MULTICRITERIA VERBAL ANALYSIS FOR THE DECISION OF CONSTRUCTION PROBLEMS

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Abstract. The paper aims to analyse the construction contracts and to determine their effectiveness by verbal methods. Contractors of international construction projects are often faced with complicated situations working in the conditions of uncertainty in construction. One of the potential risk factors is associated with the requirements of contract conditions. A simple quantitative method for evaluating the requirements defined in specifications of the contract is presented. One of the major aspects is project or contract management. Project developers need various models of managing large and complex projects. The suggested method for evaluating contract effectiveness may be widely applied at one of the stages of project management. A case study of practical use of verbal methods is presented.

Keywords: verbal decision analysis, expert system, decision-making, multi-criteria choice problem, criteria preference-independence, consistency control.

1. Introduction

The solution of construction problems often requires the analysis of the available alternatives under uncertainty conditions (Peldschus and Zavadskas 2005; Zavadskas and Turskis 2008; Turskis *et al.* 2009). This particularly applies to the solution of organizational and management problems in construction. The quality of management largely depends on the effectiveness of contract making (Mitkus and Trinkūnienė 2007, 2008; Keršulienė 2007; Brauers *et al.* 2008a,

b; Banaitienė *et al.* 2008). Therefore, the authors of the present paper illustrate the application of verbal analysis to the selection of the effective construction contract.

The problems associated with construction contracts are widely discussed in the scientific literature. Construction sustainability performance is indispensable to the attainment of sustainable development (Zavadskas and Vilutienė 2006; Zavadskas and Antuchevicienė 2006; Zavadskas *et al.* 2006, 2007, 2008a, d, e; Viteikienė and Zavadskas 2007; Ginevičius *et al.* 2007, 2008; Ginevičius and Podvezko 2008; Ugwu *et al.* 2006; Kaklauskas *et al.* 2006, 2007a, b). Various techniques and management skills have previously been developed to help improving sustainable performance from implementing construction projects. However, these techniques seem not being effectively implemented due to the fragmentation and poor coordination among various construction participants. In one of the papers (Shen *et al.* 2007; Paulauskas and Paulauskas 2008) a framework of sustainability performance checklist is developed to help understanding the major factors affecting a project sustainability performance across its life cycle. This framework enables all project parties to assess the project sustainability performance in a consistent and holistic way, thus improving the cooperation among all parties to attain satisfactory project sustainability performance.

The authors (Turskis 2008; Mitkus and Trinkūnienė 2007, 2008; Zavadskas *et al.* 2008b, c) analyse the standards and conditions of contracts which are of special importance in making contracts in the construction industry in European countries. They focuse on the need for project managers to review their strategies against possible commercial developments over the expected project lifetime. The new-style ICE contract may provide flexibility, clarity, simplicity and an emphasis on good project management.

Contractors of international construction projects are often faced with the situation of uncertainty working in the field of construction (Bubshait and Almohawis 1994; Luce and Raiffa 1989; Keršulienė 2007; Shevchenko *et al.* 2008). The specifications of contracts and their requirements make a potential source of risk. The paper presents a simple quantitative method for evaluating technical specifications of a construction contract. This method is based on 11 attributes, including clarity, conciseness, completeness, internal and external consistency, practicality, fairness, effect on quality, cost, schedule, and safety. This procedure can also be used to assess the risk level associated with contract conditions.

Contractual relationships are mainly based on confrontational situations (Zaghloul and Hartman 2003; Keršulienė 2007) that reflect the level of trust (or mistrust) in the contract documents. This determines the relationships among contractors. This paper presents some of the results of a survey conducted across the Canadian and North American construction industry. It should be obvious that trust and constructing methods are related and this relationship is of vital importance to effective project management and contract administration. Trust relationship between the contracting parties provides some opportunities for developing a better risk allocation mechanism and contracting strategies, as well as for significant saving in the annual bill for construction.

The papers (Chen and Shr 2003; Ustinovichius *et al.* 2006; Ustinovichius *et al.* 2008b; Ustinovichius and Kochin 2003; Vaidogas 2007) discuss methods for determining contract price and risks. However, an algorithm for cost estimation is not provided there. An emphasis is placed on the standard requirements to cost estimation in getting the insurance policy from an insurance company.

