



Andrius GULBINAS

**MULTIPLE CRITERIA WEB-BASED DECISION
SUPPORT SYSTEM FOR REFURBISHMENT OF
PUBLIC BUILDINGS**

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

1208

Vilnius  **2005**

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Andrius GULBINAS

**MULTIPLE CRITERIA WEB-BASED DECISION
SUPPORT SYSTEM FOR REFURBISHMENT OF
PUBLIC BUILDINGS**

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

Vilnius  2005

Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2001 – 2005.

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 Habil Gintaris KAKLAUSKAS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T)

Members:

Prof Dr Habil Vytautas STANKEVIČIUS (Kaunas University of Technology, Technological Sciences, Civil Engineering – 02T)

Assoc Prof Dr Habil Leonas USTINOVIČIUS (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T)

Assoc Prof Dr Dalė DZEMYDIENĖ (Mykolas Romeris University, Physical Sciences, Informatics – 09P)

Dr Nerija BANAITIENĖ (Vilnius Gediminas Technical University, Technological Sciences, Civil Engineering – 02T)

Opponents:

Prof Dr Habil Genadijus KULVIETIS (Vilnius Gediminas Technical University, Technological Sciences, Informatics Engineering – 07T)

Prof Dr Arvydas JUODIS (Kaunas University of Technology, 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 11 a.m. on 22 December 2005.

Address: Saulėtekio al. 11, LT-10223 Vilnius-40, Lithuania

Tel.: +370 5 274 49 52, +370 5 274 49 56; fax +370 5 270 01 12;

e-mail doktor@adm.vtu.lt

The summary of the doctoral dissertation was distributed on 22 November 2005

A copy of the doctoral dissertation is available for review at the Library of Vilnius Gediminas Technical University (Saulėtekio al. 14, Vilnius, Lithuania).

© Andrius Gulbinas, 2005

VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Andrius GULBINAS

**VISUOMENINIŲ PASTATŲ RENOVACIJOS
DAUGIAKRITERINĖ INTERNETINĖ SPRENDIMŲ
PARAMOS SISTEMA**

Daktaro disertacijos santrauka
Technologijos mokslai, statybos inžinerija (02T)

Vilnius  2005

Disertacija rengta 2001–2005 metais Vilniaus Gedimino technikos universitete.

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. habil. dr. Gintaris KAKLAUSKAS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T),

Nariai:

prof. habil. dr. Vytautas STANKEVIČIUS (Kauno technologijos universitetas, technologijos mokslai, statybos inžinerija – 02T),

doc. habil. dr. Leonas USTINOVIČIUS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, statybos inžinerija – 02T),

doc. dr. Dalė DZEMYDIENĖ (Mykolo Romerio universitetas, fiziniai mokslai, informatika – 09P),

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

Oponentai:

prof. habil. dr. Genadijus KULVIETIS (Vilniaus Gedimino technikos universitetas, technologijos mokslai, informatikos inžinerija – 07T),

prof. dr. Arvydas JUODIS (Kauno technologijos universitetas, technologijos mokslai, statybos inžinerija – 02T).

Disertacija bus ginama viešame Statybos inžinerijos mokslo krypties tarybos posėdyje 2005 m. gruodžio mėn. 22 d. 11 val. Vilniaus Gedimino technikos universiteto senato posėdžių salėje.

Adresas: Saulėtekio al. 11, LT-10223 Vilnius-40, Lietuva

Tel.: +370 5 274 49 52, +370 5 274 49 56; faksas +370 5 270 01 12;

el. paštas doktor@adm.vtu.lt

Disertacijos santrauka išsiuntinėta 2005 m. lapkričio 22 d.

Disertaciją galima peržiūrėti Vilniaus Gedimino technikos universiteto bibliotekoje (Saulėtekio al. 14, Vilnius, Lietuva).

VGTU leidyklos „Technika“ 1208 mokslo literatūros knyga

© Andrius Gulbinas, 2005

Relevance of the research

Lithuania has been experiencing sweeping reforms in the construction sector for more than one decade already just as the other Central European countries. Fast development of the cities has created conditions for review of already implemented projects, which need to be changed and reconstructed under current circumstances. The process includes not only the construction of new residential, commercial or public objects in a historically set environment, but also the refurbishment of old buildings. Most of such buildings are depreciated and do not satisfy the requirements of modern designing and construction in Lithuania.

The stock of the Lithuanian public buildings is considerably young compared to the average data from Western Europe. However, buildings constructed later than 1970 are of worse quality than the buildings constructed previously. One more trend characteristic of the latter decade is “overdue maintenance of buildings“. Economic decline during the transition period aggravated the situation and the quality of public buildings deteriorated more. Currently, there are many public buildings in poor or very poor technical conditions in Lithuania. Therefore, the refurbishment of buildings and energy saving seem to be one of the key problems in the developed and East and Central Europe countries (including Lithuania). The most part of energy resources brought to Lithuania is used for heating.

The constant rise of maintenance costs for buildings requires effective, simple and cheap solutions for buildings’ refurbishment. Modernization of heating systems, heat insulation for walls and roofs, replacement of windows and doors are listed among the most efficient measures. It is also very important to be aware of the fact that the proposed energy saving measures give the planned effect and that real energy saving corresponds to the projected.

On the other hand, it is important to understand that the refurbishment of buildings can not only reduce energy consumption but can improve the state of a building in general: its maintenance, sound insulation properties, appearance, comfort, lifecycle of the building and also an increased value of the building. Investments may be divided into those of energy saving and technical maintenance respectfully. The results of monitoring of buildings show that about 84% of investments are in energy savings, and 16% go to the technical refurbishment of a building.

The selection of the refurbishment variant mostly depends on needs and the financial state of landlords and organizations working in it, on government policy (tax exemptions, subsidies, easy credits), on the level of

physical and moral deterioration of a building, on legal environment, etc.

The research object

The research object integrates the refurbishment process of public buildings, participating interest groups with specific goals and the external micro and macro environment.

Aim and objectives of the research

The aim of the dissertation is to improve the efficiency of the refurbishment process of public buildings by using methods of multiple criteria analysis, the developed model for integrated analysis of the lifecycle of a public building, the model for integrated analysis of the negotiations process for refurbishment of buildings and the Multiple Criteria Decision Support System for Refurbishment of Public Buildings developed on the basis of these models. The following objectives are selected to achieve the aim:

- To review research studies of scientists from various countries in the sphere of integrated analysis of the lifecycle of public buildings' refurbishment.
- To create an original model for integrated analysis of the lifecycle of a public building.
- To implement in practice the model for integrated analysis of the lifecycle of a public building.
- To determine an efficient process of refurbishment of public buildings, when a number of various building's components participate in the process and thousands of alternatives are available.
- To describe the refurbishment process of public buildings, the participating interests groups and the environment affecting the project in quantitative and conceptual forms.
- To develop a system of criteria which describes alternatives for refurbishment of public buildings and their components at length.
- To create the Multiple Criteria Decision Support System for Refurbishment of Public Buildings.
- To create a unique model for integrated analysis of the negotiations process for refurbishment of public buildings and integrate the model into the Multiple Criteria Decision Support System for Refurbishment of Public Buildings.
- To test the effectiveness of the developed Multiple Criteria Decision Support System for Refurbishment of Public Buildings in practice and in an international scientific project.

