014):

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{n} r_{ij}^2}} \quad (i = 1, \ldots, n; \quad j = 1, \ldots, m), \tag{20}$$

where $\tilde{r}_{ij}$ is the normalised value of j-th criterion for i-th alternative.

The best alternative V^* and the worst alternative V^- were calculated by

$$\begin{aligned} V^* &= \{V_1^*, V_2^*, \ldots, V_m^*\} = \{(\max_i \omega_j \tilde{r}_{ij} / j \in J_1), (\min_i \omega_j \tilde{r}_{ij} / j \in J_2)\}, \\ V^- &= \{V_1^-, V_2^-, \ldots, V_m^-\} = \{((\min_i \omega_j \tilde{r}_{ij} / j \in J_1), ((\max_i \omega_j \tilde{r}_{ij} / j \in J_2)\}, \end{aligned} \tag{21}$$

where J_1 is a set of indices of the maximised criteria, J_2 is a set of indices of the minimised criteria.

The distance D_i^* of every considered alternative to the ideal (best) solutions and its distance D_i^- to the worst solutions were calculated:

$$D_i^* = \sqrt{\sum_{j=1}^{m} (\omega_j \tilde{r}_{ij} - V_j^*)^2}, \; D_i^- = \sqrt{\sum_{j=1}^{m} (\omega_j \tilde{r}_{ij} - V_j^-)^2}. \tag{22}$$

The criterion C_i^* of the TOPSIS method was calculated by

$$C_i^* = \frac{D_i^-}{D_i^* + D_i^-} (i = 1, \ldots, n) \; (0 \le C_i^* \le 1). \tag{23}$$

The largest value of the criterion C_i^* corresponds to the best alternative.

4.3. The COPRAS method

The criterion of the COPRAS method (Zavadskas et al., 1994; Podvezko, 2011) Z_i was calculated as follows:

$$Z_i = S_{+i} + \frac{\sum_{i=1}^{n} S_{-i}}{S_{-i} \sum_{i=1}^{n} \frac{1}{S_{-i}}} \tag{24}$$

$S_{+i} = \sum_{j=1}^{m} \omega_j \tilde{r}_{+ij}$ is the sum of the weighted values of the maximised criteria $\tilde{r}_{+ij}$,

$S_{-i} = \sum_{j=1}^{m} \omega_j \tilde{r}_{-ij}$ is same for the minimised criteria,

where ω_j is the weight of the j-th criterion and $\tilde{r}_{ij}$ is the normalised value of the j-th criterion for the i-th alternative calculated by formula (19).

4.4. The EDAS method

The idea behind the EDAS method is similar to the idea of the TOPSIS method. In addition, in the EDAS method an evaluation criterion is used, which is linked to the idea of the SAW method. In the TOPSIS method, the desirable alternative has lower distance from the ideal solution and higher distance from the nadir solution. In the EDAS method, the best alternative is related to the distance from the average solution (Keshavarz Ghorabaee et al., 2015). In this method, we have two measures dealing with the desirability of the alternatives. The first measure is the positive distance from average (*PD*), and the second is the negative distance from average (*ND*). The evaluation of the alternatives is made according to higher values of *PD* and lower values of *ND*. The steps for using the EDAS method are presented as follows:

Step 1: Construct the decisions matrix (R):

$$R = \|r_{ij}\|, \tag{25}$$

criterion statistics (experimental criterion values) and criteria weights vector

$$\Omega = (\omega_i), \tag{26}$$

where $i = 1,2, \ldots, n$; $j = 1,2, \ldots, m$; m - the number of criteria; n - compared the number of options

Step 2: Calculate the average to all criteria:

$$AV_j = \sum_{i=1}^{n} r_{ij}/n. \tag{27}$$

Step 3: Calculate the positive distance from average (*PD*) and the negative distance from average (*ND*):

$$\begin{aligned} PD_{ij} &= \frac{\max(0, (r_{ij} - AV_j)}{AVj}, \\ ND_{ij} &= \frac{\max(0, (AV_j - r_{ij})}{AVj}, \end{aligned} \tag{28}$$

j_{th} criterion is maximised (beneficial), and

$$\begin{aligned} PD_{ij} &= \frac{\max(0, (AV_j - r_{ij})}{AVj}, \\ ND_{ij} &= \frac{\max(0, (r_{ij} - AV_j)}{AVj}, \end{aligned} \tag{29}$$

j_{th} criterion is minimised (non-beneficial), where PD_{ij} and ND_{ij} denote tye positive and negative distance of *i*th alternative from average solution in terms of *j*th criterion, respectively.