Project management embraces the development of contract to be signed by employer and one or more contractors. Economic success of both parties largely depends on the contract developed, which also determines the behaviour of managers seeking to increase profit and protect themselves from losses (Branconi and Loch 2004). Taking into account the significance of contract, top managers of both parties should be involved in contract development and negotiation. However, in the literature on the problem, contract is considered to be a technical aspect of project development, which should be a responsibility of project managers and lawyers. In the paper considered, 8 key criteria of contract evaluation to be analysed by top managers in developing contracts for large projects are described. Thus, top managers developing contract conditions should pay special attention to these 8 criteria.

The need for various management models is increasing among project managers. Some authors believe that in developing project management methods the investigation of both project success and critical success factors should be made.

2. Structuring the problem

At the stage of structuring, the DM should state the selection problem in a natural language in terms of the respective problem area. The alternatives available for selection should be listed, the evaluation criteria determined, and verbal scales of evaluation, based on each criterion, should be defined. A set of alternatives for selecting the best of them will be denoted by A.

The DM determines the characteristics of the alternatives to be used as the criteria of evaluation. Let us denote a set of the criteria $C = \left\{C^1, ..., C^k\right\}$, $K = \left\{1, ...k\right\}$ as a set of the criteria numbers. The criteria may be both quantitative and qualitative (verbal).

The estimate of the alternative $a \in A$, based on the criterion C^j, will be denoted by $C^j(a)$. The scale of evaluation $S^j = \left\{s_1^j, s_2^j, ..., s_{m_j}^j\right\}$, $j \in K$, associated with a particular criterion, is not specified beforehand, but is formed based on the estimates of all actual alternatives according to a particular criterion $S^j = \bigcup_{a \in A} C^j(a)$. In this approach, the preliminary arrangement of the estimates on the criterion scales is not required. Various combinations of estimates make a k-dimensional space, which is, in fact, the Cartesian product of the criterion scales $S = \prod_{j=1}^{k} S^j$. Each alternative $a \in A$ corresponds to a vector estimate (tuple) $C(a) = (C^1(a), C^2(a), ..., C^k(a)$, consisting of the alternative estimates $C^j(a)$ based on the criteria $C^1, ..., C^k$. Let us denote by A a set $\{C(a) | a \in A\}$ of vector estimates of the real alternatives from the set A. It is evident that $A \subseteq S$.

Thus, at this stage of problem structuring, sets of alternatives A and criteria C, as well as scales of criteria S^j and vector estimates A are determined. The task is to elicit a subset of the best alternatives, based on the DM preferences.

2.1. Formalizing the DM preferences

Let us introduce an additional space of vector estimates, which will be required later for developing the procedures of eliciting the DM preferences. Let us also extend the scale of each

criterion S^j by introducing a fictitious estimate $\omega^j : Q^j = S^j \cup \{\omega^j\}$. Then, a set of various vector estimates, including the fictitious ones, may be described by the Cartesian product of the new criterion scales $Q = \prod_{j \in K} Q^j$, similar to the set $S = \prod_{j \in K} Q^j$.

Let us consider a particular vector estimate $x \in Q$ and a subset of the numbers of the criteria $J \subseteq K$. Let us denote by x^j a vector estimate, whose j-th component is equal to the j-th component of the vector estimate x, if $j \in J$, and is equal to ω^j if $x \in K \backslash J$. A vector estimate, whose all but one estimates are fictitious, will be referred to as one-criterion estimate. If 2 estimates are real, the vector estimate will be referred to as a two-criterion estimate, etc.

A description of the DM preferences is based on binary relations P and I defined on the set of vector estimates Q:

$(x,y) \in P$ if x is more preferable y,

$(x,y) \in I$ if x and y are equally preferable,

and the resulting binary relation is $R = P \cup I$.

In this case, for any pair of vector estimates (x,y), making a binary relation P or I, the statement is valid that if the j-th component of one of them is equal to the fictitious estimate ω^j, the j-th component of the other vector estimate is also equal to ω^j.

It is believed that the binary relations P, I and K have the following properties:

P rigorous partial order (irreflexively and transitively),

I equivalence (reflexively, symmetrically and transitively),

R quasi-order (transitively, reflexively),

$$P \cap I = \varnothing \; ; \; R = P \cup I. \tag{1}$$

In addition to the above properties, it will be assumed that the criteria are interindependent in preference.

2.2. Eliciting the DM preferences

Special procedures have been developed for eliciting the DM preferences.