Research methodology

The research methodology for the improvement of the efficiency of the refurbishment process of public buildings and for the new models (the model for integrated analysis of the lifecycle of a public building and the model for integrated analysis of the negotiations process for building's refurbishment) is based on the analysis of studies of Lithuanian and foreign scientists in this area. Multiple criteria methods are used to compare real estate alternatives, to calculate both the level of usefulness and market value.

The research is based on scientific and other articles of the Lithuanian and foreign authors, encyclopaedic dictionaries, on-line statistical data of different countries, other scientific and information articles of Lithuanian and foreign educational institutions.

Scientific novelty and originality of the thesis

- A unique model for integrated analysis of the lifecycle of a public building was developed with focus on refurbishment.
- Systems and subsystems of criteria for refurbishment of public buildings and their components were offered; the systems and subsystems of criteria were compiled using economic, technical, technological, quality (comfort, architecture and aesthetic) and other criteria.
- Integrated description of the refurbishment process for public buildings, participating interests groups and the environment affecting the process is provided in quantitative (systems and subsystems of criteria, measuring units, values and weights) and conceptual (text, formulae, graphic expression (schemes, charts, diagrams), tapes) forms.
- An original Multiple Criteria Decision Support System for Refurbishment of Public Buildings was developed; it enables to develop an integrated analysis of the refurbishment process of public buildings, its components, participating interest groups and the environment affecting this project.
- The developed unique model of integrated analysis of the negotiations process for refurbishment of public buildings is integrated into the Multiple Criteria Decision Support System for Refurbishment of Public Buildings.

Work approbation and use of the results in practice

The main results of the dissertation were discussed during scientific conferences and seminars in Cincinnati, Taiwan, Minsk and Vilnius.

Theoretical results of the paper were adjusted and implemented in Lithuania and the EU during the *Framework 6* project "Bringing Retrofit Innovation to Application in Public Buildings" (BRITA in PuBs) and were used in a practical

multiple criteria analysis for refurbishment of the VGTU main building.

The research results were used in an educational process of Vilnius Gediminas Technical University for the creation of computer learning systems for master students in Construction Management and Real Estate Evaluation & Management programs.

Research results are provided in 12 scientific articles (nine of them in reviewed scientific publications).

Volume and structure of the research

The dissertation consists of the introduction, five chapters, conclusions and suggestions, bibliography and appendixes. The size of the dissertation is 148 pages. Figure 1 illustrates the structure of the report.

Chapter 1. Problems related to refurbishment of public buildings and their solutions

Requirements for public buildings and problems related to the refurbishment of public buildings in Lithuania are reviewed and the main problems related to the refurbishment of such buildings are determined. The market of the refurbishment of public buildings is also analyzed.

It is stressed in the dissertation that the refurbishment decisions are influenced by a number of micro-level factors (deterioration and obsolescence of a building, indoor environment quality, technological, technical, health benefits (reduced cold and damp related illnesses), lower bills for residents) and by macro-level factors (environmental (a less polluted environment, saving of limited nature resources), social (increasing social equity, improving human health) and economic (increasing employment, creation of wealth) benefits).

The problem is how to define an efficient building refurbishment process when a number of different parties are involved and thousands of alternative versions are available. Moreover, the realization of some objectives seems to be more rational from the economic perspective, although from other perspectives (i.e. ecological, indoor environment quality, social, etc.) their significance is different.

A few examples for the determination of rational alternatives are provided in Chapter 1 of the dissertation.

A thorough building's refurbishment evaluation is quite difficult to undertake, because a building and its environment are a complex system (technical, technological, ecological, social, comfort, aesthetical, etc.), where all subsystems influence the total efficiency performance, and where the interdependence between subsystems plays a significant role.

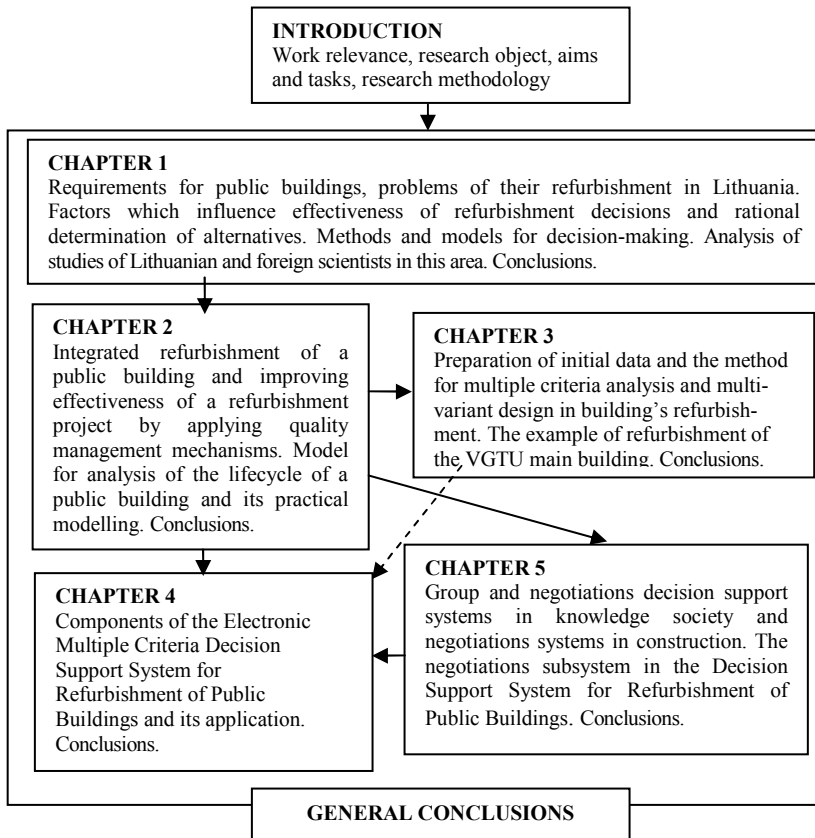


Figure 1. The structure of the dissertation

Many decision making models and methods (cost-benefit analysis (C. Goodacre et al., 2002), multiple criteria analysis (E. Brandt et al., 2002), the lattice method for global optimization (A. Saporito et al., 2001), predicted building's habitability index (T. Kusuda, 2001) and energy rating systems for existing houses (R. Zmeureanu et al., 1999), etc.) have been developed in the world to solve the above and other problems.

The major parties in building's refurbishment process can use spreadsheets, analyzers, software, neural networks, expert and decision support systems, etc.

Websites sometimes contain refurbishment spreadsheets: Comfort calculator (analyses thermal comfort and estimates the optimal temperature), Lighting calculator (identifies and analyses options for reducing lighting costs), Ventilation calculator (examines the supply of outside air ventilation to premises), Home Improvement Calculators, etc.

Interested parties also use software with various purposes: Holistic building analysis (energy simulation, load calculation, renewable energy, retrofit analysis and sustainability/green buildings), Codes and standards, Materials, components, equipment, and systems (envelope systems, HVAC equipment and systems and lighting systems), Other applications (atmospheric pollution, energy economics, indoor air quality, multi-building facilities, solar/climate analysis, training, utility evaluation, validation tools, ventilation/airflow and water conservation).

