



Jolanta TAMOŠAITIENĖ

**THE MULTI-ATTRIBUTE ASSESSMENT
OF MANAGEMENT DECISIONS AT THE STAGE
OF CONSTRUCTION PLANNING**

**Summary of Doctoral Dissertation
Technological Sciences, Civil Engineering (02T)**

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Jolanta TAMOŠAITIENĖ

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Scientific Supervisor

Prof Dr Habil Edmundas Kazimieras ZAVADSKAS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T).

The dissertation is being defended at the Council of Scientific Field of Civil Engineering at Vilnius Gediminas Technical University:

Chairman

Prof Dr Povilas VAINIŪNAS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T).

Members:

Assoc Prof Dr Rasa APANAVIČIENĖ (Kaunas University of Technology, Technological Sciences, Civil Engineering – 02T),

Prof Dr Habil Henrikas PRANEVIČIUS (Kaunas University of Technology, Technological Sciences, Informatics Engineering – 07T),

Prof Dr Habil Henrikas SIVILEVIČIUS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T),

Assoc Prof Dr Antanas ŠAPALAS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T).

Opponents:

Prof Dr Dalė DZEMYDIENĖ (Mykolas Romeris University, Technological Sciences, Informatics Engineering – 07T),

Dr Jonas ŠAPARAUSKAS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T).

The dissertation will be defended at the public meeting of the Council of Scientific Field of Civil Engineering in the Senate Hall of Vilnius Gediminas Technical University at 10 a. m. on 19 June 2009.

Address: Saulėtekio al. 11, LT-10223 Vilnius, Lithuania.

Tel.: +370 5 274 4952, +370 5 274 4956; fax +370 5 270 0112;

e-mail: doktor@adm.vgtu.lt

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Jolanta TAMOŠAITIENĖ

DAUGIATIKSLIS VALDYMO SPRENDIMŲ VERTINIMAS STATYBOS PLANAVIMO ETAPE

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Mokslinis vadovas

prof. habil. dr. Edmundas Kazimieras ZAVADSKAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T).

Disertacija ginama Vilniaus Gedimino technikos universiteto Statybos inžinerijos mokslo krypties taryboje:

Pirmininkas

prof. dr. Povilas VAINIŪNAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T).

Nariai:

doc. dr. Rasa APANAVIČIENĖ (Kauno technologijos universitetas, technologijos mokslai, technologijos mokslai, statybos inžinerija – 02T),

prof. habil. dr. Henrikas PRANEVIČIUS (Kauno technologijos universitetas, technologijos mokslai, informatikos inžinerija – 07T),

prof. habil. dr. Henrikas SIVILEVIČIUS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T),

doc. dr. Antanas ŠAPALAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T).

Oponentai:

prof. dr. Dalė DZEMYDIENĖ (Mykolo Romerio universitetas, technologijos mokslai, informatikos inžinerija – 07T),

dr. Jonas ŠAPARAUSKAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T).

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Adresas: Saulėtekio al. 11, LT-10223 Vilnius, Lietuva.

Tel.: (8 5) 274 4952, (8 5) 274 4956; faksas (8 5) 270 0112;

el. paštas doktor@adm.vgtu.lt

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General characteristic of the dissertation

Topicality of the problem

In the last decade construction was one of the most important industrial branches. The quality of building highly depends on rational selection of a construction process, planning and management. Today, the creation of mathematical models for management decisions, in order to get the best economic rates becomes the background of rational construction. Modeling is especially important, because every construction is unique due to its processes and different conditions. Such models are especially necessary for engineers, planners, organizers and different managers, especially for those, who have never met similar situations. The paper is meant for theoretical modeling of construction processes and their application in the assessment of construction management decisions at the stage of construction planning. The basis and models that are analyzed in the dissertation can easily be applied in other building's lifetime stages. Only successful cooperation between building existence process interest groups can ensure smooth construction planning process and projects management. Otherwise, construction management process is not smooth; there are many unnecessary, construction process disturbing arguments, work is procrastinated. Such management process may cause inefficient decision taking, defects, as well as huge financial and moral damage. Interest groups' concerns about management, technical or other decision taking at the planning stage are not clearly defined, and the information is not completely detailed and is at some different intervals.

Aim and tasks of the work

To prepare rational, based on multi-attribute assessment methods with index meanings, determined by interval, management decisions taking model that can be used at the stage of construction planning.