The DM compares the vector estimates of the form x^J and y^J, where $J = \{j_1, j_2, ..., j_s\} \subseteq K$, presented in 2 rows of the table, containing only real estimates $x^{j_1}, ..., x^{j_s}$ and $y^{j_1}, ..., y^{j_s}$ (Table 1). The columns are called the same as the respective criteria. The estimates based on other criteria with the numbers $K \backslash J$ are assumed to be arbitrary and pairwise equal. The result of the comparison is introduced into the binary relation $\tilde{P}$ or $\tilde{I}$ as a pair of vector estimates (x^j, y^j) (or (y^j, x^j), if y^j is more preferable than x^j).

Table 1. The comparison of vector estimates x^j and y^j

C^{j_1}	C^{j_2}	...	C^{j_s}
x^{j_1}	x^{j_2}	...	x^{j_s}
y^{j_1}	y^{j_2}	...	y^{j_s}

The eliciting of preferences begins with the comparison of one-criterion vector estimates. The DM makes a pairwise comparison of the estimates on the scale of each criterion. As a result, the estimates based on each particular criterion are arranged in the order of the DM preferences. Unlike other methods, where the order on the criterion scale is predefined at the stage of structuring, in the case of using the method UniComBOS, the criterion scales are arranged, when one criterion vector estimates are compared. If the scale of some particular j-th criterion has m_j estimates, $m_j(m_j-1)/2$ comparisons will be made with respect to this criterion.

Then, a pairwise comparison of 2, 3 (and more) criteria vector estimates is made. The number of the criteria with real estimates is increased only if the problem cannot be solved with the available number of criteria. A special optimization procedure is used for searching for a pair of vector estimates presented to the DM. It is based on the prediction model, allowing the judgements given by the DM in the process of comparing the vector estimates to be predicted. The above optimization procedure used at this stage of eliciting the DM preferences yields pairs of vector estimates and the order of their comparison by a decision-making person.

The DM preferences elicited in every operation of pairwise comparison of vector estimates (including one-criterion ones) are checked for agreement (consistency), and an attempt is made to determine a subset of the best alternatives. If a disagreement is observed, its cause is determined and eliminated. This is made by showing the DM his/her previous estimates and their logical consequences. The DM may indicate the wrong answer or disagree with some intermediate result. In the first case, the DM corrects his/her estimate. In the second case, the hypothesis about the independence of the criteria of preference and/or transitivity is violated. Therefore, the DM may require problem restructuring. If a disagreement is observed, its cause is determined and eliminated. This is made by showing the DM his/her previous estimates and their logical consequences. The DM may indicate the wrong answer or disagree with some intermediate result. In the first case, the DM corrects his/her estimate. In the second case, the hypothesis about the independence of the criteria of preference and/or transitivity is violated. Therefore, the DM may require problem restructuring. If any disagreement has not been found or has been already eliminated, and a subset of the best alternatives has been determined, this subset is presented to the DM, and the procedure of eliciting the preferences is completed. In comparing arbitrary vector estimates, the derivation of the formulas in the logic of the 1st-order predicates by means of the rule of derivation – modus ponens is performed.

In the method UniComBOS, an individual mechanism of controlling the reliability of information about the comparisons of vector estimates is offered for each criterion. The number of criteria is being increased until the proportion of the DM estimates leading to disagreement exceeds the specified threshold value or the set of the best alternatives is determined. A large number of contradictory judgements exceeding the threshold value elicited from the DM indicates that a comparison of the vector estimates based on the given number of criteria is too difficult for the DM. Therefore, further increase of the criteria number will make the information obtained unreliable.

In Fig. 1, a diagram of the procedure used for structuring the problem of determining the subset of the best alternatives and the procedure of eliciting the DM preferences is given.
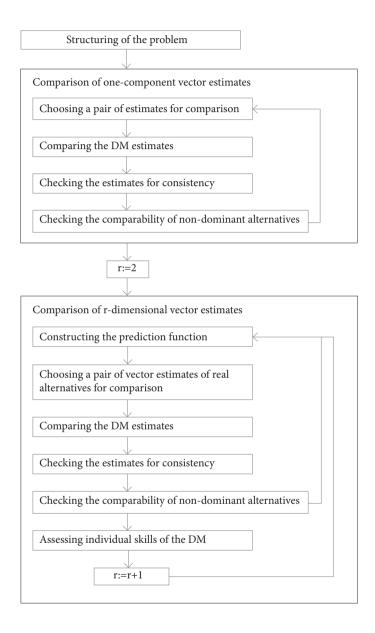

Fig. 1. A diagram of the procedure for eliciting the DM preferences

3. The analysis of construction contracts

Based on the analysis of the available engineering contracts and practical experience, the key criteria for economic evaluation of a business deal may be identified. These are the parameters to be clearly defined in contract. They should reflect the main conditions of the contract (e.g. technical specifications and warranties, cost, schedule of payment, etc.) and define general obligations and responsibilities of the parties involved (securities, damage claims and liability limits, etc.).