The major parties in a building's refurbishment can use various decision support systems. A decision support system (DSS) provides a framework through which decision-makers can obtain the necessary assistance needed for decision-making through an easy-to-use menu or command system. Generally, a DSS will provide help in formulating alternatives, accessing data, developing models and interpreting their results and by selecting options or analyzing the impacts of a selection.

A special issue of "Energy and Buildings" (Volume 31, Issue 2, February 2000) was prepared by the developers of EPIQR (Energy Performance Indoor Environmental Quality Retrofit) and is in use today. EPIQR is a methodology that has been developed to assist apartment building owners who are considering the refurbishment or retrofitting (upgrading) their building stock (M. Jaggs et al. 2000). EPIQR is a decision tool that combines financial, technical, energy and comfort analysis (J. L. Genreet al., 2000). EPIQR has been developed to act as an assisting tool for surveyors, architects or building owners to select the most suitable refurbishment actions for an apartment block by enabling them to upgrade the physical and functional state of the building, to improve indoor conditions for tenants and to reduce the energy consumption (D. Caccavelli et al., 2000).

Neural network is a method of computing that tries to copy the way the human brain works. A group of processing elements receives data and at the same time links are made between the elements, as the repeated patterns are recognized (Oxford, 1996). Many various-purpose neural networks can be used for refurbishment.

It may be stressed that scientists from various countries have not considered the research object selected by the author while analyzing issues

related to the lifecycle of a building or integrated designing of its components; the author selected building's lifecycle with focus on refurbishment, participating interest groups and external micro, meso and macro environment as an integrated group which influences the project efficiency.

Chapter 2. The model for analysis of the lifecycle of a public building

Integrated analysis of depreciation of a public building (nonconformity to modern requirements) and its components is performed. It is also pointed that the lifecycle and integrated depreciation level of public buildings changes with time depending on the influence of physical, economic, engineering equipment, legal, architectural/aesthetic, functional, comfort, maintenance, social and other factors.

Various quality management mechanisms can be applied in the management of public buildings' lifecycle: laws, market, institutions, the client, traditions and experts control the quality.

A model for analysis of building's lifecycle has been created to implement the aims. The model includes multi-variant design, multiple criteria analysis and determination of the most effective variants for the interested parties of building's lifecycle with focus on refurbishment, participating interest groups with own goals and the external environment (Figure 2).

The model for integrated analysis of refurbishment of public buildings was practically implemented in such main stages:

- The lifecycle of public buildings, participating interest groups and the external environment, which affects the project's efficiency, were described in quantitative and conceptual forms.
- An integrated database on the basis of the description of the research object was developed in quantitative and conceptual forms.
- The Multiple Criteria Decision Support System for the Refurbishment of Public Buildings and its components has been developed to automate multi-variant design of public building's lifecycle and its components and to determine the level of usefulness, priority and market value of the alternatives.
- External micro and macro environment, which influences building's lifecycle and possibilities for its rationalization were analyzed.

For example, the system of criteria may be conditionally divided into five sub-systems of primary level when describing public buildings' lifecycle, participating interest groups and the external environment, which affects project efficiency as an integrated group in quantitative and concept forms: The criteria sub-system describing influence of macro-level factors on project

efficiency, The criteria sub-system describing influence of meso-level factors on project efficiency, The criteria sub-system describing influence of micro-level factors on project efficiency, The criteria sub-system describing influence of interest groups on project efficiency, The criteria sub-system describing influence of separate stages of building refurbishment lifecycle on project efficiency.

The examples provided in this chapter lead to a conclusion that interests groups and their aims may be expressed on the basis of many exhaustive criteria system.

Chapter 3. Multi-variant design and multiple criteria analysis of building's refurbishment

An exhaustive description of the model for building's lifecycle with focus on refurbishment offered by the author is provided and the example of refurbishment of the VGTU main building based on the model is presented.

One of the most important stages in multiple criteria analysis of public building's lifecycle with focus on refurbishment is the determination of values and weights of criteria, which describe alternatives. Integrated databases for public building's refurbishment are presented in this chapter with integrated descriptions of alternatives from economic, technical, infrastructure, quality, technology and other perspectives. The developed system enables integrated analysis of refurbishment projects for public buildings in quantitative and concept real forms on the basis of such integrated databases. The systems of criteria compiled by the author describe refurbishment of public buildings exhaustively.

Multiple criteria methods created by E.K. Zavadskas and A. Kaklauskas were used to compare refurbishment of building's components and variants of engineering systems, to calculate the level of usefulness and to determine the market value: Multiple Criteria Integrated Proportional Evaluation Method, Method for Multiple Criteria Multi-variant Design of Alternatives, Multiple Criteria Method for Determination of Market Value and of the Level of Usefulness, Multiple Criteria Alternative Designing Method for Building's Lifecycle.

While comparing alternatives of building refurbishment, calculating the level of usefulness and determining the market value, it is important to normalize and whereupon evaluate indicator values describing comparative objects. This process enables to compare indicator values, which describe comparative objects, expressed in different measuring units and to determine the most effective alternatives.

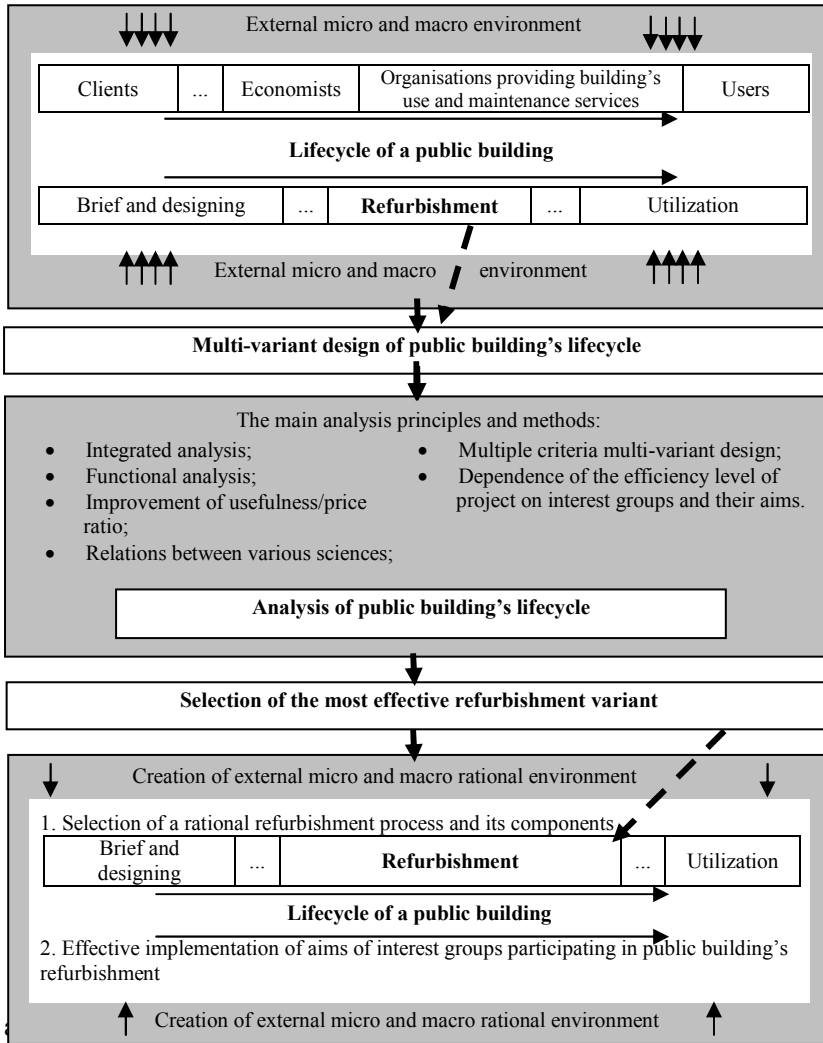


Figure 2. Model of the integrated analysis of public building's lifecycle

Indicator values normalized during evaluation of indicators are multiplied by their weights. Therefore, all indicator weights must be inter-