According to the interval system theory, to create a new multi-attribute assessment method COPRAS-G, that is applied to solve the tasks with index meanings, defined by intervals.

The aim of the work to be reached, the following tasks need to be solved:

1. To analyze, survey and create tasks models for the most important construction process management tasks that are solved at the stage of planning.
2. To distinguish the possibilities of the interval system theory and apply index meanings determined by the interval for multi-attribute assessment methods TOPSIS and COPRAS.

3. To create a new multi-attribute assessment method COPRAS-G with index meanings, determined by interval.
4. To check the efficiency of the methods in management solutions making process at the stage of the process planning using traditional multi-attribute assessment methods TOPSIS, COPRAS, created COPRAS-G and new TOPSIS “grey” with index meanings, determined by interval, and Game Theory rules.

Scientific novelty

Preparing the dissertation the following results that are new to the science of construction engineering were gained:

1. Research shows, that the topic of construction process has not been deeply surveyed in scientific literature.
2. There are given management solutions so that to assess the indetermination of the information using interval system theory.
3. In the dissertation there have been used traditional models for taking management decisions: TOPSIS, COPRAS multi-attribute assessment methods and the Game Theory. It was recommended to solve construction process management tasks using a new TOPSIS “grey” method and created multi-attribute assessment COPRAS-G method, the indeterminacy of index meanings expressing with intervals.

Methodology of the research

Carrying out the research there were used interval system methods theory, multi-attribute assessment methods, the Game Theory, synthesis, comparison of results, modeling and expert assessment.

Practical value

The task models of construction process management can be used at the decision making stage in the construction process. Traditional multi-attribute assessment methods TOPSIS, COPRAS, created COPRAS-G and new TOPSIS „grey“ methods can be used in different construction planning and other processes at the stage of construction planning. The Game Theory can be applied to strategic tasks.

Defended propositions

1. Multi-attribute management decisions assessment at the stage of construction planning.

2. Using traditional multi-attribute assessment methods TOPSIS, COPRAS, created COPRAS-G and new TOPSIS „grey“ methods decision taking while solving tasks with values determined by the intervals at the stage of construction planning.

The scope of the scientific work

The volume of the research is 164 pages including appendixes. In the text there are used 59 numerated formulas, 50 pictures and 30 tables. Writing dissertation there were used 241 sources of literature. The dissertation is composed of the introduction, five chapters and the summary of results.

In the introductory chapter there are discussed the actuality of the problem, the aim and tasks formulated, novelty described, the author's reports presented and the structure of the dissertation.

The first chapter gives the survey of the literature and have been of the construction management problems that are being solved.

The second chapter gives traditional, new and created multi-attribute assessment methods derivation algorithms and mathematical description.

The third, fourth and fifth chapters present the solution of management tasks at the stage of construction planning. Third chapter analyzes construction objects risk evaluation; the fourth – the choice of a construction contractor and projects' manager, as well as contractor's risk assessment; the fifth chapter gives of the assessment of planned technical and construction building solutions.

1. Management decision at the stage of construction planning

Building construction as a system is described as adjusted complex of elements, having particular to processes characteristics which are not inherent to single elements. The systems can be called dynamic because they consist of a variety of different system. Dynamic systems capable of expedient working self regulated. The system of construction consists of the building and process management:

1. Building is the product of construction process, having its particular characteristics;
2. Process management – particular works in order to achieve the result – the erected building.

The general task in project management is showed in Fig. 1.