A brief description of each set of evaluation criteria is presented in Table 2. The key issues to be included in the contract are defined in this table. Then, every set of criteria will be described in detail. Risk assessment should include 8 evaluation criteria for major projects exposed to higher risks. Highly risky projects should be considered more carefully. Risky projects may be classified (through risk identification and evaluation), depending on the relevant criteria.

Contract definitions are: specifications, project price (quality of cost estimates), work schedule, terms and conditions of payment, performance guarantees (for defects), warranties, liability limits, securities.

The evaluation criteria are associated with Williamson's transaction costs theory extended by Jarillo, Stinchcombe and Heimer. The present investigation is based on Jarillo's concepts of 'classic market' and 'strategic network' of partners. The latter, however, requires the continuous collaboration and relationships. Usually, projects do not meet these conditions because the collaboration is over when the project is completed and is not likely to be continued in the future.

Table 2. Major contract provisions and their effect on contract management

Criteria	The effect of contract form on management	
	Positive	Negative
Specifications	Concentrated on key criteria	Too detailed
Price	Reasonable	Not beneficial for contractor
Terms of payment	Favourable for contractor	Unfavourable for contractor
Schedule	Rational delay time	High coverage of losses
Performance guarantees	Concentrated on key criteria	Too detailed
Warranties	Rather limited	All including
Liability	Not high with respect to contract price	High with respect to contract price
Securities	Not broad with respect to contract price	Broad with respect to contract price

Jarillo and Stinchcombe and Heimer further developed Williamson's theory of transaction costs by considering varying requirements (i.e. of the clients or regulations), instability of expenses (i.e. cost factors or technical defects) and the control problems of contract execu-

tion. To solve these problems, the authors suggest that some 'hierarchical' elements, relating to a key management structure, dispute settlements and standard management procedures, incentives, etc. be included in contracts.

It can be shown that well-known procedures and methods improve the standards, dispute settlements and management of contracts. However, the evaluation criteria may differ, depending on a particular project.

The experience of the authors of the present research shows that a set of properly selected project evaluation criteria can help avoid strong negative effects of the most critical factors in 80% of cases. If some actions or procedures do not satisfy the above-mentioned criteria, it may greatly affect project execution, which in this case can hardly be successful. However, if some other requirements are not satisfied, the project is not likely to fail. Therefore, it may be recommended to managers to pay a special attention to the described issues.

3.1. Description of the economic impact on the contract deal

General conditions include adequate and complete description of work, when technical and commercial aspects are balanced. The client defines the work to be done under project which actually determines its long-term profit.

Price (cost estimates) embraces such issues as price stability and the assessment of expenses. In fact, price should be in agreement with the standards required by technical specifications, including the stability of expenses. The client should avoid offering the lowest bid in all cases.

Terms of payment define a schedule of partial pay determining how ready cash, obtained by the contractor, covers the expenses in the course of project execution.

Schedule fixes the dates of feasible work completion (especially in the middle and the end of the process), which should not be altered. The influence of the expenses caused by delays on the levels of liquidated damages is also described.

Guarantees of project execution refer to satisfying the requirements to plant performance according to specified technological parameters. The conditions of satisfying these technological requirements and those for the levels of liquidated damages in the case of deviation from the specified parameters are defined.

Warranties (warranty period) define payments for defect remedying or replacement of faulty equipment. Compensation for unsatisfactory services may also be provided.

Liability limit defines the highest limit of contractor's liability. Liquidated damages levels and warranties protect the employer, while contract liability limit protects the contractor.

Insurance (deposits, securities, bonds, etc.) determines how the contractor guarantees project execution to the employer and how the employer ensures payment for the contractor's work.

Six key levers (evaluation criteria) make a basis for performing these procedures. The contract defines the behaviour of the contracting parties because, first, the project does not provide for continuous relationships which could discipline people. Second, the turnover of employees is a common practice. Therefore, the contract defines the scope of work as well as standards of behaviour and trust in others as well as project execution. The validity, realism,

completeness and coherence of a business venture are the main features evoking confidence and contributing to success of the project.

