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COMPLEX EVALUATION OF CONTRACTS FOR CONSTRUCTION

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Abstract. The effectiveness of construction processes largely depends on the effective contract preparation. To draw an effective contract for construction, the methods of assessment and comparison of these types of contract should be developed. In recent years, multicriteria methods have been widely used for evaluating various complex phenomena. The development of construction evaluation methods requires the analysis of construction technology and organization, as well as economic factors and legal aspects of contracting in construction. In the present investigation, the criteria describing contracts for construction from various perspectives are determined based on the estimates elicited from experts. The weights of nine criteria used in complex evaluation of construction contracts are determined based on the use of the AHP method. The consistency of expert estimates is also assessed. Using multicriteria evaluation methods, construction contracts are compared and the best alternative is determined.

Keywords: contract for construction, multicriteria evaluation, criterion, AHP method, consistency of expert estimates.

1. Introduction

Building management includes drawing up contracts between customers and contractors. Proper contract execution largely determines the economic success of the parties involved, increasing their profit and ensuring them against losses.

Recently, more emphasis has been placed in the literature on the analysis of construction contracts (Belaj, Rajcic 2008; Bockovic 2008; Cheng 2008; East *et al.* 2009; Nemato, Maritz 2007). Bushait and Almohawis (1994) defined eleven qualitative characteristics (e.g. clarity, detailed description, quality, etc.), allowing us to achieve quality formulation of a contract. However, the question of what aspects should be considered in the contract still remains unanswered. Cheung *et al.* (2002) considered the problem of choosing an architect. They stated that cost could not be the only criterion used in choosing an architect. The authors of the present paper made a questionnaire survey which helped them to determine the criteria relevant for choosing an architect and their significances. The procedure of choosing an architect was performed by using the Analytic Hierarchy Process (AHP), a method developed by Saaty (Saaty 1980). Using the model constructed based on the data obtained in the research, a system of choosing an architect was developed. Zavadskas *et al.* (2008b, 2008c), Brauers *et al.* (2008a, 2008b), Ustinovichius *et al.* (2006), Turskis (2008), Kaklauskas *et al.* (2006) considered the problem of choosing the project's supervisor based on a set of criteria. Based on the analysis made, the authors suggest evaluating the contract cost and economic efficiency in terms of quantitative and qualitative characteristics. To achieve this, the use of multicriteria decision-making methods is recommended. However, the above authors consider only major conditions of contract, not discussing some minor factors. However, the latter may strongly affect construction contract execution. When these minor conditions are ignored, the consequences may be the violation of the terms of the contract, delays in performing various works, etc.

Quite a few researchers discuss other problems related to increasing the effectiveness of construction processes (Kaplinski 2008; Rutkauskas *et al.* 2008; Šarka *et al.* 2008; Zavadskas *et al.* 2008d). However, a very important problem associated with the evaluation of contracts for construction has not been thoroughly investigated. Even when the contractor for construction has been chosen and the cost and time of work execution have been agreed upon, the customer may make several versions of contract with the contractor. The choice of the most effective contract alternative is a complicated problem requiring the development of special methods for its solution.

To develop the effective methods of multicriteria evaluation of contracts, a set of criteria describing the construction contracts should be generated, the weights (significances) of these criteria should be determined and the appropriate multicriteria evaluation methods should be chosen and applied.

Mitkus, Trinkūnienė (2006), Trinkūnienė (2006) created the models of construction contract conditions and determined that the model based on the functions associated with contract conditions is most suitable for multicri-

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teria evaluation of construction contracts. In recent years, multicriteria methods have been widely used for evaluation of complex processes (Figueira *et al.* 2005; Ginevicius 2008; Ginevicius, Podvezko 2008c, 2009; Ginevicius *et al.* 2007, 2008a; Banaitienė *et al.* 2008; Kaklauskas *et al.* 2007; Sivilevičius *et al.* 2008; Ustinovichius *et al.* 2007; Zavadskas, Antuchevičienė 2006; Zavadskas, Vaidogas 2008; Zavadskas, Turskis 2008; Zavadskas *et al.* 2008a). For comprehensive evaluation of construction contracts, the criteria used in quantitative multicriteria evaluation should be defined and their weights should be determined. In this work, the criteria weights were determined based on the use of AHP method (Saaty 1980, 2005; Podvezko 2009). The tentative calculations aimed at determining the best construction contract alternative were made, using the construction contract model based on the functions of contract conditions.

2. Generating a set of criteria describing contracts for construction

In the course of construction, a lot of important decisions should be made. At the initial stage, it is necessary to decide which contract variant is the best for the customer as one of the contracting parties.

It should be noted that, making contracts for construction, information technologies are not effectively used. This leads to ineffective use of managers' time and the need for contract makers to apply for legal advice and other specialists' consultation to solve the arising problems.

To assess and compare the alternatives of construction contracts, their structural analysis should be made and the relevant evaluation criteria chosen.