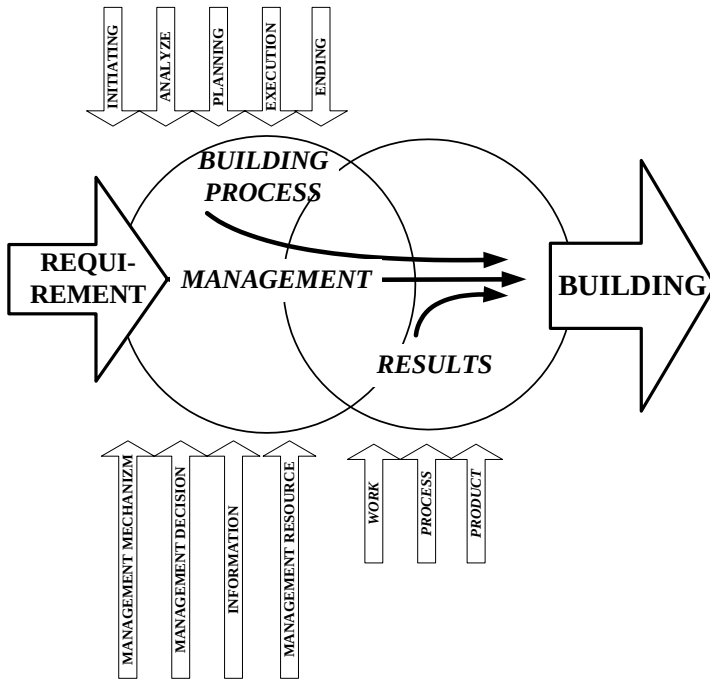


Fig. 1. Resulting process

Planning is a continuous process performed in order to find the best sequence of activities, the best measures and means suitable to solve problems of construction processes. The means for achievement the result are determined by planning. This process involves the whole construction of the building – from initiation to maintenance. Its aim is to provide the sequence of the main activities and works complex, to schedule, to count the demand of essential resources as well as to forecast general value of the building. The tasks solved in the planning process, distinguished in literature, are shown in Fig. 2.

Planning in construction process provides such advantages:

- Minimizes the risk;
- Forms the clear understanding of the tasks;
- Establishes standards of processes performance;
- Composes the sequence of works;
- Provides the relevant procedures of control;
- Provides the minimum time and least attempt to the best results.

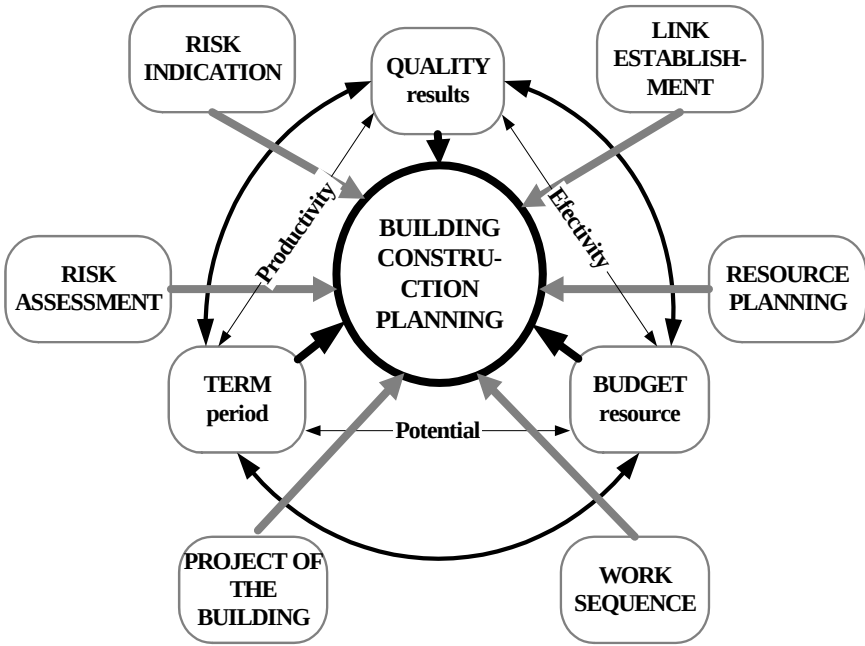


Fig. 2. The main tasks of building construction planning

2. Traditional and proposed multi-attribute decision methods

Multi-attribute analysis is a useful tool in many economic, managerial, and constructional problems. The accuracy of performance measures in COPRAS (The multiple criteria COmplex PROportional ASsessment of alternatives) method is usually assumed to be accurate.

This method assumes direct and proportional dependence precise on the weight and utility degree of investigated versions on a system of attributes adequately describing the alternatives and on value and weight of the attributes. However, there is usually some uncertainty involved in all multi-attribute model inputs. The objective of this research is to demonstrate how simulation can be used to reflect fuzzy inputs, which allows more complete interpretation of the model results.

In 1982, Deng developed the Grey system theory. In 1988, Deng presented grey decision-making systems.