Step 4: Determine the weighted sum of *PD* and *ND* for all alternative:

$$SP_i = \sum_{j=1}^{m} \omega_j PD_{ij},$$
$$SN_i = \sum_{j=1}^{m} \omega_j ND_{ij}, \tag{30}$$

where ω_j is the weight of jth criterion.

Step 5: Normalise the values of SP and SN for all alternatives:

$$NSP_i = \frac{SP_i}{max_i SP_i},$$
$$NSN_i = 1 - \frac{SN_i}{max_i SN_i}, \tag{31}$$

Step 6: Calculate the appraisal score (AS) for all alternatives:

$$AS_i = \frac{1}{2}\left(NSP_i + NSN_i\right), \text{ where } 0 \leq AS_i \leq 1 \tag{32}$$

5. Data description and evaluation of the criteria values of experts

Construction contract processes differ very much by scope of works, work complexity, the building site, time limits, liability and other characteristics. The provisions of the construction contract predetermine all these conditions. For performance of small or medium-scope contracting works, construction contracts lacking detail are often prepared; in fact, these contracts have a general description, but along with this do not evaluate the specificity of works, which means that they are good for everything other than a specific case of construction. Usually construction contracts are confidential; for this reason, it is very difficult for different stakeholders of the construction contract process to share the experience of other entities operating in the field of construction. Therefore, the standard contract versions proposed by different public or professional organisations are used here.

In the case under consideration, completely different construction contracts were taken for evaluation. In reality, the number of contracts may be larger or smaller. This depends on the number of stakeholders representing the interests of the customer and the contractor.

The first construction contract is recommendable and is proposed by the website esablonai.lt. Another contract is proposed by the National Paying Agency as a recommendable one, while the sixth contract is proposed as a recommendable one by the Lithuanian Builders Association. The third contract is the construction contract applied by some construction company. The fourth and the fifth construction contracts for the time being are in court, where disputes regarding the poor quality of performance of construction works are considered.

Quality assurance criteria: the obligation to act diligently and carefully (the second criterion), delivery of materials and the quality of materials (the fourth criterion), the obligation of the customer to notify to the contractor deviations from the provisions of the contract if any (the sixth criterion) and the cooperation obligation (the seventh criterion), are maximised. Criteria that are minimised include: time limits for performance of works (the first criterion), deviations from normative documents and the contract terms (the third criterion) and supplementary and unforeseen works (the fifth criterion).

The contracts were evaluated in accordance with the expert evaluation data. Three experts who were specially selected for this task performed evaluation. The main criterion of selection of experts was their experience in analysing the terms of construction contracts. During evaluation, the position of the contractor or the customer was not adhered to. The prime objective was quality assurance in contracts to the extent that would enable minimising of uncertainty that could predetermine disputes between the contractor and the customer.

The first criterion, *time limits for performance of works*, was awarded the best evaluation of the experts in the third and the fourth contracts, because these contracts outline not only the beginning and the end of performance of works but also set interim time limits for performance of works (works are performed according to the schedule of works approved in writing) and indicate liability for late performance – a late performance fee for each day of delay. These contracts impose on the customer the obligation to let the contractor promptly start performing the works and to complete construction works in due time. Meanwhile the sixth contract, which was evaluated as the worst, only indicates the beginning and the end of works, while the other party to the contract, in the event of a failure to comply with time limits, only has the right to claim indemnity for damages in the amount which in each case has to be proved by an aggrieved party in court, whereas the amount of late performance fee should not be proved because it is set in the contract. The third and the fourth contracts provide for a possibility to amend the schedule for performance of works, introducing such amendments in good faith and cooperating so that construction works would be performed with premium quality, by giving a prior written 10-day notice. The sixth contract does not indicate a possibility to amend time limits.