coordinated according to their quantitative and qualitative characteristics. Weights of quantitative indicators may be inter-coordinated precisely by expressing their values in equivalent monetary expression. When weights of quantitative indicators are already inter-coordinated, the same procedure is applied to weights of qualitative indicators. Thus weights of all quantitative and qualitative indicators match.

Analysis results for compared projects were included in a decision-making matrix to determine efficiency of the analyzed building's refurbishment alternatives. When the decision-making matrix was ready, multiple criteria analysis of building's refurbishment alternatives was carried out. The Multiple Criteria Integrated Proportional Evaluation Method was used for this analysis. Priority, weight and the level of usefulness of analyzed building's refurbishment components and engineering systems' alternatives were calculated in six stages, which are described in detail in Chapter 3 of the dissertation.

Excessive information is characteristic of multi-variant designing and multiple criteria analysis of building's refurbishment alternatives, and it requires integrated evaluation. The number of possible alternatives may reach tens of thousands. Each alternative is described by qualitative and conceptual information. The method of multiple criteria alternative designing is used for creation of alternatives. Multiple criteria multi-variant designing of alternatives is carried out in five stages on the basis of this method; the stages are summarized in Chapter 3 of the dissertation.

In order to describe the methods and apply them in practice, the task of VGTU main building is solved. Firstly, the state of the refurbished building, of its constructions and of engineering systems is described. Then the building's state before the refurbishment, performed repair works in the building and constructions and engineering systems of the refurbished building were analyzed.

Multiple criteria analysis of walls (Appendix 3 of the dissertation), windows, roof (Appendix 4 of the dissertation), entrance door (Appendix 5 of the dissertation) and the heating node refurbishment (Appendix 6 of the dissertation) of the VGTU building were carried out for the dissertation. Alternative variants for the entire building were formulated and multiple criteria analysis for refurbishment of the entire building was carried out after multiple criteria analysis of separate solutions. The Multiple Criteria Alternative Designing Method and the Method for Multiple Criteria Multi-variant Design of Alternatives were used for this purpose.

A theoretic testing of the solution for the VGTU main building was

carried out in Lithuania and the EU during the *Framework 6* project “Bringing Retrofit Innovation to Application in Public Buildings“ (BRITA in PuBs).

Chapter 4. Multiple criteria decision support system for refurbishment of public buildings

The Electronic Multiple Criteria Decision Support System for Refurbishment of Public Buildings (hereinafter EMCDSSRPB) developed by the author is described in this chapter. This system was developed on the basis of the analysis of existing software, neural networks and expert and decision support systems; it is used to determine the most efficient process of public buildings’ refurbishment.

Widely applied software and the newest and the most popular technologies were used to create the EMCDSSRPB. Several types of software were selected to make the system effective; the software was used for different functions.

The following technologies are used in the EMCDSSRPB system: *Microsoft Access* programming language is used for database programming, HTML (Hypertext markup language) programming language is used for plain websites without calculations or data from databases, ASP (Active server pages) technology is used in websites with data from databases and various calculations, *Java Script* and *ActiveX* technologies are used for designing and creation of separate modules and user interface. *Java Script* programming language is used for executable data, and *ActiveX*-based components are used for creation of many other programs.

With the help of these technologies the EMCDSSRPB system was adjusted to the *Windows NT* server platform. Combination of software and technologies ensures functional and flexible work of the system and facilitates its use.

EMCDSSRPB is the system which accumulates data and knowledge from various sources and processes them; with the help of multiple criteria methods a decision-maker gets from the system the necessary information for analysis, formulation and evaluation of possible decision alternatives and for decision-making; the system is also used to produce and save results. Various sources point out that EMCDSSRPB system helps its users to transform huge unprocessed amounts of data to information necessary for problem analysis and for decision-making.

Figure 3 illustrates the main components of the EMCDSSRPB system and their relations.

The system unites databases and model bases managed by system users via user interface. These components are closely interrelated and unite smaller components of the system.

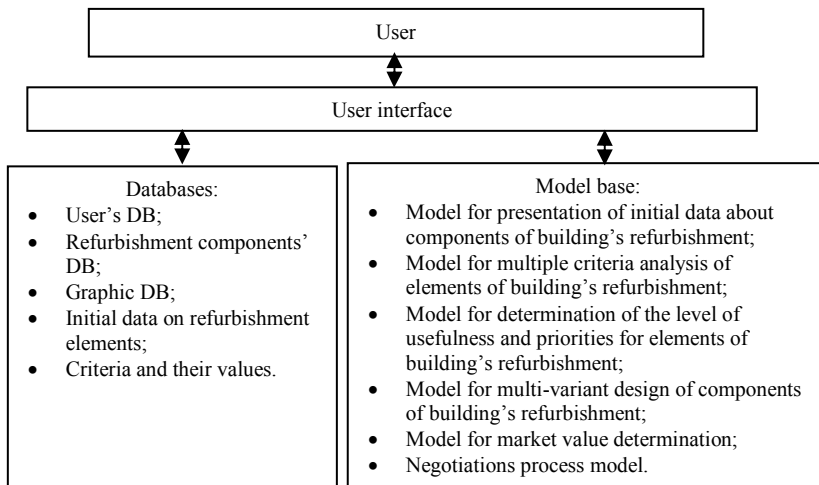


Figure 3. Components of the Electronic Multiple Criteria Decision Support System for Refurbishment of Public Buildings

The model base of this system consists of the following models: Model for presentation of initial data about components of public building's refurbishment, Model for multiple criteria analysis of elements of public building's refurbishment, Model for determination of the level of usefulness and priorities for elements of public building's refurbishment, Model for multi-variant design of components of public building's refurbishment, Model for market value determination, Negotiations process model.

Various models are adjusted to user's needs using the model base management system. The system is based on artificial intelligence. Some models are independent in the model base management system and some provide initial information for other models to be used in their calculations.

The models offers assistance to users in creation of alternatives. Using model base management system, users can analyze various variants, change scope of analysis and concentrate on necessary information. The functionality of the model base determines the functionality of the whole EMCDSSRPB system.

The EMCDSSRPB system is designed for internet use (Figure 4).

Therefore, it is rational, simple and understandable to users with various educational and knowledge background. Mixed user interface is used in the system: different interface types for different tasks.