3.2. Evaluation criteria and contract form selection

Let us consider how 3 main types of contract including fixed price, cost reimbursable and mixed contracts may be evaluated by the suggested criteria. According to *LSTK* (*Lump sum turn key*), all objectives may be incorporated in a single contract with the highest risk and liabilities allocation and minimized number of interfaces.

All *EPCM* contracts are complicated, with the risk of subcontractor not defined. Due to irregular supply, some technological lines cannot be installed. Only highly experienced contractors can avoid these problems. Since the risks of subcontractor are not defined in *EPCM* contract, the value of some *LSTK* contracts is decreased by about 20–30%. *EPCM* contract becomes very complicated when signed directly by. Besides, multiple interfaces may cause misunderstandings. Due to irregular supply, some technological lines cannot be installed. Only highly experienced contractors can avoid these problems.

LSTK contracts are not so complex because of a smaller number of interfaces. This allows for parallel consideration, negotiations and decision-making. The limits of the project under *LSTK* contract are clearly defined. When the project is very substantial, multilateral contracts are unavoidable.

Some additional hierarchical contract issues include:

a) contract efficiency factors. These are regulatory and financial conditions ensuring project finance when the work is commenced by the contractor;

b) taking over a building on completion of construction. The conditions of taking over the responsibility for the completed project by the employer and dismissal of the contractor;

c) insurance. This concerns the external risks and liability of the 3rd party;

d) the right of the 3rd party for intellectual property. It is a definition of risks associated with the 3rd party patents and their violation;

e) events of force majors. Liabilities in the case of events beyond a party's control, i.e. war, disasters, natural calamities, etc. are described;

f) duration of work. Cost reimbursement after the completion of project suitable for the client;

g) taxes. Allocation of tax and legislative risks;

h) applicable law. Knowledge of legislative aspects of contract coming into force;

i) dispute resolution/arbitration. Dispute settlement by various mechanisms including more drastic measures (after a certain period of time).

4. Practice of DSS UniComBOS for determining the effectiveness of construction contracts

Strategic economic and political decision-making and research planning are referred to non-structured problems. Since the essential characteristics of such problems are qualitative, they can hardly be used in the analysis. On the other hand, the quantitative models are not sufficiently reliable.

Non-structured problems have the following common characteristics. They are unique decision-making problems, i.e. every time a decision-maker is faced with an unknown problem or the one having new features compared with the previously considered case. These problems are associated with the uncertainty of the alternatives to be evaluated, caused by the lack of information for making a decision. The evaluation of the alternatives is of qualitative nature, being usually expressed verbally (in statements). Very often, experts cannot measure qualitative variables against an absolute scale, where the level of quality does not depend on the alternatives (Ustinovichius 2004; Ustinovichius *et al.* 2008a; Ustinovichius *et al.* 2007a; Ustinovichius *et al.* 2007b). When the uncertainty is high, experts can only compare the alternatives qualitatively, based on particular criteria. Experts first use the extended verbal evaluation, making then the comparisons in terms of 'better-worse'; 'nearly equal'.

The following aspects of behaviour are evaluated by verbal methods of decision-making (Korhonen *et al.* 1997; Larichev 1992; Furems and Gnedenko 1992; Ларичев 2000; Ларичев, Мошкович 1996; Асанов *et al.* 2001; Arditi and Gunaydin 1998; Srinivasan and Shocker 1973):

– Qualitative measurements allow for an adequate description of an unstructured problem.
– Formulation of final decision-making rules according to data processing principles of humans and allow for explaining the methods psychologically.
– The procedures used to screen the conflicting data ensure the reliability of the information obtained, allowing a DM to formulate the final rules.

The suggested method is needed to arrange a number of alternatives according to the DM preferences. First, the preferences are stated based on qualitative parameters and then a logical scheme for comparing the alternatives is developed. The criteria are considered against the scales with the estimates expressed verbally by statements. A survey may be conducted to elicit the DM preferences and to eliminate the dependence of the criteria. Some special procedures are suggested to identify and eliminate the criteria dependence, which makes the use of the obtained information more effective.

To evaluate the effectiveness of construction contracts, a classification consisting of evaluation criteria and final decisions should be developed. For this purpose, the data from Table 2 (i.e. major goals of a business deal and their influence on the forms of contract) are applied to the model of the first *FIDIC* construction investment project. A verbal decision support system UniComBOS (Ashikhmin *et al.* 2003) is taken from the Internet: <http://iva.isa.ru>.