Drawing up contracts for construction has become a complicated process, requiring special skills and knowledge. A well-prepared contract reduces business risk. In the countries observing the legislation of continental Europe, contract for construction is considered to be a specific independent type of contract regulated by the laws stating the demands to it. The same applies to Lithuania, where contracts for construction differ from other contracts. The main difference lies in the fact that, usually, the contractor performs various works at his own risk, determining how to fulfill a task given by the employer. In addition, he performs the works specified in the contract by using his own materials and devices, if not stated otherwise in the contract. The construction contract also differs from others in having great and long-term financial responsibilities. The contents of the contract, including all contract conditions, make one of its major components. Contract conditions define the rights and responsibilities of the parties, i.e. their behaviour. In practice, it is important to accurately define contract conditions because they determine the particular rights and responsibilities under compulsion and their proper implementation. The conditions of contracts for construction may be subdivided into two main groups, depending on the type of contract they belong to. The first group includes contract conditions specific only for construction contracts, while the second group embraces the conditions included in other types of contracts as well. By grouping contract conditions in this way, a set of criteria based on contract conditions' classification into general and special ones is generated. (Trinkūnienė 2006; Mitkus, Trinkūnienė 2006).

In making a contract, the conditions are attached different importance. Lithuanian legislation differentiates between major and minor contract conditions. Taking into account legislative power of contract conditions, a set of criteria based on their essential features was generated (Trinkūnienė 2006; Mitkus, Trinkūnienė 2006).

A system of construction contract conditions may be developed, taking into account the functions (aims) of these conditions. All conditions of construction contracts perform some particular functions. For example, contract conditions regulating guarantees, damages, etc. perform the function of ensuring the meeting of liabilities. All conditions related to this function make one criterion. Thus, a set of criteria based on the functions performed by the conditions was generated (Trinkūnienė 2006, 2007; Mitkus, Trinkūnienė 2007b, 2008). This system is most suitable for developing methods of multicriteria evaluation of contracts for construction. This conclusion may be drawn because experts can easily determine the significance of contract conditions grouped according to the functions performed. Moreover, in this case, the conditions of construction contracts are legally equal irrespective of the group to which they are referred to based on any classification discussed. However, the latter classification reflects the contract and its functions in the best way.

Experts chose nine criteria describing the contents of construction contract in terms of the functions performed by their conditions (Mitkus, Trinkūnienė 2007b, 2008). Such criteria as the cost of construction works and terms of work execution were not included in the analysis because these are the basic conditions of construction contracts, which are necessary and sufficient for making a contract and defining the rights and responsibilities of the parties. Therefore, it makes no sense to assess them in legal terms. The necessity is perceived in the following way: until the parties come to agreement about the key points of the contract, the latter cannot be considered made. If the contract is not made, pre-contract relations are maintained. Sufficiency implies that the parties came to agreement about minor conditions is delayed. If the major conditions are not reflected in the contract, the contract is not valid and, consequently, the parties have no rights and responsibilities. For this reason, experts evaluated minor conditions of construction contract based on their functions.

Minor contract conditions are neither necessary, nor sufficient for the contract. Their presence or absence in the contract has no influence on contract making. If the parties agreed upon all minor conditions, but did not agree upon at least one major condition, the contract cannot be made. There are two main kinds of minor conditions: common and optional conditions.

Common conditions are law-stated conditions which become obligatory for the parties when the contract is made. Then, they automatically become a part of the contract. Common conditions may be defined by the imperative codes, e.g. CK (Civil Code of the Republic of Lithuania) article 6.682 p. 1 . The risk of accidental failure of a building construction or its part, which was not taken over by the customer, is always undertaken by the contractor if it was not caused by the materials, parts or poor quality structures provided by the customer or happened when his order was being performed. The imperative laws are obligatory standards for the parties, who can neither alter nor eliminate them, even if they are not involved in the contract. Contract conditions can also be stated by dispositive legal regulations, e.g. CK article 6.686 , p. 1 states a condition that the contractor should provide structural materials, equipment and other items for construction if the contract does not specify it to be the customer's responsibility.

The gaps in the contract caused by optional conditions may be filled by the court which should explain contract clauses in the case of a dispute. Optional contract conditions are not essential. They are defined not by law, but by the parties themselves. They are not automatically included in the construction contract as common conditions. The absence of these conditions does not make a contract invalid, and they become important only when included in the contract.

3. Characteristics of construction contract criteria

Using expert estimates, the criteria describing the contract for construction were determined as follows:

1) Customer's obligations;
2) Contractor's obligations,
3) The right to change the cost of construction works if it increased by more than 15% due to circumstances beyond the contractor's control;
4) Guarantee;
5) Payment conditions;
6) Subcontracting;
7) Contract insurance;
8) Contract suspension;
9) Contract termination.

The first two conditions – contractor's and customer's obligations are inessential construction contract conditions which show its different character compared to other civil contracts (Mitkus, Trinkūnienė 2007a). These conditions are generally described in Table 1.

The criterion No 3, the right to *demand contract recalculation, if the actual cost of construction increased by more than 15% due to the circumstances beyond the contractor's control.* This is a common dispositive contract condition. The contractor can exercise this right only until the contract has not come into effect and only under the following conditions: when the conditions (e.g. rising of market prices) become known to the contractor after the signing of contract; when the contractor could not predict them, when they are beyond his control; when the contractor did not take the risk of price rising. Only under all these conditions the contractor can apply to the customer for recalculating the contract price. The contractor's application for recalculating the contract price should be well-grounded and submitted as soon as possible.