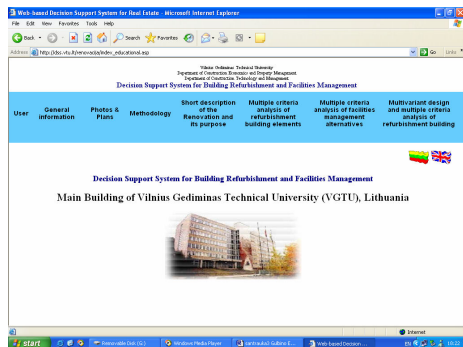


Figure 4. Multiple Criteria Decision Support System for Refurbishment of Public Buildings

One of the main functions of all electronic systems is to collect and accumulate information. The EMCDSSRPB system may provide the information necessary for decision-making in digital, text and graphic (charts, schemes, drawings) form, also in form of formulae, images, audio, video, etc. All information and its forms differ according to the desirable variant of public buildings' components (walls, windows, façade, etc.). Since information describing these parts differs, the structure of information and form of presentation also differ. The EMCDSSRPB system does not strictly define the form of information or limit the amount of information. Unlike traditional cases, all information is stored at various levels in structured databases. However, problems related to information collection and processing can still occur. Information stored in different databases differs according to information storing standards (different software, different structure of information and form of presentation, etc.). This problem is especially acute when different databases are used for decision-making (information accumulated in one database is not sufficient; therefore, several databases must be used). Besides, the use of initial data necessary for decision-making may be impossible if different databases are based on different programming languages.

This problem is solved in the EMCDSSRPB system by creating united databases. Data in the system are stored in one database consisting of different tables; the database is independent from the decision-making model

base. Table relationships enable retrieval of all necessary information for decision-making. Besides, users of the EMCDSRPB system who enter data to the database provide all necessary information in compact form, and this information is not repeated.

Efficiency of variants of public buildings' refurbishment is evaluated from economic, technical, social, aesthetic, legal and other perspectives; therefore, the EMCDSRPB system consists of models, which help the user (decision-maker) to perform an integrated analysis of refurbishment variants and to make an appropriate decision.

Registered users of the EMCDSRPB system can easily add information and change criteria values considering client's priorities or on the basis of expert surveys. While formulating possible variants for a refurbished building, various limitations may be entered. Every system user performs certain calculations according to his/her needs and aims and also provides information to other users.

The more alternatives are analyzed before the final decision is made, the bigger is the likelihood to receive a rational final result. The EMCDSRPB system can automatically compile up to 100,000 variants of components of public building's refurbishment (walls, windows, roof, floor, engineering networks, etc.) on the basis of the accumulated information and can carry out multiple criteria analysis of these variants, determine the level of usefulness and priorities and select the most effective variants using these models. Strengths and weaknesses of the analyzed variants are also provided: why and how much one alternative is better than the other.

The integrated feedback grants constant need for improvement of the existing system striving to implement global standards.

The EMCDSRPB system is universal and may be used for various theoretic and practical objectives; therefore, various education institutions, construction companies, consultants, end users, experts and other interest groups can use the functions offered by this system.

Practical testing of the solution for the task of the VGTU main building was carried out in Lithuania and the EU during the *Framework-6* project "Bringing Retrofit Innovation to Application in Public Buildings" (BRITA in PuBs). The results of practical and theoretic testing coincided.

Chapter 5. Negotiations subsystem in the decision support system for refurbishment of public buildings

Research studies of scientists from various countries in the area of the group and negotiations decision support systems have been reviewed and

strengths and weaknesses of these systems are presented. It was also attempted to determine the most effective sequence of negotiations processes.

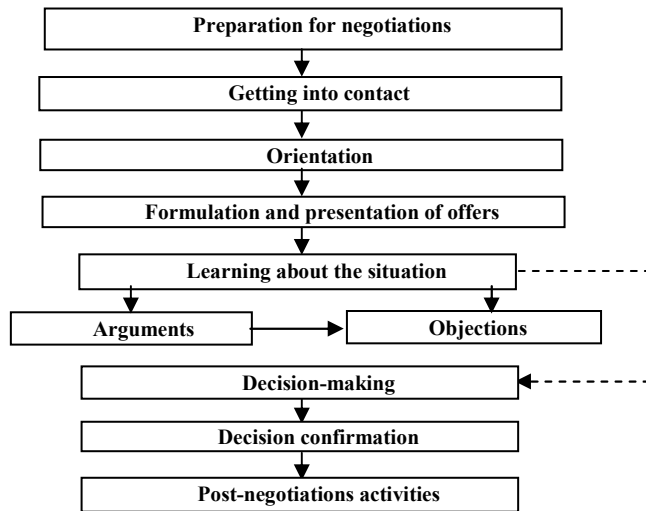


Figure 5. Model of integrated analysis of negotiations process

Since the refurbishment of public buildings and construction of new buildings is in full swing in Lithuania currently, new small companies appear, other international companies, although large, are sold and some liquidated and reorganized, negotiations become an inseparable part of competitiveness in the construction sector. Representatives of construction companies increasingly use the art of negotiations to reach agreement with suppliers, subcontractors and potential clients.

Refurbishment of public buildings consists of a number of various integral processes and procedures; therefore, the refurbishment process of public buildings is very complex, incorporates a number of processes and requires sufficient amount of work from the brief to the implementation. Negotiations systems could help a company, which is involved in refurbishment of buildings, to master the complex and multistage refurbishment process' management program faster and efficiently and could help to solve encountered problems more effectively. The most important components of negotiations, their particularities, strategy, types and other features are reviewed in this chapter. Each stage of negotiations must be managed as an inseparable part of the whole process. After the review of

negotiations' stages, a model of integrated analysis of negotiations' process was created (Figure 5).

Electronic negotiations are defined as mediation, thus traditional and other communication methods may be used (e.g. verbal or written), which may be supplemented or replaced by direct technologies. The Electronic Negotiations System (hereinafter ENS) is a powerful and convenient tool of electronic information, which supports and complements traditional communication and mediation. Therefore, electronic negotiations systems are analyzed in this chapter and negotiations systems in construction are reviewed.

The negotiations module was developed using the same software and technologies as for the entire EMCDSRPB system. Read more in Chapter 4.

Dear V. Jonaitis,

After an electronic search for windows, we have received 34 offers. Your offer partially suits us. However, it takes position 8 in the priority list according to your conditions (price, quality, etc.) after the analysis of all offered windows (see dss.vtu.lt/.....). Besides, the calculations of the market value (see dss.vtu.lt/.....) showed that the market value of 1 m² of your window is 267.75 litas and not the requested 315 litas. Thus we suggest reducing the offered price by 15% on the basis of performed calculations. The provided calculations (criteria system, values and weights of criteria) may not fully reflect the existing situation. Therefore, you can change the information defining your windows (criteria system, values and weights of criteria) and provide reasons. System will automatically send us your changes and the new results and we will make a decision on the basis of the results in the nearest future.