The second criterion, *the obligation to act diligently and carefully*, was evaluated by experts as the best in the second and the third contracts with due consideration of complex contract terms. The second contract provides for the contractor's obligation to insure its civil liability and to submit an insurance policy to the customer. According to this contract, the contractor shall provide a building site with equipment, tools and materials and submit all documents for performance of works (drawings of the works completed, certificates of materials and other documents shall be submitted to the construction technical supervision manager). Prior to hiding or coating any construction elements, the contractor shall notify this to the technical supervision manager. This contract explicitly indicates the manner of informing: notices should be sent by fax, post or e-mail, an original document always should be submitted to the contractor or the customer against signed acknowledgement. However, the experts did not allocate the maximum evaluation score because the contract does not provide for liability in the event when the contractor fails to submit documents to the construction technical supervisor, does not indicate time limits for submission of these documents and does not mention the necessity to have a log of construction works. The fifth contract was evaluated as worst according to the second criterion; this contract does not mention the performance of technical supervision, which means that the contract will be fulfilled in accordance with the procedure prescribed by the Civil Code; this contract states that any deviations from construction documents shall be notified within a reasonable period and does not provide for any liability. This contract stipulates the obligation to fill in a log of construction works in accordance with applicable legal acts and to keep this log for auditing at an accessible place.

The third criterion, *deviations from normative documents and the contract terms*, was evaluated the best in the fifth contract. This contract stipulates the contractor's obligation to check the project documentation once more prior to starting construction works. The contractor shall be liable for deviations from the requirements of normative construction technical documents and for not achieving the performance indicators of construction works set forth in these documents or the construction contract. If defects are detected, the customer shall have the right to request in writing to eliminate them and to postpone payments for works that have not been performed duly. In this contract, the contractor assumes the obligation to issue a full warranty for the works completed for 5 years. The warranty shall be null and void if the construction object is exploited unduly (the contract explicitly describes the normal exploitation conditions). Thus, this contract sets not only warranty time limits but also explicitly describes events when the warranty becomes null and void. Deviations from normative documents and the contract terms were evaluated the worst in the fourth contract. The contract indicates that during the performance of construction works the contractor shall act in accordance with law, decisions of the government, technical planning documentation, normative construction documents and other legal acts. This is a statement of a general effect, and this wording does not indicate specific laws, specific decisions of the government, which means that it is a general phrase of the Law on Construction. These legal acts are of a dual character; some have a recommendable character, while other construction technical regulations are subject to mandatory execution. To avoid possible disputes regarding the quality of performance of works, the contract should explicitly indicate specific legal acts that are subject to mandatory execution. This contract does not specify a liability for deviations from the contractual project and warranty periods.

The fourth criterion, *delivery of materials and the quality of materials*, was evaluated as the best in the third and the sixth contracts. The third contract indicates that the customer shall deliver construction materials to the contractor together with the certificates of conformity of these materials. If the contractor detects any defects of materials, it shall immediately notify this to the customer. The contract does not indicate the manner of informing and does not disclose the meaning of the word 'immediately'. The contractor shall have the right to postpone works if the customer fails to hand over materials or submit the documents related thereto and to request to reimburse for damages. The sixth contract sets forth that materials, goods, products and equipment used for performance of works shall comply with the requirements set for them in project documentation. In this case, project documentation explicitly indicates construction materials to be applied in construction by giving references to the manufacturers of these materials. However, the contract does not indicate who will be liable if the materials used in construction are manufactured by a manufacturer other than indicated in the contract. The first contract was evaluated by the experts as the worst. This contract does not describe the procedure of delivery of materials, it just indicates that the contractor shall perform all construction works in accordance with the project documentation submitted by the customer.

The fifth criterion, *supplementary and unforeseen works*, was evaluated as best in the sixth contract. This contract has a provision which prevents occurrence of any supplementary and unforeseen works and indicates that, if any supplementary works that were not foreseen by the contractor at the moment of entering into the contract or during execution of project documentation but should or might have been foreseen by the contractor and that are mandatory for due fulfilment of the contract arise and are to be performed, the contractor shall perform these works at its own expense. The second contract was evaluated the worst according to the fifth criterion. This contract indicates that, if any supplementary works resulting from amendments arise, the contractor shall notify this to the customer within eight calendar days. This contract does not indicate the manner of informing. Furthermore, supplementary works are not always related to amendments, and the nature of changes is unclear, which means that the contract does not specify what specifically will be changed: a price, time limits or project design.