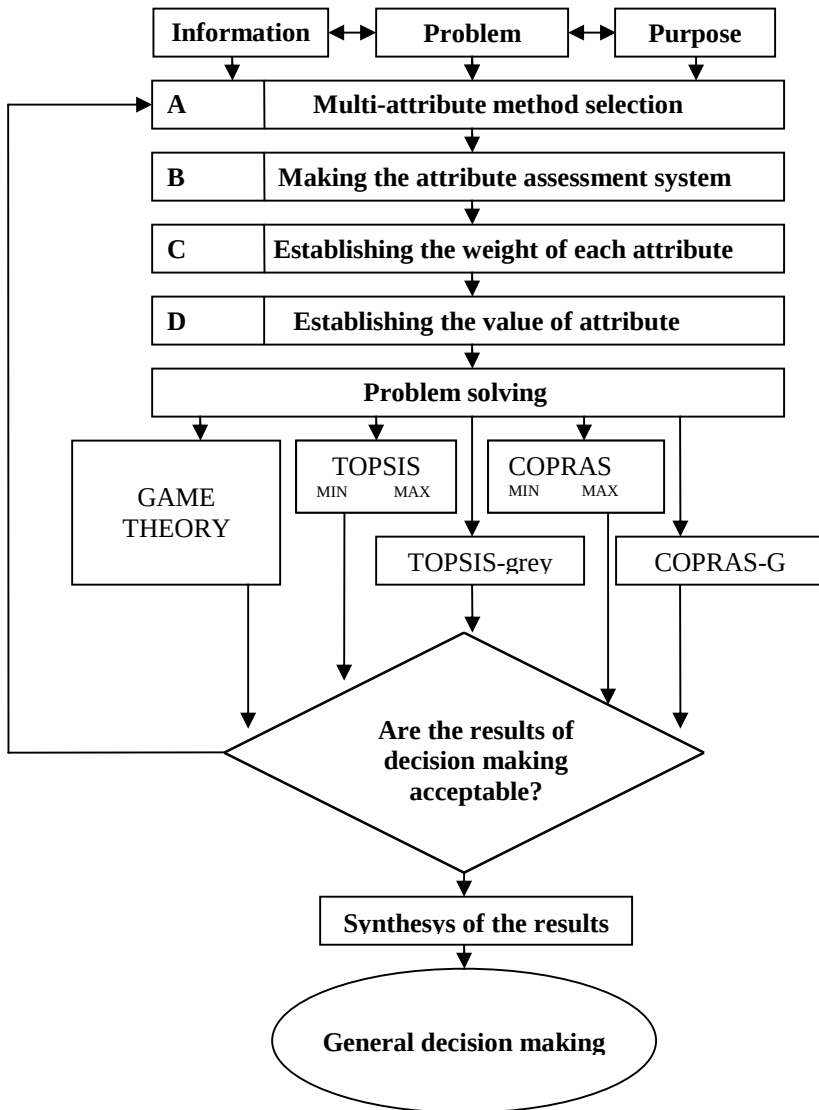


Fig. 3. Ranking of alternatives by applying Multi-attribute decison method

According to Deng, the Grey relational analysis has some advantages: it involves simple calculations and requires a smaller number of samples; a

typical distribution of samples is not needed; the quantified outcomes from the Grey relational grade do not result in contradictory conclusions to qualitative analysis; the Grey relational grade model is a transfer functional model that is effective in dealing with discrete data. In 2008 E. K. Zavadskas with co-authors developed the COPRAS-G method.

TOPSIS is a multi-attribute method to identify solutions from a finite set of alternatives based upon simultaneous minimization of distance from an ideal point and maximization of distance from a negative ideal point. TOPSIS can incorporate relative weights of attributes. The TOPSIS method was developed by Hwang and Yoon (1981). The only subjective input needed is weights. Lin *et al.* (2008) applied TOPSIS grey method with attribute values determined at intervals.

The model of problem solution is presented in Fig. 3. The problem has been assessed by this model. In this case, the results have been gained by the average, Copeland and Borda methods.

3. The main problems assessed in the dissertation

The risk factor in construction business is very high. Construction objects are unique and built only once. The life cycle of construction objects is full of various risks. The risks come from many aspects: temporary project team composed from different companies, places. Moreover, the size and complexity of construction objects are increasing which increases the risks. This is in addition to the political, economic, social conditions where the object is to be undertaken. Object risk can be defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective, such as time, cost and quality. The risks have been shown to cause cost and time overruns in construction projects. Risk management is about defining sources of uncertainty (risk identification), estimating the consequences of uncertain events/conditions (risk analysis), generating response strategies in the light of expected outcomes and finally, based on the feedback received on actual outcomes and risks emerged, carrying out identification, analysis and response generation steps repetitively throughout the life cycle of a object to ensure that the project objectives are met. In the future the multi-attribute modeling of multi-alternative assessment problems with some attribute values, must be expressed in intervals. The research results show the different risks level in construction objects. The results of problem solution showed, that in construction process of construction objects, object risk is more important than internal and external risk.