Best regards,
V. Petraitis

Figure 6. An automatically generated typical e-mail for negotiations (marked places are variable)

The negotiations subsystem of the Electronic Multiple Criteria Decision Support System for Refurbishment of Public Buildings was developed on the basis of the analysis of existing group and negotiations decision support systems and of their strengths and weaknesses. Its aim is to determine the most effective sequence of negotiations processes. This model is integrated in the EMCDSRPB and creates conditions for integrated analysis of the refurbishment process of public buildings and for effective negotiations as a result.

The negotiations subsystem of the EMCDSRPB system can prepare exhaustive and motivated e-mails for negotiations with each selected supplier and create a website. Using the information obtained during previous

calculations and pre-defined rules and procedures, the negotiations subsystem prepares an e-mail for negotiations with each selected supplier (Figure 6); the e-mail reasonably suggests to reduce price of a product or to sell better quality product for the offered price. The e-mail contains links to calculations.

General conclusions

1. Having performed analysis of the state of public buildings in Lithuania the main problems related to the refurbishment of these buildings were put forward. Problem solutions were suggested.
2. Factors influencing efficiency of decisions related to refurbishment of public buildings and rational determination of alternatives were reviewed. Worldwide decision-making models and methods were described.
3. Software, expert and decision support systems available in the world and neural networks used for problem solving in building's refurbishment were analyzed; the services offered by participants of refurbishment market in the most advanced countries of the world using the newest information and internet technologies were also analyzed.
4. An original model for integrated analysis of the lifecycle of a public building with focus on refurbishment was created; the model enables integrated analysis of the lifecycle of a public building, participating interest groups and external micro and macro environment which influences this process. The model was implemented in practice.
5. The refurbishment process of public buildings, participating interest groups and the environment that affects this process were described in quantitative and conceptual forms.
6. The systems of criteria describing alternatives for refurbishment of public buildings, their components and engineering systems were compiled.
7. An integrated data and knowledge base of building's lifecycle was developed. The refurbishment process of a public building, participating interest groups and the micro and macro level environment which affects the process are described from economic, technical, infrastructure, quality, technology, legal and other perspectives, are integrated and are provided in this data and knowledge base.
8. An original Multiple Criteria Web-based Decision Support System for Refurbishment of Public Buildings was developed; it enables integrated analysis of the refurbishment process of public buildings, its

components, participating interest groups and the environment affecting this process.

9. Practical multiple criteria analysis for refurbishment of the VGTU main building and multiple criteria multi-variant design for the whole building were performed.
10. Research works by scientists from various countries in area of group and negotiations decision support systems were reviewed and their strengths and weaknesses defined. General negotiations process was analyzed. Negotiations systems in construction were reviewed.
11. A model for integrated analysis of negotiations process for refurbishment of public buildings was created; the model unites all positive aspects of group and negotiations decision support systems, enables integrated analysis of the refurbishment process of public buildings and helps to have effective negotiations as a result. This model is integrated in the Decision Support System for Refurbishment of Public Buildings.

The main results of the dissertation were discussed in scientific conferences and seminars in Cincinnati, Taiwan, Minsk and Vilnius.

Theoretic results were applied and implemented in Lithuania and the EU during *Framework-6* project “Bringing Retrofit Innovation to Application in Public Buildings”.

Research results were used in educational process of Vilniaus Gediminas Technical University by creating learning systems for master students majoring in Construction Management and Real Estate Evaluation & Management programs.

LIST OF SCIENTIFIC PUBLICATIONS REGARDING DOCTORAL DISSERTATION

Articles in reviewed publications:

1. Kaklauskas A., Zavadskas E.K., Gikys M., Gulbinas A. Multiple Criteria Property E-business System. In: The Organization and Management of Construction innovation and global competitiveness. 10th International Symposium. September 9th–13th, Cincinnati, USA, 2002, p. 739–752, (in ISI Proceedings).
2. Kaklauskas A., Zavadskas E.K., Raslanas S., Gulbinas A. Multiple criteria decision support web-based system for building refurbishment. 6th international conference. In: Energy for buildings. Proceedings Edited by E. Abel, V. Martinaitis, B. Todorovich. 7–8 October, Lithuania, Vilnius.

Gediminas Technical University Press „Technika“, 2004, p. 284–291, (in ISI Proceedings).

3. Zavadskas E.K., Kaklauskas A., Gulbinas A. Multiple criteria decision support web-based system for building refurbishment. *Journal of civil engineering and management*, 2004, Vol. X, No 1, p. 77–85.

4. Kaklauskas A., Gulbinas A. Pastatų atnaujinimo žiniomis grįsta sprendimų paramos sistema. *Ūkio technologinis ir ekonominis vystymas*, 2005, tomas XI, Nr. 3, p. 176–182.

5. Zavadskas E.K., Kaklauskas A., Gulbinas A., Lepkova N., Kaklauskienė J. A Multiple Criteria Decision Support Web-Based System for Facilities Management. In: *Global E-Business in Knowledge-Based Economy: Management Practice and Opportunities*. ICEB 2002 Taipei, December 10-13, 2002, p. 109–111.

Kaklauskas A., Gulbinas A. Integration decision support and expert systems, neural networks, GIS and multimedia in real estate decision support systems. In: *Экономика, оценка и управление недвижимостью: Международная научно-практическая конференция, 1–3 декабря 2004 г.: Материалы конференции*, Белорусский государственный технологический университет, Институт недвижимости и оценки, Национальное кадастровое агентство, Университет Вармии и Мазурии(Польша). – Minsk: BGTU, 2004, p. 202–214.

6. Zavadskas E.K., Kaklauskas A., Gikys M., Gulbinas A. Efficiency Increase of Property E-Business Systems by Applying Multiple Criteria Decision Support Systems. In: *Proceedings. 54th Meeting of the European Working Group "Multicriteria Aid for Decisions"*, Durbuy, Belgium, October 4th and 5th, 2001, p. 9. CD-ROM.

7. Zavadskas E.K., Kaklauskas A., Gikys M., Gulbinas A. E - business and Multiple Criteria Analysis. Decision support systems electronic and mobile commerce multicriteria decision aid human centered processes ethical dilemmas in decision making. In: *12th mini EURO conference / The Association of European Operational Research Societies within INFORS*. Vrije Universiteit Brussel. Belgium. April 2–5, 2002. Brussels, 2002, p. 96.

Articles in other publications:

1. Zavadskas E.K., Kaklauskas A., Gikys M., Gulbinas A. Efficiency Increase of Real Estate E-business Systems by Applying Multiple Criteria Decision Support Systems. In: *8 th International Colloquy "Rational decisions of activity in construction companies"*. 14–15 May,

Lithuania, 2001. CD-ROM.

2. Gulbinas A., Gikys M. Vizualinio dinamiškumo didinimas bei interaktyvumo diegimas distanciniame mokyme. Iš: 7-oji Lietuvos jaunųjų mokslininkų konferencija „Lietuva be mokslo – Lietuva be ateities“, įvykusios Vilniuje 2004 m. kovo 25–26 d., medžiaga. Statyba. Vilnius: Technika, 2004, p. 15–20.

3. Gulbinas A., Gikys M. Internetinė elektroninė mokymo sistema. Iš: 6-oji Lietuvos jaunųjų mokslininkų konferencija „Lietuva be mokslo – Lietuva be ateities“, įvykusios Vilniuje 2003 m. kovo 27 d., medžiaga. Statyba. Vilnius: Technika, 2003, p. 32–36.