The criterion No 4 is *warranty.* It includes the warranty's duration, which may be of three kinds:

five years for general works and structures;

ten years for the buried building elements (e.g. structures and pipelines);

twenty years for the cases when a deliberate damage to the buried elements, structures and pipelines was found.

The above periods are calculated from the time of establishing that a building is fit for use, or the warranty period may be extended in the contract for construction by the parties involved. The contractor must ensure that during the warranty period a building should meet the requirements of construction regulations and fit for the intended use. During the warranty period the contractor is responsible for the failure of a building or the detected defects if he cannot prove that they occurred not due to his fault, but because of normal deterioration of the building or its parts, as well as the improper building maintenance or repairs.

The criterion No 5, *payment conditions,* includes payment on account and schedule of payment. The Civil Code does not provide a detailed description of payment, stating only that the customer should pay for the works according to the provisions of the contract. The contract may provide for paying in advance for particular amounts of work or for the accepted work under the condition that the works were performed properly and in time. When the terms of payment, payment on account, etc. are not defined in the contract for construction, it is considered that the customer should pay for the properly completed works after they were taken over by him.

The criterion No 6, subcontract, implies that the contractor himself should perform all the works according to the construction regulations. This legal condition is dispositive. The contractor has the right to employ other people, subcontractors, to perform the work, but only if this right is provided to him by the contract for construction. In this case, the contractor becomes a general contractor. A subcontractor is a person performing part of the work or a person, who is entitled to perform part of the work under the permission of the customer. If the contractor employs subcontractors to execute the contract, violating the law or contract conditions, he is responsible to the customer for losses made by subcontractors doing the contract work.

The criterion No 7 is contract insurance. Contract conditions regulating warranty, guarantee and penalties perform the insurance function, therefore, they refer to criterion No 7. Contract insurance is an optional condition, allowing the creditor to more effectively defend his interests and make the debtor to pay the debt. Both the customer and the contractor can ask the other party to insure the construction contract fulfilment. The contractor is interested in timely payment for the works performed by the customer, while for the customer it is important that the contractor would perform the works properly and in time.

Table 1. Classification of rights and responsibilities of customer and contractor in contract for construction

Contractor's obligations based on the Civil Code of the Republic of Lithuania (2007)	Customer's Obligations based on the Civil Code of the Republic of Lithuania (2007)
The contractor should perform the construction works according to the requirements of building codes and contract documents defining the cost of the construction works and the requirements to their quality (article 6.684, p. 1). Following the requirements of construction regulations in the construction work is the responsibility of contractor irrespective of the fact if they are reflected or not in the contract for construction. This is an imperative provision. However, the parties are free to choose the building codes and regulations of international or European organisations, reflecting this possibility in the contract.	The customer should provide a site for construction. The size and state of the plot should meet the requirements of the contract for construction, allowing the contractor to begin and complete the construction in time. This legal regulation is dispositive, stating a common condition of construction contract. This condition implies that, first, the constructor should either own the plot as his property or use it based on other legal grounds (e.g. lease, sublease, etc.). There is no complete list of the forms of ownership and use of the plot, allowing a person to realize his right to be a constructor.
The contractor performing the construction or other related works should follow the laws and regulations requiring him to take measures for the environment protection and work safety (article 6.692). This is an imperative statement providing a common condition of contract for construction.	Getting permission for construction is an imperative statement in the contract for construction. If a permission has not been obtained, the construction will be considered illegal. However, the customer can arrange the documents for getting the permission for construction himself or commission the contractor or some other person to do this.
Some jobs can be performed only if a person has a legally obtained certificate. This condition refers to contractor because without a certificate he cannot undertake or continue the construction works. The contracting parties should define what kind of certificates the contractor should have to perform the particular construction works.	The customer performs his duties and exercises his rights associated with maintenance and control of construction together with a designer and other persons (e.g. engineer, consultant, technical supervisor, etc.). In this way, with the help of specialists of his own choice, the customer can control project execution and implementation of architectural solutions (article 6.690, p. 1) By exercising this right, the customer has no right to meddle with the commercial and economic activities of the contractor.
The contractor should provide the materials, equipment and other goods for construction unless the construction contract states that it is the responsibility of the customer. This implies that the contractor should provide building products for construction in two cases: • when it is stated in the construction contract; • when the problem of providing the building products is not considered in the contract. It is clear that the parties may agree that a certain part of building products can be provided by the customer, while another part can be supplied by the contractor. This contract condition embraces two obligations: timely supply of quality products.	The contract defines the cases and establishes the order of putting the buildings or equipment at the contractor's disposal, providing freight transportation services, arranging temporary power and water supply systems, getting the required permissions for the contractor to perform certain works and providing some other services specified in the contract (article 6.688, p. 2). This means that the customer has to transfer buildings and equipment to the contractor for use in construction only in the case when it is specified in the contract for construction. If it is not possible to state what the customer should transfer to the contractor based on the contract, it is considered that this condition does not exist.
Article 6.694 states that when the customer takes over a building, the risk of accidental loss or damage goes over to him. It follows that, before handing over the construction, the contractor should take measures to ensure safety of the materials and the construction site, irrespective of the fact if it is provided in the construction contract or not. If the term of handing or taking over the building was missed, the risk goes to the party which missed it. Based on the article 6.686, p. 1, stating a general rule that the contractor provides the materials and plant for construction, if the contract does not state otherwise, it can be affirmed that the risk of accidental loss or damage to materials and other goods is with the contractor in the case when he provides the materials to the construction site.	If construction works were suspended due to circumstances which are beyond the parties' control and the construction was laid up, the customer has to pay for all the works performed before laying up the works, as well as covering the expenses associated with the suspension and laying up of construction, including the benefits obtained (or which could be obtained) by contractor due to suspension of the works. In all cases, this is a responsibility of the contractor.
According to article 13, p. 7 (2007) of the Law on Construction of the Republic of Lithuania, the contractor should take part in establishing the fitness of the building for use. This legal statement is imperative, implying that the contractor has this obligation in both cases, whether it is provided or not provided in the contract. Meanwhile, the customer should arrange the process of establishing the fitness of the completed building for use (tests on completion).	The customer should make the arrangements for establishing the fitness of the completed building for proper use. This is an imperative statement of the law. A building is considered to be fit for use, when all construction works provided for by the building project were performed and design conditions were met. In legislative terms, the construction of a building is the creation of a new thing. If the constructor follows building construction laws and other regulations valid at the time of construction, the construction work is considered to be legal and he acquires the ownership right of the building constructed.
The obligation of the contracting parties to cooperate implies that, if obstacles in implementing the contract for construction occur, any reasonable measures should be taken to eliminate these obstacles. If a party does not perform this function, it is deprived of the right to be indemnified for losses due to not eliminated obstacles.	Take-over of the works is carried out by the customer unless specified otherwise in the contract for construction. The customer should commence the take-over of the works as soon as the contractor declares that he is ready to transfer the completed building to the customer. This condition should be discussed in detail in the contract, indicating within how many days the customer should accept the works after the contractor declared the completion of the works.