In determining the effectiveness of construction contracts, the following factors are taken into consideration: technical specifications, costs, terms of payment, performance guarantees, insurance costs and liability limit.

Every criterion is assigned an estimate, e.g. large, average and small. Entering the estimates, a matrix (3×7) is constructed and the evaluation Table 3 is obtained. When all the criteria are entered, the contracts of 3 various forms will be evaluated.

The comparisons are made in the following way: the system displays 2 alternative sets of estimates upon some criteria and a DM gives his/her preferences between these sets. The system allows 4 variants to be considered.

Table 3. Available contract alternatives

Alternatives (A)	Criteria (C)						
	Technical specifications	Price of estimates	Terms of payment	Schedule	Performance guarantees	Warranties	Limit of liability
	1	2	3	4	5	6	7
Fixed-price contract	Highest consistency	Suitable for contractor	Fixed in advance	Rational delay time	Very important	High	High
Incentive contract	Well defined	Suitable for contractor	Not fixed	Rational delay time	Important	Interme-diate	Interme-diate
EPCM	Not defined clearly	Not suitable for contractor	Not fixed	Inadmissible delay time	Important	Low	Low

A comparison of construction contracts of 3 forms by the DSS UniComBOS yielded the results (Fig. 2), according to which the second form of contract (incentive contract) was found to be better than the first one (fixed price contract), while the alternative No. 3 (cost reimbursable contract) was rated third.
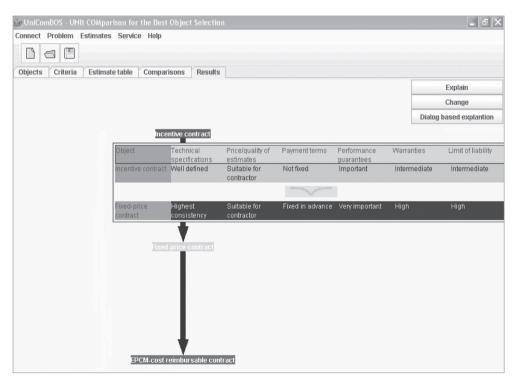

Fig. 2. Results of comparative assessment of alternatives

5. Conclusions

Ample literature on project management has been reviewed. However, scarce data on the key issues to be incorporated in the contracts of major engineering projects have been found. Six key criteria for contract evaluation have been developed based on the analysis of engineering projects performed by the largest international enterprises. They include technical specifications, price (precise cost estimates), terms of payment, performance guarantees, insurance costs and liability limits. The logic clarity and fairness of these factors help determine project performance, providing the basis for a well-managed project.

The analysis has shown that LSTK (*Lump sum turn key*) concept gives the priority to responsibility and the reduced number of interfaces. Therefore, according to the suggested evaluation criteria, this type of contract is most suitable in the construction industry.

DSS UniComBOS is designed to discrete multi-criteria choice problems on the base of a DM's preferences. The correctness of procedure implemented in it for preference elicitation has been proved with psychological studies. The Rule of combining relations has good resolution, thus it is possible to choose the only best alternative in most cases. Qualitative information on preferences of each participant allows obtaining elements of their opinion uniformity.

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STATYBOS UŽDAVINIŲ SPRENDIMŲ ANALIZĖ DAUGIATIKSLIU VERBALINIU METODU

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Santrauka

Siekiama išanalizuoti statybos sutartis ir nustatyti jų efektyvumą daugiatiksliu verbaliniu metodu. Tarptautiniuose statybos projektuose rangovai dažnai susiduria su sudėtingomis situacijomis ir darbo sąlygų neapibrėžtumais. Tai yra pagrindinis rizikos veiksnys sudarant statybos rangos sutartis. Pateiktas metodas įvertina sutarties specifikacijų reikalavimus. Vienas iš svarbiausių aspektų yra projekto ar sutarties valdymas, todėl projekto valdytojams reikalingi įvairūs modeliai dideliems ir sudėtingiems projektas kontroliuoti. Siūlomas sutarties efektyvumo įvertinimo metodas gali būti plačiai taikomas visam projektui ar atskirai jo daliai. Straipsnyje yra pateiktas pavyzdys taikant daugiatikslį verbalinį metodą.

Reikšminiai žodžiai: verbalinės analizės metodai, ekspertinės sistemos, sprendimų priėmimas, daugelio kriterijų pasirinkimo problema, kriterijų pirmenybės nepriklausomybės, kontrolės nuoseklumas.

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