In competitive and risky environment selection contractors of must be performed according to multiple attributes. The application of the model offered in this paper may reduce the risk involved in the selection of a contractor and can lead to the elimination of unqualified contractors during the bidding process. The selection of contractor can be in different risk level. Hodges-Lehman rule allows stakeholders to select contractor taking into account different risk level.

There are a number of attribute and associated sub-criteria influencing the selection of managers to construction projects. Attribute and sub-attribute were identified based on a thorough review of the related literature and interviews of management personnel involved in the selection of project managers. Project managers' characteristics are considered to be less important for effective project management. The model is based on multi-criteria evaluation of project managers. The evaluation embraces the identified attribute influencing the process of construction project manager selection. In this model, the parameters of the alternatives are determined by the grey relation grade and expressed in intervals. A case study presents the selection of construction project manager. The results obtained show that this method may be used as an effective decision aid in multi-attribute selection.

In the future the decision-making in practice and other planning decisions in construction might be assessed by expressing the attribute values at intervals.

4. General conclusions

1. During scientific research there was settled that the most important stage from all stages of construction decision making is the planning of construction processes. The aim should be achieved by making the decision systems of task models. It has been established, that construction task models assess the alternatives in macro-, mezzo- and microenvironment. The sum of the results of effective decisions is the constructed building. The decisions made in construction planning stage during the time give the results. There were chosen the traditional methods TOPSIS and COPRAS to tackle the management tasks. The systems of attributes were designed for these tasks.

2. The research indicates that there are made various decisions in the processes of construction, management and others and its background is the information. Depending on the construction stage, it is necessary a different amount of information is necessary for decision making. Many decisions are made with not comprehensive data in the stage of construction planning. The values of the attribute in this construction stage are determined in a certain interval. In real life multi-attribute modelling of multi-alternative assessment

problems some attribute values, which deals with the future, must be expressed in intervals. For this reason new method of multi-attribute *Complex Proportional Assessment* method with values determined in intervals – COPRAS-G is developed. This approach is intended to support the decision making process and increase the efficiency of the resolution process.

3. After survey there were concluded that for management problems and for planning of construction processes could be applied the system theory at intervals. Regarding this research multi-attribute method COPRAS-G was created together with co-authors authors.

4. It has been estimated, that the risk of construction processes are twice as important as the outside one and 1.7 times as important as the inside risk. The group of risk indicators of the processes by significance might be ranked the following: price, quality and time. The main decision in construction planning stage is the selection of contractor and sub-contractor. There was created the technique of contractors' risk assessment, used to estimate and evaluate the risky contractors' decisions. The results gained from multi-attribute methods COPRAS-G and TOPSIS "grey" were 5-17 % different, than the one gained using the traditional TOPSIS and COPRAS methods.

5. Contractor selection task can be applied to select alternatives in construction under risky environment. The research has concluded that the COPRAS-G method is appropriate to use. The chapter 4 illustrates the selection of contractors and project manager and the problems solved using the multi-attribute methods. The results of applying COPRAS-G method for the problem of contractor and project manager selection were in 2-21 % different the from one gained using the traditional COPRAS methods.

6. There was created a model for the selection of external walls construction. In applying this model of construction selection the contracting authority is able to assess technical characteristics of the building, in this case – external walls constructions. A case study of an assessment of external walls consisting of four alternatives was used to demonstrate the applicability and the effectiveness of the proposed approach. The results of the calculations with COPRAS-G method indicate that the best external walls are made from silicate brick masonry with masonry outer finishing layer. The results show that this COPRAS-G method can be implemented as an effective decision aid in multi-attribute selection.

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About the author

Jolanta Tamošaitienė was born in Vilnius, on 9 of August 1977.