The criterion No 8 is *the suspension of contract*. Contract suspension may be considered from two perspectives, depending on which party, the customer or the contractor can use it. Civil Code defines the procedure of contract suspension for all contracts, even when it is not provided for in some of them. If the parties have to fulfill the contract simultaneously, then, each of them has the right to suspend contract execution until the other party begins to fulfill it. Other suspension possibilities may be provided in the contract by the parties. To ensure that the suspension conditions of the contract should take effect, it is recommended to determine within how many days one party would inform the other party of the suspension of the contract. It is also reasonable to define who would pay for the losses experienced because of contract suspension (Mitkus, Trinkūnienė 2007a).

The criterion No 9, *contract termination*, is relevant for any contract. However, it depends on particular building conditions. Therefore, interested parties should define possibilities of contract termination, specifying its causes, time of advance notice and the party paying the expenses associated with contract termination.

Thus, breaking up the contract for construction into particular conditions influencing the construction process, the criteria which could be used in choosing the most favourable alternative of contract for construction (Fig. 1) may be obtained.

To determine the significance of the criteria more objectively, the calculations should be based on expert group estimates. For this purpose, performing the preliminary calculations, a group of experts, including lawyers, builders and VGTU researchers, was made (Trinkūnienė 2006; Mitkus, Trinkūnienė 2008). It has been found that most of the filled in questionnaires do not meet the requirement to expert's concordance coefficient to be smaller than unity. For this reason, ten experts revised the criteria estimates in their questionnaires.

4. Determining significances of construction contract criteria

In practice, a great number of various methods of quantitative evaluation of criteria significances (weights) are used. The methods are considered to be subjective if they are based on expert estimates. They include ranking of criteria, when the most significant criterion is given the highest rank equal to one, the second most important criterion is assigned the rank of 2, etc., while the least significant criterion obtains the value m, where m denotes the number of criteria. Any scale of measurement