The sixth criterion, *the customer's obligation to notify to the contractor deviations from the contract terms if any*, was evaluated by experts as the best in the fourth contract. This contract provides not only for the obligation to notify to the customer if any deviations from the contract terms are detected. This is a recommendable contract, and for this reason the time limit for notification is indicated as a reasonable period rather than in terms of calendar days. However, this was a sole contract that described the contractor's liability for deviations from the contract terms and from the performance indicators of construction works. This contract also stipulates the protection of the contractor and sets forth that the contractor shall have the right to claim indemnity for reasonable damages caused by detection and elimination of shortcomings of documentation of the construction contract. The sixth contract was evaluated the worst. This contract does not have provisions regarding deviations from the contract terms. This contract uses the definition of the additional expenses related to amendments, and, if any dispute arises, these will be understood as supplementary unforeseen works.

The seventh criterion, *the cooperation obligation*, was evaluated by experts as best in the second and the third contracts. The second contract imposes the cooperation obligation not only on the contractor but also on the customer, and indicates that the customer shall be responsible for due cooperation of its personnel. This obligation in this contract was not evaluated by experts maximally well because, according to this contract, all notices shall be delivered in writing while, from a legal perspective, this is understood as delivery by a registered mail only. In this contract, time limits also are not explicitly specified for all events, for example, the period for delivery of the notice to the contractor to notify the defects of performance of works if any or occurrence of supplementary works. The cooperation obligation in the sixth contract is outlined as the worst because this contract does not even mention this obligation. Experts allocated scores having in mind that, if this obligation is omitted in the contract, it shall automatically arise in accordance with the Civil Code. In the sixth contract, general law phrases are set forth: if any defects arise, the contractor shall immediately notify this to the customer, while to assure due cooperation, the parties to the contract shall understand the contract clearly and expressly. This contract should stipulate the option of e-cooperation and convert the word 'immediately' in terms of calendar days.

The mean evaluation scores allocated by the experts for all six contracts are presented in Table 1.

6. Application of MADM methods for evaluation of construction contracts in respect of the quality assurance aspect

6.1. Determination of weights of criteria by the FAHP method

Once quality assurance and the legal comprehension of quality, which affects the terms of the construction contract, has been evaluated, we obtain seven criteria that can be widely

Table 1. The mean scores allocated by the experts to the contracts.

	Criterion direction	Contract 1	Contract 2	Contract 3	Contract 4	Contract 5	Contract 6
1 criterion	min	8.000	9.333	7.000	7.000	8.000	9.667
2 criterion	max	5.000	6.667	6.667	6.000	3.000	3.333
3 criterion	min	7.333	8.667	6.667	9.000	6.000	7.000
4 criterion	max	2.667	6.667	7.667	6.000	4.667	7.667
5 criterion	min	3.333	7.667	6.667	7.000	4.000	2.667
6 criterion	max	4.000	6.667	6.000	8.000	4.333	3.000
7 criterion	max	4.000	7.000	7.000	6.000	3.333	2.667

Source: Authors' calculations.

applied for selection of the most eligible version of a construction contract, with due consideration of quality assurance.

Twelve experienced experts have expressed their opinion on importance. Weights of seven criteria were determined by FAHP method. Every expert's consistency in the filled pairwise comparison matrix was checked by establishing their Consistency Index and Consistency Ratio (CR). Next, expert matrixes that had the $CR < 0.1$ were selected, and consistency of the expert group was checked by establishing the Coefficient of Concordance W and $\chi 2$ criteria (Kendall, 1955). All expert weights of AHP matrixes were consistent since $W = 0.245$ and, accordingly, the value of $\chi^2 = 17.66$ is significantly higher than the critical value $\chi^2_{kr(0,05,6)}$=12.59.