First degree in Civil Engineering, Faculty of Civil Engineering, Vilnius Gediminas Technical University, 2000. Master of Science in Civil Engineering, Faculty of Civil Engineering, Vilnius Gediminas Technical University, 2002. At 2000 she held managerial positions in construction enterprises subdivision. At 2004 head of a part of design of an exceptional significance construction works and head of supervision of the implementation of a part of the design documentation of an exceptional significance construction works. In 2004–2009 – PhD student of Vilnius Gediminas Technical University. At present, she is a Dean assistant in the Civil Engineering Faculty and assistant of the Dept. of Construction Technology and Management of Vilnius Gediminas Technical University.

DAUGIATIKSLIS VALDYMO SPRENDIMŲ VERTINIMAS STATYBOS PLANAVIMO ETAPE

Mokslo problemos aktualumas

Viena iš svarbiausių paskutinio dešimtmečio pramonės šakų – statyba. Racionalus statybos proceso parinkimas, planavimas ir valdymas lemia tai, koks bus pastatas sukurtas. Valdymo sprendimų matematinių modelių sukūrimas, siekiant gauti geriausius ekonominius rodiklius, šiuo metu tampa racionalios statybos pagrindu. Modeliavimas ypač svarbus, nes kiekviena statyba unikali, dėl statybos procesų ir sąlygų unikalumo. Tokie modeliai labai reikalingi inžinieriams, planuotojams, organizatoriams ir įvairaus lygio vadovams, o ypač tiems, kurie nėra anksčiau susidūrę su analogiškėmis situacijomis. Darbas skirtas teoriniam statybos procesų modeliavimui ir jo taikymui statybos valdymo sprendimams vertinti statybos planavimo etape. Disertacijoje nagrinėjami pagrindai ir modeliai gali būti sėkmingai pritaikyti ir kituose pastato gyvavimo proceso etapuose. Tik sėkmingai bendradarbiaujant pastato gyvavimo proceso suinteresuotoms grupėms galima kalbėti apie sklandų statybos planavimo procesą ir projektų vykdymą. Priešingu atveju statybos valdymo procesas yra nesklandus, kyla daug nereikalingų, trikdančių statybos procesą ginčų, darbai užsitiesia. Toks valdymo procesas gali būti neefektyvių sprendimų priėmimo, defektų, o kartu ir didžiulių finansinių bei moralinių nuostolių priežastis.

Suinteresuotų grupių interesai, priimant valdymo, techninius ar kito pobūdžio sprendimus planavimo etape yra neraiškiai apibrėžti, o turima informacija nėra iki galo tiksli ir yra tam tikruose skirtinguose intervaluose.

Darbo tikslas ir uždaviniai

Parengti racionalų, pagrįstą daugiatikslio vertinimo metodais su rodiklių reikšmėmis, apibrėžtomis intervalu, valdymo sprendimų priėmimo modelį, naudotiną statybos planavimo etape.

Remiantis intervalų sistemų teorija, sukurti naują daugiatikslio vertinimo metodą COPRAS-G, pritaikytą uždaviniams spręsti su rodiklių reikšmėmis, apibrėžiamomis intervalu.

Darbo tikslui pasiekti reikia išspręsti šiuos uždavinius:

1. Išanalizuoti, apžvelgti ir sudaryti uždavinių modelius svarbiausiems statybos procesų valdymo uždaviniams, sprendžiamiems planavimo etape.

2. Ištirti intervalų sistemų teorijos galimybes ir pritaikyti rodiklių reikšmes apibrėžiamas intervalu daugiatikslio vertinimo metodams TOPSIS ir COPRAS.
3. Sukurti naują daugiatikslio vertinimo metodą COPRAS-G su rodiklių reikšmėmis, apibrėžiamomis intervalu.
4. Remiantis tradiciniais daugiatikslio vertinimo metodais TOPSIS, COPRAS, sukurtu COPRAS-G ir nauju TOPSIS „grey“ su rodiklių reikšmėmis, apibrėžiamomis intervalu, lošimų teorijos taisyklėmis patikrinti metodų veiksmingumą, priimant valdymo sprendimus statybos procesų planavimo etape.

Mokslinis naujumas

Rengiant disertaciją buvo gauti šie statybos inžinerijos mokslui nauji rezultatai:

1. Tyrimai rodo, kad mokslinėje literatūroje statybos procesų tema nagrinėjama gana siaurai įsigilinant į kiekvieną atvejų sprendžiamą siaurą problemą. Tačiau statybos procesų tema nenagrinėjama kompleksiskai, sprendžiant statybos procesų valdymo uždavinius.