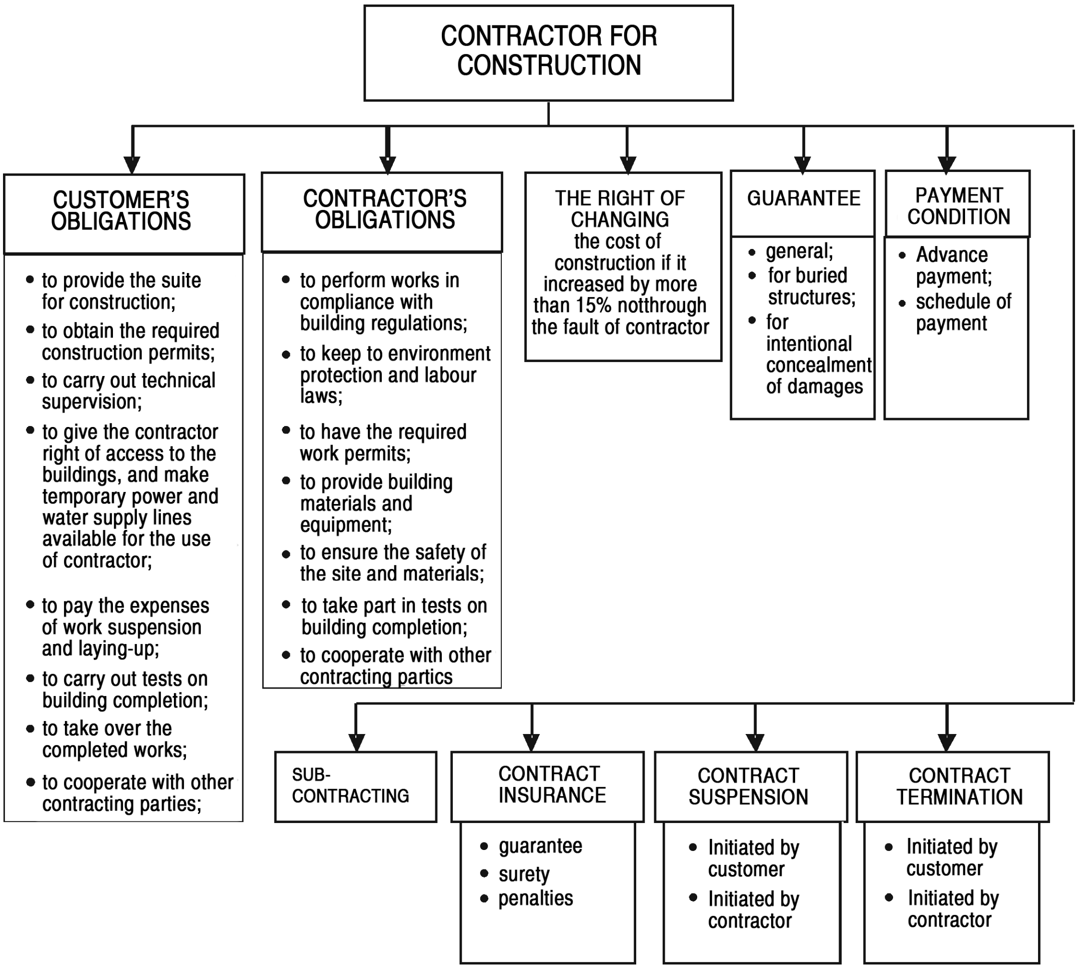

Fig. 1. A model of conditions of contract for construction based on their functions

may be used in evaluation, including units, percentage, fractions of unity, ten-point evaluation system as well as pairwise comparison of criteria, e.g. a popular AHP (Analytic Hierarchy Process) approach (Saaty 1980, 2005).

In this work, AHP approach to determining the criteria weights is used (Saaty 1980). The method is based on the matrix of pairwise comparison (Ginevičius *et al*. 2004):

$$p = \|p_{ij}\| \ (i, j = 1, 2, ..., m).$$

The elements p_{ij} of the matrix P are the relationships between the unknown weights of criteria. Experts compare all the criteria R_i and R_j, to be evaluated against the scale 1–3–5–7–9, $i, j = 1, 2, ..., m$. The elements of the matrix range from 1, if both criteria are of the same importance, to 9, if one criterion is much more important than the other. The matrix P is inversely symmetric, i.e. $p_{ij} = 1/p_{ji}$. It follows that the portion of the matrix above or below the principal diagonal can be filled in.

The weights in Saaty's AHP method – the vector $\boldsymbol{\omega}$ are normalized components of eigenvector corresponding to the largest eigenvalue λ_{max} of the matrix **P**:

$$\mathbf{P}\boldsymbol{\omega} = \lambda_{max}\boldsymbol{\omega}.$$

The concordance (consistency) degree of particular estimates of each expert is determined by the concordance index S_I and concordance ratio S.

The concordance index is defined as the ratio (Saaty 1980):

$$S_I = \frac{\lambda_{max} - m}{m - 1}, \quad (1)$$

where m is the matrix row, the number of the criteria compared.

The smaller the concordance index, the higher the matrix consistency. Ideally, $S_I = 0$.

In practice, the level of consistency of the matrix **P** may be determined if we compare the calculated concordance index S_I in the evaluation matrix with randomly generated (against the scale 1-3-5-7-9) concordance index S_A found in the same row of the inversely symmetric matrix (Saaty 1980). The ratio of the concordance index S_I calculated in a particular matrix to the mean value of the random index S_A is referred to as concordance ratio, assessing the degree of matrix consistency:

$$S = \frac{S_I}{S_A}. \quad (2)$$

The matrix is consistent if the concordance ratio S is smaller than 0.1 (Saaty 1980):

$$S \le 0.1.$$

In the case considered, the level of concordance of the estimates elicited from 10 out of 26 experts was acceptable, implying that the concordance ratio was smaller than 0.1. The comparison matrix of one of the experts is given in Table 2 as an example.