After application of fundamental scale of absolute numbers for estimation of the weights of seven criteria, one expert matrix is as follows:

$$P = \begin{bmatrix} 1.00 & 2.00 & 0.33 & 0,25 & 0,50 & 3,00 & 0,50 \\ 0.50 & 1.00 & 0.25 & 0,20 & 0,33 & 2,00 & 1,00 \\ 3.00 & 4.00 & 1.00 & 0,50 & 3,00 & 6,00 & 4,00 \\ 4.00 & 5.00 & 2.00 & 1,00 & 4,00 & 3,00 & 5,00 \\ 2.00 & 3.00 & 0.33 & 0,25 & 1,00 & 4,00 & 5,00 \\ 0.33 & 0.50 & 0.17 & 0,33 & 0,25 & 1,00 & 2,00 \\ 2.00 & 1.00 & 0.25 & 0,20 & 0,20 & 0,50 & 1,00 \end{bmatrix}$$

Having applied formulas (4–5), the group FAHP matrix is obtained as follows:

$$\tilde{P} = \begin{pmatrix} 1.00;1.00;1.00 & 0.17;1.52;5.00 & 0.25;1.01;4.00 & 0.17;0.57;2.00 & 0.25;2.10;6.00 & 0.20;2.05;9.00 & 0.17;1.23;5.00 \\ 0.20;0.66;6.00 & 1.00;1.00;1.00 & 0.17;1.51;4.00 & 0.20;1.26;3.00 & 0.20;2.92;5.00 & 0.33;2.36;4.00 & 0.33;1.24;5.00 \\ 0.25;0.99;4.00 & 0.25;0.66;6.00 & 1.00;1.00;1.00 & 0.33;0.94;2.00 & 0.50;2.71;6.00 & 0.50;2.63;7.00 & 0.25;1.58;5.00 \\ 0.50;1.75;6.00 & 0.33;0.79;5.00 & 0.50;1.06;3.00 & 1.00;1.00;1.00 & 1.00;3.00;5.00 & 0.50;2.71;9.00 & 0.25;1.90;5.00 \\ 0.17;0.48;4.00 & 0.20;0.34;5.00 & 0.17;0.37;2.00 & 0.20;0.33;1.00 & 1.00;1.00;1.00 & 0.25;1.17;4.00 & 0.20;1.31;5.00 \\ 0.11;0.49;5.00 & 0.25;0.42;3.00 & 0.14;0.38;2.00 & 0.11;0.37;2.00 & 0.25;0.85;4.00 & 1.00;1.00;1.00 & 0.20;0.96;3.00 \\ 0.20;0.82;6.00 & 0.20;0.81;3.00 & 0.20;0.63;4.00 & 0.20;0.53;4.00 & 0.20;0.77;5.00 & 0.33;1.04;5.00 & 1.00;1.00;1.00 \end{pmatrix}$$

The degree of possibility of criteria is presented in Table 2.

The weight vector of criteria is presented in Table 3.

The maximum weight was allocated by the experts to the criterion *delivery of materials and quality of materials* (the fourth criterion). In the opinion of the experts, the quality and terms of delivery of materials have the biggest effect on the construction quality.

Furthermore, the contractor is exposed to the biggest risk related to poor quality materials. The contractor must determine quality by visual examination and according to certificates of conformity of materials. In the case when construction materials are delivered by the builder, the contractor shall inform the customer of poor quality materials. If the customer fails to replace poor quality materials by materials that are fit to construction, the contractor shall cancel the contract. Otherwise, the contractor shall be liable for the poor quality of performance of works. A smaller weight was allocated to the criterion *the obligation to act diligently and carefully* (the second criterion). This condition arises out of the general principle of performance of contracts and is one of conditions for the imposition of civil liability. *Deviations from normative documents and the contract terms* (the third criterion) is the third criterion according to weight. To summarise data regarding this criterion, it can be said that, if the structure does not comply with essential applicable requirements, it cannot be qualified as completed and cannot be exploited. In the event of minor deviations from quality requirements, the customer shall accept works and indicate defects in a taking-over certificate. If defects are not indicated in the taking-over certificate, this will mean the absence of the statement of fact, therefore the party shall have no right to refer to the fact of defects thereafter. The criterion *time limits for performance of works* (the first criterion) was ranked as the fourth according to weight. In the opinion of the experts, serious consideration must be paid not only to the deadline for performance of works but also to interim time limits as well as to the liability for late performance. The fifth according to its weight criterion *the cooperation obligation* (the seventh criterion) is the general principle of contract law. If a party to the contract breaches the cooperation obligation, it shall lose the right to recover damages. Weight that was allocated to the criterion *supplementary and unforeseen works* (the fifth criterion) is among the least weights. The least weight was given to the criterion *the customer's obligation to notify to the contractor deviations from the contract terms if any* (the sixth criterion).