2. Disertacijoje pateikiami priimamų valdymo sprendimų modeliai įvertinantys informacijos neapibrėžtumą su rodiklių reikšmėmis apibrėžtomis intervalu.

3. Pasiūlyta statybos procesų uždavinius spręsti nauju daugiatikslio vertinimo TOPSIS „grey“ ir sukurtu daugiatikslio vertinimo COPRAS-G metodu, intervalų sistemų teorijos rodiklių neapibrėžtumą išreiškiant intervalu. Disertacijoje pateikiami valdymo sprendimų priėmimui naudojami tradiciniai TOPSIS, COPRAS, sukurti ir nauji daugiatikslio vertinimo metodai ir lošimų teorija.

Tyrimų metodika

Atliekant tyrimus disertacijoje taikoma intervalų sistemų teorija, lošimų teorija ir daugiatikslio vertinimo metodai, sintezė, rezultatų palyginimas, modeliavimas ir ekspertinis vertinimas.

Praktinė vertė

Statybos procesų valdymo uždaviniai modeliai gali būti taikomi sprendimų priėmimui statybos planavimo etape. Tradiciniai daugiatikslio vertinimo

metodai TOPSIS, COPRAS, sukurtas COPRAS-G ir naujas TOPSIS „grey“ gali būti naudojami įvairiems, statybos valdymo ir kt. uždaviniams spręsti planavimo etape. Strateginiams uždaviniams taikytina lošimų teorija.

Ginamieji teiginiai

1. Daugiatikslis valdymo sprendimų vertinimas statybos planavimo etape.
2. Tradiciniais daugiatikslio vertinimo metodais TOPSIS, COPRAS, sukurtu COPRAS-G ir nauju TOPSIS „grey“ sprendimų priėmimas sprendžiant uždavinius su rodiklių reikšmėmis apibrėžiamomis intervalu statybos planavimo etape.

Darbo apimtis

Darbo apimtis – 164 puslapiai, įskaitant priedus. Tekste panaudotos 59 numeruotos formulės, 50 paveikslų ir 30 lentelių. Rašant disertaciją buvo naudotasi 241 literatūros šaltinis.

Disertaciją sudaro įvadas, penki skyriai ir rezultatų apibendrinimas.

Įvadiniame skyriuje nagrinėjamas problemos aktualumas, formuluojamas darbo tikslas bei uždaviniai, aprašomas mokslinis darbo naujumas, pristatomi autorės pranešimai ir publikacijos disertacijos struktūra.

Pirmajame skyriuje pateikta literatūros ir statybos valdymo sprendžiamų problemų apžvalga. Skyriaus pabaigoje formuluojamos išvados ir konkretinami disertacijos uždaviniai.

Antrajame skyriuje pateikti tradicinių daugiatikslų vertinimo metodų TOPSIS ir COPRAS, naujo TOPSIS „grey“ bei sukurto COPRAS-G daugiatikslio vertinimo metodų sprendimo algoritmai bei matematiniai aprašymai.

Trečiajame, ketvirtame, penktajame skyriuose pateikti išspręsti valdymo uždaviniai statybos planavimo etape. Trečiajame nagrinėjamas statybos objektų rizikos įvertinimas; ketvirtajame – statybos rangovo, statybos projektų vadovo parinkimas, rangovo rizikos įvertinimas; penktajame – planuojamų pastatų techninių, konstrukcinių sprendimų vertinimas.

Bendrosios išvados

1. Atlikus mokslinius tyrimus nustatyta, kad iš visų statybos sprendimų priėmimo etapų svarbiausias – statybos procesų planavimo etapas. Tikslu turi būti siekiama sudarius uždavinių modelių sprendimų sistemas. Nustatyta, kad

statybos uždavinių modeliai, vertinantys alternatyvas, turi būti sudaromi makro-, mezo- ir mikroaplinkose. Priimtų sprendimų rezultatų visuma – pastatytas pastatas. Statybos planavimo etape numatomi sprendimai, įgyvendinami per tam tikrą laiką, tampa rezultatais. Valdymo uždaviniams spręsti pasirinkti tradiciniai daigiatikslio vertinimo metodai TOPSIS ir COPRAS. Uždaviniams spręsti sudarytos rodiklių sistemos.