4. Gikys M., Gulbinas A. Nekilnojamojo turto e-verslo sistema. Iš: 5-oji Lietuvos jaunųjų mokslininkų konferencija „Lietuva be mokslo – Lietuva be ateities“, įvykusios Vilniuje 2002 m. kovo 27–29 d., medžiaga. Statyba. Vilnius: Technika, 2002, p. 37–42.

VISUOMENINIŲ PASTATŲ RENOVACIJOS DAUGIAKRITERINĖ INTERNETINĖ SPRENDIMŲ PARAMOS SISTEMA

Santrauka

Darbo aktualumas

Lietuva kaip ir kitos vidurio Europos šalys jau keliolika metų išgyvena didelių pertvarkymų statybos sektoriuje laikotarpį. Sparčiai vykstanti miestų plėtra sudaro sąlygas naujai peržiūrėti įgyvendintus projektus, kurie dabartinėmis sąlygomis yra keistini ir rekonstruoti. Daugelis tokių pastatų Lietuvoje yra nusidėvėję, neatitinka šiuolaikinių projektavimo – statybos reikalavimų.

Lietuvos visuomeninių pastatų fondas, palyginti su Vakarų Europos šalių vidutiniais duomenimis yra pakankamai jaunas. Tačiau pastatai, pastatyti po 1970 metų pagal statybos kokybę nusileidžia anksčiau statytiems pastatams. Dar viena pastarojo dešimtmečio tendencija – „uždelstos pastatų priežiūros“ – tendencija. Ekonominis nuosmukis pereinamuoju laikotarpiu pablogino padėtį ir visuomeninių pastatų kokybę dar labiau pablogėjo. Lietuvoje šiuo metu yra daug visuomeninių pastatų, kurių techninė būklė prasta arba labai prasta. Todėl pastatų atnaujinimas ir energijos taupymas yra viena iš pagrindinių ir išsivysčiusių ir Rytų bei Centrinės Europos šalių (taip pat ir Lietuvos) problemų. Didžioji dalis įvežamų į Lietuvą energijos išteklių naudojama pastatams apšiltinti.

Nuolatinis pastatų eksploatavimo brangimas reikalauja efektyvių, nesudėtinų ir nebrangių pastatų renovacijos sprendimų. Šildymo sistemų modernizavimas, sienų, stogo apšiltinimas, langų ir durų keitimas yra vienos

iš rezultatyviausių priemonių. Taip pat labai svarbu žinoti ir būti tikriems, kad siūlomos energiją taupančios priemonės veikia taip, kaip buvo numatyta, kad realūs energijos sutaupymai atitinka projektinius. Antra vertus, svarbu suvokti, kad renovuojant pastatus galima ne tik sumažinti energijos suvartojimą, bet ir visapusiškai pagerinti pastato būklę: jo eksploatavimą, garso izoliacines savybes, išvaizdą, komfortą, pastato gyvavimo trukmę bei padidinti pastato vertę.

Atnaujinimo varianto parinkimas daugiausia priklauso nuo pastato savininkų ir jame dirbančių organizacijų poreikių ir esamų finansinių galimybių, vyriausybės vykdomos politikos (mokesčių lengvatos, dotacijos, lengvatiniai kreditai), pastato fizinio ir moralinio nusidėvėjimo lygio, teisinės aplinkos ir pan.

Tyrimo objektas

Tyrimų objektą sudaro visuomeninių pastatų renovacijos procesas, jame dalyvaujančios ir savo tikslus norinčios įgyvendinti suinteresuotos grupės bei išorinė mikro ir makro aplinka kaip viena visuma.

Tyrimo tikslas ir uždaviniai

Darbo tikslas – yra visuomeninių pastatų renovacijos proceso efektyvumo didinimas taikant daugiakriterinės analizės metodus, sukurtą visuomeninio pastato gyvavimo proceso kompleksinės analizės modelį, pastato renovacijos derybinio proceso kompleksinės analizės modelį bei šių modelių pagrindu sukurtą Visuomeninių pastatų renovacijos daugiakriterinę sprendimų paramos sistemą. Tikslui pasiekti sprendžiami šie uždaviniai: atlikti įvairių pasaulio šalių mokslininkų tyrimų visuomeninių pastatų renovacijos gyvavimo proceso kompleksinės analizės srityje apžvalgą; sukurti originalų visuomeninio pastato gyvavimo proceso kompleksinės analizės modelį; atlikti visuomeninio pastato gyvavimo proceso kompleksinės analizės modelio praktinį realizavimą; nustatyti efektyvų visuomeninių pastatų renovacijos procesą, kai procese dalyvauja daug įvairių pastato sudedamųjų dalių ir yra tūkstančiai alternatyvų versijų; aprašyti visuomeninių pastatų renovacijos procesą, jame dalyvaujančias suinteresuotas grupes ir šį projektą veikiančią aplinką kiekybine ir koncepcine formomis; sudaryti kriterijų sistemą išsamiai aprašančią visuomeninių pastatų ir jų sudėtinių dalių renovacijos alternatyvas; sukurti Visuomeninių pastatų renovacijos daugiakriterinę sprendimų paramos sistemą; sukurti unikalų Visuomeninių pastatų renovacijos derybinio proceso kompleksinės analizės modelį ir integruoti jį į visuomeninių pastatų renovacijos daugiakriterinę sprendimų paramos sistemą; sukurtos visuomeninių pastatų renovacijos daugiakriterinės

sprendimų paramos sistemos efektyvumą patikrinti praktikoje ir tarptautiniame moksliniame projekte.

Tyrimų metodika

Visuomeninių pastatų renovacijos proceso efektyvumo didinimo bei naujai sukurtų modelių – visuomeninio pastato gyvavimo proceso kompleksinės analizės modelio, pastato renovacijos derybinio proceso kompleksinės analizės modelio – tyrimo metodikos paremtos Lietuvos ir užsienio šalių mokslininkų šioje srityje atliktų darbų analize. Atliktiems tyrimams pritaikyti daugiakriterinės analizės duomenų apdorojimo metodai, informacinės technologijos, analogijos principai, palyginamoji analizė.

Rengiant darbą remtasi Lietuvos ir užsienio autorių mokslinėmis ir kitomis publikacijomis, enciklopediniais žinynais, įvairių šalių statistiniais duomenimis internete, kitais Lietuvos ir užsienio mokslo institucijų moksliniais ir informaciniais leidiniais.