Table 2. Example of pairwise comparison of criteria by an expert

Criterion No	1	2	3	4	5	6	7	8	9
1	1	1/2	3	1/2	1/4	5	1/8	2	1/6
2	2	1	5	1/2	1/3	6	1/3	4	1/6
3	1/3	1/5	1	1/5	1/6	2	1/7	1/2	1/7
4	2	2	5	1	1/3	4	1/2	4	1/6
5	4	3	6	3	1	7	1/2	3	1/2
6	1/5	1/6	1/2	1/4	1/7	1	1/5	1/3	1/8
7	8	3	7	2	2	5	1	5	1/2
8	1/2	1/4	2	1/4	1/3	3	1/5	1	1/4
9	6	6	7	6	2	8	2	4	1

The first expert attaches the highest significance to contract termination, insurance, payment conditions, warranties, i.e. casual conditions found in any type of contract. For this reason, he thinks that these conditions should be corrected according to a particular situation. Lower significances were attached to such criteria as liabilities of customer and contractor, the right of changing the cost of construction if it increased by more than 15% for reasons not dependent on contractor, i.e. to minor ordinary conditions. In expert's opinion, these conditions will be automatically included in the contract, irrespective of the fact whether they were discussed by the parties in the contract or not. A party should only check if these conditions had not been changed to the advantage of the other party. However, it should be noted that some of the above conditions are imperative, implying that the parties cannot change the regulations of the Code by their agreement.

The weights $\boldsymbol{\omega}$ calculated by applying AHP approach are given in Table 3. The largest eigenvalue in the comparison matrix is $\lambda_{max} = 9.435$, the concordance index is $S_I = 0.054$ and the concordance ratio is $S = 0.0375 \le 0.1$. This shows that expert's estimates are consistent.

It is important to determine not only the consistency (concordance) of estimates of every expert, but to establish the level of consistency of the data, elicited from all

Table 3. Weights calculated by an expert using AHP approach

Criterion No	1	2	3	4	5	6	7	8	9
Weights	0.0534	0.0847	0.0247	0.0978	0.1639	0.0204	0.2100	0.0407	0.3045

Table 4. Matrix of criteria ranking

Criterion \ Expert	1	2	3	4	5	6	7	8	9	10	Sum of ranks	Total rank
1	6	4	3	2	1	6	8	3	6	8	47	5
2	5	3	2	1	2	5	3	4	5	5	35	1–2
3	8	2	9	3	6	7	4	8	9	9	65	8
4	4	1	6	7	7	4	2	7	3	1	42	4
5	3	5	8	4	3	2	7	1	2	3	38	3
6	9	6	7	9	9	9	5	9	7	4	74	9
7	2	7	1	8	8	3	9	2	8	7	55	6
8	7	8	4	6	5	8	6	5	4	6	59	7
9	1	9	5	5	4	1	1	6	1	2	35	1–2

experts. If the estimates of the group of experts are consistent, generalized weight values of the criteria may be further used in multicriteria evaluation.

The level of consistency of group evaluation may be determined by the W. Kendall's concordance coefficient (Kendall 1970) ($i=1,2,...,r;\ j=1,2,...,m$), where **r** is the number of experts. To calculate it, the criteria should be ranked as described above with respect to every expert. Equal estimates are given the same rank, i.e. the arithmetic mean of the successive ranks.

Based on the comparison matrix of each expert, AHP determines the criteria weights ω_{ik} , Here, $i=1,2,\dots,m$; $k=1,2,\dots,r$. Based on the weight decrease, the estimates of each expert may be ranked and concordance coefficient calculated (Podvezko 2007). The results of ranking of the criteria e_{ik} are given in Table 4.

To calculate the concordance coefficient W , one should know the sum of ranks of each criterion $e_i = \sum_{k=1}^{r} e_{ik}$ (Table 4, last but one column), the total mean value $\bar{e} = \frac{\sum_{i=1}^{m} e_i}{m}$ and the sum of squares of deviations of e_i values from the total mean $\bar{e} - S = \sum_{i=1}^{m}(e_i - \bar{e})^2$.

The concordance coefficient W is calculated by the formula:

$$W = \frac{12S}{r^2 m(m^2 - 1)}, \tag{3}$$

where m is the number of criteria; r is the number of experts.

The significance of concordance coefficient and the consistency of group evaluation are determined by the criterion χ^2 (Kendall 1970):

$$\chi^2 = Wr(m-1) = \frac{12S}{rm(m-1)}. \tag{4}$$

If χ^2 calculated by formula (4) is larger than the critical χ^2_{kr} obtained from the table of χ^2 distribution with the degree of freedom $\nu = m - 1$ and the significance level α chosen to be about zero, then, the estimates elicited from the experts are considered to be consistent.

In the case considered, when the total mean rank is $\bar{e}$ = 50, the sum of square deviation $\bar{e}_i$ is S = 1574, the concordance coefficient W= 0.262. Although the concordance coefficient is relatively small, the calculated value of χ^2, $\chi^2 = 20.99$, is larger than the critical value χ^2_{kr} =15.51 with the degree of freedom $\nu = 8$ and the significance level $\alpha = 0.05$. Therefore, the estimates of the experts are consistent.