The weights estimated by the FAHP method differ little from each other. Therefore subjective weights were evaluated in the paper.

Table 2. The degree of possibility of criteria.

l	*m*	*u*
0.0113	0.1628	1.7409
0.0125	0.1881	1.5232
0.0158	0.1806	1.6865
0.0209	0.2098	1.8497
0.0112	0.0859	1.1968
0.0106	0.0768	1.0880
0.0120	0.0961	1.5232

Source: Authors' calculations.

Table 3. The weight vector of criteria.

Weights of criteria	*Values*
ω_1	0,1460
ω_2	0,1480
ω_3	0,1474
ω_4	0,1500
ω_5	0,1357
ω_6	0,1334
ω_7	0,1395

Source: Authors' calculations.

The entropies calculated by formulas (9) to (12), (13) to (16) and (17), CILOS, IDOCRIW objective weights and the weights aggregated by (17a) are presented in Table 4.

The determined aggregate weight of criteria is used for the calculations made by means of the MADM methods selected by the authors.

6.2. Results of evaluation of MADM methods

During the investigation, some quality assurance criteria were minimised, while others were maximised. It is impossible to visually evaluate which construction contract is better than another. The best version of a contract also cannot be determined without calculations. Therefore multi-criteria TOPSIS, COPRAS, SAW and EDAS methods were selected to solve such a problem.

Six contracts were compared based on the data of Table 1 and by applying the weights of criteria from Table 4. The results of evaluation of different MADM methods are presented in Table 5.

Contract No 3 was ranked the best. This is a contract that is applied by some construction company. It received the best evaluation of the experts according (hereinafter also 'acc.') to the first criterion *time limits for performance of works* (consistent with contract No 4), acc. the second criterion *the obligation to act diligently and carefully* (consistent with contract No 2), acc. the fourth criterion *delivery of materials and the quality of materials* (consistent with contract No 6) and acc. the seventh criterion *the cooperation obligation* (consistent with contract No 2). In accordance with expert evaluations, this contract was not ranked the absolute leader according to any criterion referred. However, it is interesting to note that this contract was not ranked the least according to any criterion referred. It is likely that the high ranking of this contract was due to the fact that it was drawn up by an experienced contractor who has been engaged in construction business for many years.

The second position of ranking was given to contract No 2, a recommendable construction contract that is proposed by the National Paying Agency. This agency allocates

Table 4. Objective entropies, CILOS, IDOCRIW and the aggregate weights of criteria.

Method	1	2	3	4	5	6	7
FAHP	0.146	0.148	0.1474	0.15	0.1357	0.1334	0.1395
Entropy	0.0264	0.1489	0.0338	0.1682	0.2408	0.1728	0.2090
CILOS	0.1166	0.1707	0.2433	0.1208	0.0905	0.1055	0.1527
IDOCRIW	0.0238	0.1970	0.0638	0.1575	0.1690	0.1413	0.2474
Aggregate	0.0245	0.2054	0.0662	0.1664	0.1616	0.1328	0.2431

Source: Authors' calculations.

Table 5. Results of evaluation obtained by MADM methods.

		Contract					
Method		1	2	3	4	5	6
TOPSIS	Value	0.4180	0.6478	0.6984	0.6257	0.3393	0.4293
	Rank	5	2	1	3	6	4
COPRAS	Value	0.1465	0.1894	0.1969	0.1814	0.1363	0.1495
	Rank	5	2	1	3	6	4
SAW	Value	0.1461	0.1889	0.1971	0.1810	0.1345	0.1523
	Rank	5	2	1	3	6	4
EDAS	Value	0.2682	0.7716	0.9097	0.6929	0.1527	0.2811
	Rank	5	2	1	3	6	4
	Final rank	5	2	1	3	6	4

Source: Authors' calculations.