Mokslinis darbo naujumas ir originalumas

- Sukurtas unikalus visuomeninio pastato gyvavimo proceso kompleksinės analizės modelis, kuriama ypatingas dėmesys kreipiamas renovacijai.
- Pasiūlytos visuomeninių pastatų ir jo sudėtinųjų dalių renovacijos procesą apibūdinančios kriterijų sistemos ir posistemiai, sudaryti iš ekonominių, techninių, technologinių, kokybinių (komforto, architektūrinių, estetinių) ir kitų kriterijų.
- Kiekybine (kriterijų sistemos ir posistemiai, matavimo vienetai, reikšmės ir reikšmingumai) ir koncepcine (tekstas, formlės, grafika (schemos, grafikai, diagramos), vaizdajuostės) formomis kompleksiskai aprašytas visuomeninių pastatų renovacijos procesas, jame dalyvaujančios suinteresuotos grupės ir ši procesą veikianti aplinka.
- Sukurta originali Visuomeninių pastatų renovacijos daugiakriterinė sprendimų paramos sistema, sudaranti sąlygas kompleksiskai analizuoti visuomeninių pastatų renovacijos procesą, jo sudėtinę dalį, jame dalyvaujančias suinteresuotas grupes ir ši projektą veikiančią aplinką.
- Sukurtas unikalus visuomeninių pastatų renovacijos derybinio proceso kompleksinės analizės modelis integruotas į visuomeninių pastatų renovacijos daugiakriterinę sprendimų paramos sistemą.

Darbo aprobavimas ir praktinis rezultatų naudojimas

Pagrindiniai darbo rezultatai buvo aptarti mokslinėse konferencijose ir seminaruose Cincinati, Taivanyje, Minske ir Vilniuje. Teoriniai darbo

rezultatai buvo pritaikyti ir įdiegti Lietuvoje ir Europos Sąjungoje vykdant Framework 6 projektą „Visuomeninių pastatų atnaujinimas taikant inovacijas“ (BRITA in PuBs) bei atlikta praktinė VGTU Centrinų rūmų renovacijos daugiakriterinė analizė. Tyrimų rezultatai buvo panaudoti Vilniaus Gedimino technikos universiteto mokymo procese kuriant kompiuterines mokymo sistemas statybos valdymo ir nekilnojamojo turto vertinimo ir valdymo programų magistrams. Atliktų tyrimų rezultatai pateikti 12 mokslinėse publikacijose, iš kurių 8 recenzuojamuose mokslo leidiniuose.

Pagrindinės išvados

1. Apžvelgti faktoriai, įtakojantys visuomeninio pastato atnaujinimo sprendimų efektyvumą ir racionalų alternatyvų nustatymą bei aprašyti pasaulyje naudojami sprendimų priėmimo modeliai ir metodai.
2. Išanalizuotos pasaulyje esančios programinės įrangos, ekspertinės ir sprendimų paramos sistemos, neuroniniai tinklai skirti pastatų renovacijos problemoms.
3. Sukurtas originalus visuomeninio pastato gyvavimo proceso, kuriame ypatingas dėmesys kreipiamas į pastato renovaciją, kompleksinės analizės modelis, sudarantis sąlygas kompleksiskai analizuoti visuomeninio pastato gyvavimo procesą, jame dalyvaujančias suinteresuotas grupes ir šį procesą veikiančią išorinę mikro bei makrolygmens aplinką. Atliktas šio modelio praktinis realizavimas.
4. Aprašytas visuomeninių pastatų renovacijos procesas, jame dalyvaujančios suinteresuotos grupės ir šį procesą veikianti aplinka kiekybine ir koncepcine formomis.
5. Sudarytos kriterijų sistemos išsamiai aprašančios visuomeninių pastatų ir jų konstruktyvų elementų bei inžinerinių sistemų renovacijos alternatyvas.
6. Sudaryta pastato gyvavimo proceso kompleksinė duomenų ir žinių bazė. Šioje duomenų ir žinių bazėje visuomeninio pastato renovacijos procesas, jame dalyvaujančios suinteresuotos grupės ir šį procesą veikianti mikro bei makrolygmens aplinka kompleksiskai aprašoma ekonominiais, techniniais, infrastruktūriniais, kokybiniais, technologiniais, teisiniais ir kitais aspektais.
7. Sukurta originali Visuomeninių pastatų renovacijos daugiakriterinė internetinė sprendimų paramos sistema, sudaranti sąlygas kompleksiskai analizuoti visuomeninių pastatų renovacijos procesą, jo sudėtines dalis, jame dalyvaujančias suinteresuotas grupes ir šį procesą veikiančią aplinką. Atlikta praktinė VGTU Centrinų rūmų renovacijos

daugiakriterinė analizė bei viso pastato daugiakriterinės variantinis projektavimas.

8. Atlikta įvairių pasaulio šalių mokslininkų atliktų mokslinių tyrimų grupinių ir derybinių sprendimo paramos sistemų srityje apžvalga bei pateiktos jų stipriosios ir silpnosios savybės. Išanalizuotas bendras derybų procesas. Atlikta derybinių sistemų statyboje apžvalga.
9. Sukurtas visuomeninių pastatų renovacijos proceso derybinio proceso kompleksinės analizės modelis, apjungiantis visas teigiamas tiek grupinių, derybinių sprendimo paramos sistemų aspektus bei leidžiantis kompleksiskai analizuoti visuomeninių pastatų renovacijos procesą ir jo pasėkoje atlikti efektyvias derybas. Šis modelis integruotas į Visuomeninių pastatų renovacijos sprendimų paramos sistemą.

Trumpai apie autorių

Andrius Gulbinas gimė 1975 m. spalio 4 d. Vilniuje.

1997 m. įgijo informatikos bakalauro, o 2001 m. vadybos ir verslo administravimo magistro laipsnį Vilniaus Gedimino technikos universiteto Statybos fakultete. Nuo 2005 m. dirba jaunesniuoju mokslo darbuotoju Vilniaus Gedimino technikos universiteto Internetinių ir intelektualųjų technologijų institute ir asistentu Vilniaus Gedimino technikos universiteto Statybos ekonomikos ir nekilnojamojo turto vadybos katedroje.

2001 – 2005 m. – Vilniaus Gedimino technikos universiteto Statybos technologijos ir vadybos katedros doktorantas. Stažavosi Škotijoje.

Padėka

Norėčiau padėkoti darbo vadovui, VGTU pirmajam prorektoriui prof. habil. dr. E.K. Zavadskui ir Statybos ekonomikos ir nekilnojamojo turto vadybos katedros vedėjui prof. habil. dr. A. Kaklauskui už neįkainojamą pagalbą bei patarimus rašant šį darbą. Dėkui visiems Statybos technologijos ir vadybos katedros darbuotojams už palaikymą ir pagalbą sprendžiant iškilusias problemas. Taip pat norėčiau širdingai padėkoti savo artimiesiems už kantrybę ir supratimą.

Andrius GULBINAS

**MULTIPLE CRITERIA WEB-BASED DECISION SUPPORT SYSTEM FOR
REFURBISHMENT OF PUBLIC BUILDINGS**

Summary of doctoral dissertation

Technological Sciences, Civil Engineering – 02T

Andrius GULBINAS

**VISUOMENINIŲ PASTATŲ RENOVACIJOS DAUGIAKRITERINĖ
INTERNETINĖ SPRENDIMŲ PARAMOS SISTEMA**

Daktaro disertacijos santrauka

Technologijos mokslai, statybos inžinerija – 02T

SL 136. 2005 11 17. 1,75 apsk. leid. 1. Tiražas 100 egz.

Leido Vilniaus Gedimino technikos universiteto leidykla „Technika“,
Saulėtekio al. 11, LT-10223 Vilnius-40
Spausdino UAB „Biznio mašinų kompanija“, Gedimino pr. 60, LT-01110 Vilnius