2. Atlikti moksliniai tyrimai rodo, kad statybos, valdymo ir kituose su statyba susijusiuose procesuose priimami sprendimai, kurių pagrindas – informacija. Nustatyta, kad priklausomai nuo statybos etapo, sprendimams reikalingas skirtingas informacijos kiekis. Nustatyta, kad statybos planavimo etape daugelis sprendimų priimami turint neišsamią informaciją. Šiame statybos proceso etape rodiklių reikšmės apibrėžiamos tam tikrame intervale. Intervalo reikšmė tiesiogiai priklauso nuo tiriamo rodiklio ir sprendžiamo uždavinio pobūdžio.

3. Nustatyta, kad valdymo uždaviniams spręsti, statybos procesams planuoti gali būti taikoma intervalų sistemų teorija. Remiantis tyrimais autorė kartu su bendrautoriais sukūrė daigiatikslio vertinimo metodą COPRAS-G.

4. Nustatyta, kad statybos procesų rizika statybos objektuose yra 2 kartus svarbesnė nei išorinė ir 1,7 karto svarbesnė nei vidinė. Procesų rizikos rodiklių grupės pagal svarbą gali būti surikiuotos taip: kaina, kokybė, laikas. Statybos procesų vidaus rizikai vertinti rizikingiausias statybos dalyvių vertinimas. Sudarytas rangovų rizikos vertinimo modelis planavimo etape rizikingiems rangovų pasiūlymams nustatyti ir įvertinti. Vertinant riziką daigiatikslio vertinimo metodais COPRAS-G ir TOPSIS „grey“ gauti rizikos vertinimo rezultatai skiriasi 5–17 proc. nei vertinant tradiciniais daigiatikslio vertinimo TOPSIS ir COPRAS metodais.

5. Daigiatikslio vertinimo metodai COPRAS ir COPRAS-G gali būti taikomi suinteresuotų grupių sprendimams. Pastato statybos planavimo etape svarbiausias sprendimas – rangovo ar subrangovo parinkimas. Taikant sukurta COPRAS-G metodą statybos objekto rangovo ir projektų vadovo parinkimo uždaviniams spręsti gauti rezultatai skiriasi 2–21 proc. nuo skaičiavimų tradiciniu daigiatikslio vertinimo metodu COPRAS.

6. Sudarytas daigiatikslio vertinimo modelis išorės sienų atitvarinėms konstrukcijoms parinkti. Taikydamas pastato konstrukcijų parinkimo modelį, užsakovas gali vertinti technines būsimo pastato charakteristikas, šiuo atveju būsimo pastato išorės sienų atitvarines konstrukcijas. Skaičiavimų rezultatai COPRAS-G metodu rodo, kad laikančiosios išorės sienos iš lengvo, jo porėtojo betono blokų, apšiltintos putų polistirenu ir apdailintos plonasluoksniu tinku, yra geriausios iš įvertintų sienų konstrukcijų alternatyvų.

Trumpos žinios apie autorių

Jolanta Tamošaitienė gimė 1977 m. rugpjūčio 9 d. Vilniuje.

2000 m. įgijo statybos inžinerijos bakalauro laipsnį Vilniaus Gedimino technikos universiteto Statybos inžinerijos fakultete. 2002 m. įgijo statybos inžinerijos mokslo magistro laipsnį Vilniaus Gedimino technikos universiteto Statybos inžinerijos fakultete. Nuo 2000 dirbo statybos įmonių gamybos padaliniuose. Nuo 2004 atestuota statinio projekto dalies ir statinio projekto vykdymo priežiūros vadove. 2004–2009 m. – Vilniaus Gedimino technikos universiteto doktorantė. Šiuo metu J.Tamošaitienė dirba VGTU statybos fakulteto dekanu padėjėja, eina statybos technologijos ir vadybos katedroje asistento pareigas.

Padėka

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Jolanta TAMOŠAITIENĖ

THE MULTI-ATTRIBUTE ASSESSMENT
OF MANAGEMENT DECISIONS AT
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Summary of Doctoral Dissertation
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DAUGIATIKSLIS VALDYMO SPRENDIMŲ
VERTINIMAS STATYBOS PLANAVIMO ETAPE

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Spausdino UAB „Biznio mašinų kompanija“,
J. Jasinskio g. 16A, 01112 Vilnius