funding and supervises the implementation of different construction contracts, therefore much attention is paid to the quality aspect. Such an aspect is also shown by respective evaluations given by the experts to this contract. Two criteria: the second criterion *obligation to act diligently and carefully* (consistent with contract No 3) and the seventh criterion *the cooperation obligation* (consistent with contract No 3), were evaluated the best. As this organisation has accumulated huge experience in different construction contract projects, this recommendable contract, in contrast to other contracts of a recommendable type, pays great attention to summarising and detailing the general principles of law (such as *the cooperation obligation* and the *obligation to act diligently and carefully*). This principle of law is often construed as matter of course. However, due to different interpretations by the parties to the contract and the human factor, it often turns into a subject matter of dispute. This recommendable contract was well ranked acc. the fourth criterion *delivery of materials and the quality of materials* and acc. to the sixth criterion *the obligation of the customer to notify to the contractor deviations from the contract terms if any*. However, this contract received the least evaluation acc. the fifth criterion *supplementary and unforeseen works*. Insufficient attention to this criterion could have been due to the fact that this agency allocates funding provided only that the customer explicitly and in detail outlines the subject matter of the contract, in this way avoiding occurrence of supplementary and unforeseen works. Nevertheless, it is noteworthy that the risk factor continues to exist in any case.

The third-ranking position 3 was awarded to contract No 4, a construction contract of some construction company, which was under consideration in court with regard to a dispute concerning the quality of the construction works completed. This contract was ranked as the best acc. the first criterion *time limits for performance of works* and acc. the sixth criterion *the customer's obligation to notify to the contractor deviations from the contract terms if any*. The latter criteria may be easily outlined in the contract by specifying the exact time limits for performance of works, the form and delivery period of the notice informing of undue quality of works and detail liability for breaching these criteria. This contract received the low evaluation of the experts acc. the fifth criterion *supplementary and unforeseen works*. According to other criteria, this contract is an average one; in this way the parties to the contract are provided with an interpretation opportunity.

Contract No 6, a recommendable contract of the Lithuanian Builders Association, was placed in the fourth ranking position. This contract received the best evaluations acc. to the fourth criterion *delivery of materials and the quality of materials* (consistent with contract No 3) and acc. to the fifth criterion *supplementary and unforeseen works*. However, this contract received the least evaluation acc. the first criterion *time limits for performance of works*, acc. the sixth criterion *the customer's obligation to notify to the customer deviations from the construction contract if any* and acc. the seventh criterion *the cooperation obligation*. It is most likely that attention to time limits for performance of works is insufficient because this contract is of a recommendable nature. The problem of assurance of the sixth criterion is that it was rewritten from law < *defects shall be reported within a reasonable period*> and is absolutely inconsistent with implementation of construction works in practice. This presupposes a dispute regarding the understanding of the definition of the reasonable period, which means the understanding whether the period is reasonable or unreasonable. The seventh criterion, *the cooperation obligation*, reflects the typical attitude of builders to this issue; it is likely to be a matter of course that the parties should cooperate, so there is no need to include this provision in the contract.

Contract No 1, a recommendable esablonai.lt contract, was awarded the fifth ranking position. Lawyers in cooperation with construction professionals drew up this contract. This contract was ranked the best according to no criteria. It received the least evaluation acc. the fourth criterion *delivery of materials and the quality of materials*. The definition of this criterion in the contract depends on available practical skills in the field of performance of construction works, in terms of whether materials are delivered by the contractor or by the customer and on the scope of liability imposed in case of poor quality materials. This contract was badly evaluated acc. the first criterion *time limits for performance of works* and acc. the sixth criterion *the customer's obligation to notify to the contractor deviations from the contract terms if any*. It received good evaluation acc. to the fifth criterion *supplementary and unforeseen works*. The low evaluation of criteria by the experts was due to the fact that this contract does not go into details of the specificity of the construction process, reproduces the general law regulation (e.g., a reasonable period) and participation of professionals from the construction field was insufficient.

The lowest rank was given to contract No 5, a construction contract of some construction company, which was under consideration in court with regard to a dispute concerning the quality of the construction works completed. The third criterion of this contract, *deviations from normative documents and the contract terms*, was evaluated the best. The second criterion of this contract, *the obligation to act diligently and carefully*, was the evaluated worst. Low scores were allocated acc. the fifth criterion *supplementary and unforeseen works* and acc. the seventh criterion *the cooperation obligation*. This contract pays insufficient attention to nondescript and depending on human factor contract terms, such as the cooperation obligation and the due diligence and care obligation. The uncertainty of provisions of this contract entailed a judicial dispute, similar to the situation which occurred with contract No 4. It is therefore necessary, when preparing the construction contract, to take note of provisions of the contract, which look like a matter of course such as, for example, the cooperation obligation. Nevertheless, the contract should describe cooperation of the parties in the construction process: the manner of cooperation, periods for delivery of notices and replies to notices, actions in case the other party does not respond, an explanation whether construction works should be postponed in such a case, etc.