In this case, the criteria weights ω_i are calculated as the arithmetic means of AHP weights of the experts:

$$\omega_i = \frac{\sum_{k=1}^{r} \omega_{ik}}{r}, \tag{5}$$

where ω_{ik} denotes the calculated weights of *i*-th criterion of *k*-th expert.

The calculated weights of all experts are given in Table 5.

5. Assessing the quality of contracts for construction

An expert (representing the customer) evaluated the quality of six contracts for construction in per cent (Table 6) based on nine criteria describing their contents.

Three multicriteria evaluation methods – *VS* (Sum of Ranks), *SAW* (Simple Additive Weighting), *TOPSIS* (Technique for Order Preference by Similarity to an Ideal Solution) are used in this work to assess the quality of contracts for construction.

The criterion V_j of the method *VS* is calculated by the formula (Ginevičius, Podvezko 2008a, 2008b; Podvezko 2008):

$$V_j = \sum_{i=1}^{m} m_{ij}, \tag{6}$$

where m_{ij} is the rank of *i*-th criterion for *j*-th contract $(i = 1, \dots, m;\ j = 1, \dots, n)$; m is the number of criteria, n is the number of contract. The smallest value of V_j is the best.

Table 5. Weights of criteria

Experts \ Criterion	1	2	3	4	5	6	7	8	9
1	0.0534	0.0847	0.0247	0.0978	0.1639	0.0204	0.2100	0.0407	0.3045
2	0.0853	0.1390	0.2232	0.3388	0.0732	0.0483	0.0424	0.0282	0.0215
3	0.1997	0.2090	0.0265	0.0715	0.0327	0.0405	0.2213	0.1000	0.0988
4	0.2572	0.2933	0.1308	0.0375	0.1179	0.0163	0.0219	0.0457	0.0793
5	0.2291	0.2218	0.0685	0.0444	0.1605	0.0193	0.0402	0.1036	0.1125
6	0.0635	0.0942	0.0346	0.1296	0.2047	0.0263	0.1964	0.0318	0.2190
7	0.0380	0.1000	0.0924	0.2936	0.0441	0.0519	0.0302	0.0518	0.2980
8	0.1204	0.1124	0.0273	0.0415	0.2571	0.0190	0.2501	0.1033	0.0688
9	0.0617	0.0725	0.0198	0.1618	0.2130	0.0301	0.0300	0.1264	0.2848
10	0.0357	0.0789	0.0259	0.2532	0.1644	0.1029	0.0372	0.0613	0.2405
Average weight	0.1144	0.1406	0.0674	0.1470	0.1432	0.0375	0.1080	0.0693	0.1728
Rank	5	4	8	2	3	9	6	7	1

Table 6. Expert evaluation of six contracts for construction

Contract \ Criterion	1	2	3	4	5	6	7	8	9
First	37	58	11	57	13	77	24	79	74
Second	60	53	10	52	06	54	40	92	81
Third	30	44	32	10	14	73	28	83	50
Fourth	45	63	14	92	15	63	54	60	55
Fifth	47	50	15	73	10	43	56	92	76
Sixth	28	53	22	95	13	41	46	83	20

The method *SAW* perfectly illustrates the concept underlying multicriteria evaluation methods (Hwang, Yoon 1981; Ginevicius *et al.* 2008b). The criterion S_j of this method is the sum of the weighted criteria values:

$$S_j = \sum_{i=1}^{m} \omega_i \tilde{r}_{ij} , \quad (7)$$

where ω_i is weight of i-th criterion; $\tilde{r}_{ij}$ is normalized i-th criterion's value for j-th contract.

SAW is based on 'traditional' normalization method (Ginevicius, Podvezko 2007):

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}} \quad (8)$$

$$(i = 1, \ \ldots, m; \ j = 1, \ \ldots, n; \ \sum_{j=1}^{n} \tilde{r}_{ij} = 1).$$

The largest value of the criterion S_j is the best.

TOPSIS is based on vector normalization (Hwang, Yoon 1981; Ginevicius *et al*. 2006):

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sqrt{\sum_{j=1}^{n} r_{ij}^2}} \quad (i = 1, \ldots, m; \ j = 1, \ldots, n) . \quad (9)$$

The best alternative V^* and the worst alternative V^- are calculated by the formulas:

$$V^* = \{V_1^*, V_2^*, ..., V_m^*\} = \{(\max_j \omega_i r_{ij} \ / \ i \in I_1), (\min_j \omega_i \tilde{r}_{ij} \ / \ i \in I_2)\},$$

$$V^- = \{V_1^-, V_2^-, ..., V_m^-\} = \{(\min_j \omega_i r_{ij} \ / \ i \in I_1), (\max_j \omega_i \tilde{r}_{ij} \ / \ i \in I_2)\},$$

where I_1 is a set of maximizing criteria, I_2 is a set of minimizing criteria.

General distance of each of the alternatives compared D_j^* to the ideal solutions and D_j^- to the negative ideal solutions is calculated by the formulas:

$$D_j^* = \sqrt{\sum_{i=1}^{m} (\omega_i \tilde{r}_{ij} - V_i^*)^2} , \quad (10)$$

$$D_j^- = \sqrt{\sum_{i=1}^{m} (\omega_i \tilde{r}_{ij} - V_i^-)^2} . \quad (11)$$

The criterion C_j^* of *TOPSIS* is calculated by the formula:

$$C_j^* = \frac{D^-}{D_j^* + D_j^-} \quad (j = 1, 2, ..., n) \quad (12)$$

$$(0 \le C_j^* \le 1) .$$

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

The ranks of particular contracts determined based on particular criteria which were calculated by formula (6) are presented in Table 7.

The second contract was ranked first twice, i.e. based on the criterion 1, customer's obligations and the criterion 9, contract termination. Both these criteria were

Table 7. Ranks of contracts

Criterion \ Contract	1	2	3	4	5	6
1	4	1	5	3	2	6
2	2	3.5	6	1	5	3.5
3	5	6	1	4	3	2
4	4	5	6	2	3	1
5	3.5	6	2	1	5	3.5
6	1	4	2	3	5	6
7	6	4	5	2	1	3
8	5	1.5	3.5	6	1.5	3.5
9	3	1	5	4	2	6
Sum of ranks	33.5	32	35.5	26	27.5	34.5
Rank	4	3	6	1	2	5

Table 8. Results of comparative evaluation of particular contracts by multicriteria methods

Method		1	2	3	4	5	6
SAW	S_j	0.1736	0.1774	0.1633	0.1702	0.1720	0.1437
	Rank	2	1	5	4	3	6
TOPSIS	C_j^*	0.568	0.634	0.490	0.542	0.603	0.321
	Rank	3	1	5	4	2	6
Total rank		2–3	1	5	4	2–3	6

assigned the highest significance by the experts. Therefore, the second contract was the best. The first contract was better than the second according to some other criteria. However, according to the criterion 9, contract termination, which was assigned the highest significance, it was ranked third, though with respect to criterion 6, subcontract, having the lowest significance, it was ranked first. This fact was decisive in determining that the second construction contract was worse than the first contract.

The method *VS* is not accurate: the criterion of the method V_j does not depend on the criteria weights ω_i. Therefore, the multicriteria evaluation methods SAW and TOPSIS were used for quantitative contract evaluation.

The results of multicriteria evaluation of particular contracts by formulas (7)–(12) are given in Table 8.

Based on the data presented in Table 8, a number of conclusions can be drawn. The results obtained by using various multicriteria evaluation methods differ insignificantly. The calculations show that the contracts ranked may be divided into three equivalent groups. The first group includes the best (second) contract. The second group embraces contracts, 1 and 5 while the third group includes all other contracts (3, 4 and 6).

6. Conclusions

Three sets of criteria may be used to describe contracts for construction: the criteria based on the contents of contract conditions, those based on general or special type of conditions and a set of criteria based on the functions associated with particular conditions. It has been found that a set of criteria based on the functions associated with particular conditions is best suited for developing methods of construction contract evaluation. These criteria may be used to determine the significance of contract conditions, which, in turn, helps to create a legislative on-line decision support system for contracts for construction.

The significances (weights) of construction contract criteria were determined by using AHP (Analytic Hierarchical Process). This approach is grounded in mathematical theory and may be used for solving the problems which are difficult to define. Human experience and intuition are better suited for the solution of such problems. The estimates obtained by using AHP are easy to interpret, as well as allowing us to choose the most effective contract alternative.

Quantitative evaluation of six various contracts was performed using multicriteria methods *SAW* and *TOPSIS*. The calculations performed show that the contracts ranked may be divided into three equivalent groups. The first group consists of the best (second) contract, the second group includes contracts 1 and 5, while the third one embraces the remaining contracts (3, 4 and 6).

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KOMPLEKSINIS STATYBOS RANGOS SUTARČIŲ VERTINIMAS

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Santrauka

Didelę reikšmę statybos proceso efektyvumui turi tinkamas statybos rangos sutarties sudarymas. Siekiant sudaryti efektyvias statybos rangos sutartis, reikia sukurti rangos sutarčių įvertinimo ir palyginimo metodikas. Pastaruoju metu sudėtingiems procesams vertinti plačiai taikomi daugiakriteriniai vertinimo metodai. Jų vertinimas priklauso nuo rodiklių, charakterizuojančių procesą, ir jų reikšmingumo. Siekiant parengti statybos vertinimo metodikas, reikia išnagrinėti ne tik techninius, organizacinius, ekonominius, bet ir teisinius statybos rangos sutarties aspektus. Taikant ekspertų vertinimus, buvo nustatyti rodikliai, charakterizuojantys statybos rangos sutarties turinį. Kompleksiškai įvertinant statybos rangos sutartis AHP metodu nustatyti devynių rodiklių svoriai, įvertintas ekspertų nuomonių suderinamumas. Taikant daugiakriterinius metodus tarpusavyje palygintos statybos rangos sutartys ir nustatytas geriausias variantas.

Reikšminiai žodžiai: statybos ranga, daugiakriterinis vertinimas, rodiklis, AHP metodas, ekspertų vertinimas, suderinamumas.

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