It is easy to determine which contract is the best according to the evaluations submitted. However, it is difficult to compare and evaluate all other contracts without application of mathematical methods. The task complexity is additionally worsened by the fact that not all evaluation criteria have equal importance; therefore, to obtain an objective result of evaluation, MADM methods are applied. These methods incorporate different calculation principles, therefore to avoid accidental errors related to the calculation principles of one or another method it is worth applying several different MADM methods. In this particular case, the evaluations obtained by different methods are consistent. However, if evaluations are inconsistent, we suggest that the mean value of evaluation should be taken.

7. Conclusions

The basic legal document establishing the relationship between the customer and the contractor is a construction contract. The implementation of the construction contract to a large extent depends on the due regulation of the relationship between the customer and the contractor. The complex regulation of relationship between the contractor and the customer, the different goals of stakeholders of the construction contract process, different assessment of the terms and conditions and liability of the contractor contract and other reasons mean that disputes regarding the quality of accomplished works are the type of dispute most often observed during the performance of contracting works.

The analysis of disputes performed by the authors regarding the quality of construction works showed that such disputes generally arise because the contractor and the customer cannot agree with regard to which quality requirements should be considered as the regular requirements applied to works of this type. Often the parties to a dispute, the customer and the contractor, have different understandings of quality and quality requirements, and have different expectations. The authors developed a set of criteria reflecting quality assurance in construction contracts. This set may be applied as recommendable for evaluation of quality assurance in the construction contract of any other type.

Evaluation of conditions of quality assurance in construction contracts, including other contractor contracts, is a complex process. It is suggested that evaluation should be carried out by means of seven different criteria that have different significance. By seeking to achieve versatility, it is reasonable to hire several experts of this field. This complex attitude to quality assurance in construction contracts resulted in the possibility to improve the quality of a decision. However, due to its complexity, such an evaluation needs the application of MADM methods.

The application of the proposed principles for evaluation of quality assurance in construction contracts enables to evaluate the strengths and weaknesses of different contractor contracts. The proposed evaluation principles provide for the possibility to create out of several contracts a new contract that would meet applicable requirements the best and would help to avoid disputes regarding the performance of construction works.

Six (6) different contractor contracts were selected for evaluation of contracts. It is imported to note that, when preparing the contracts, different parties can use very limited resources. The wording of contractor contracts is considered as confidential; therefore, when entering into a new contractor contract, the contractor and customer often have to rely on their own experience. In this case, as a matter of fact the customer who has a significantly minor experience compared with the contractor is in a less good situation. Seeking to improve quality assurance evaluation in contractor contracts for both parties, it is advised at the initial stage to compare and evaluate as large a number of contracts as possible.

The proposed principles of evaluation of contracts create possibilities for quick, objective and complex evaluation of contracts. For this reason, evaluation of contracts can be performed several times (initial evaluation, evaluation after any amendment and final evaluation). Evaluation results may be used in negotiations on contract terms that would meet the requirements of both parties.

FAHP as well as CILOS and IDOCRIW methods were applied to determine the significance of the applied evaluation criteria under conditions of uncertainty. Contracts were evaluated and compared by means of the widely used SAW and TOPSIS MADM methods and the new EDAS method. The application of these methods to evaluation of contracts proved the efficiency of the intended application of methods.

The analysis of the results of complex evaluation has shown that both the application of MADM methods and the complex application of criteria for complex evaluation creates conditions for comprehensive evaluation of contractor contracts, while the evaluator (either the contractor or the customer, or any other stakeholder of the process) can evaluate the different versions of the contract according to the set of criteria rather than according to either presence or absence of individual provisions, and can determine the general eligibility of the contract.

Different MADM methods incorporate different calculation principles; therefore, to avoid accidental errors related to the calculation principles of one or another method, it is worth applying several different MADM methods. In this particular case, the evaluations obtained by different methods are consistent. However, if evaluations are inconsistent, we suggest that the mean value of evaluation should be taken.

Disclosure statement

No potential conflict of interest was reported by the authors.

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