VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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MULTIPLE CRITERIA ASSESSMENT OF THE BUILT AND HUMAN ENVIRONMENT RENOVATION PROJECTS

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GYVENAMOSIOS APLINKOS ATNAUJINIMO PROJEKTŲ DAUGIAKRITERINIS VERTINIMAS

DAKTARO DISERTACIJA

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Abstract

The dissertation investigates the issues of the efficiency improvement of the built and human environment renovation from holistic perspective by using multiple criteria decision support methods and information technologies.

The dissertation consists of Introduction, 4 Chapters, Conclusions, References, List of Publications and 3 Annexes.

The introduction reveals the investigated problem, importance of the thesis and the object of research and describes the purpose and tasks of the paper, research methodology, scientific novelty, the practical significance of results examined in the paper and defended statements. The introduction ends in presenting the author's publications on the subject of the defended dissertation, offering the material of made presentations in conferences and defining the structure of the dissertation.

Chapter 1 revises scientific literature. Scope and definition of built and human environment is presented, a survey of research investigated in the field of built and human environment renovation, developed renovation models as well as computer-based systems performed. At the end of the chapter, conclusions are drawn and the tasks for the dissertation are reconsidered.

Chapter 2 presents the Conceptual Model for the Integrated Analysis of Built and Human Environment Renovation (IABHER) developed by author.

In Chapter 3 the developed model and multiple criteria decision-making methods are applied for assessment of the Cultural Heritage Renovation Projects in Bulgaria supported to EEA and Norway Grants. The hierarchically structured system of evaluation criteria is developed, weights of criteria determined, assessment and calculations of the projects' attributes as well as multiple criteria evaluation performed by traditional methods SAW, TOPSIS and COPRAS as well as the newly developed method ARAS in order to select the best project alternatives for granting.

Chapter 4 presents the developed Computer-Aided Decision Support System for Built and Human Environment Renovation (DSS-BHER) and detailed description of its components. The working principles with the system are explained and solutions to practical tasks provided.

13 articles focusing on the subject of the discussed dissertation are published: two articles – in the Thomson ISI Web of Science register, one article – in reviewed scientific journal, four articles – in the proceedings in Thomson ISI data base, three articles – in material reviewed during international conferences and three articles during national conferences. 10 presentations on the subject have been given in conferences at national and international level.

Reziumė

Disertacijoje nagrinėjamas gyvenamosios aplinkos atnaujinimo efektyvumo didinimas holistiniu požiūriu, taikant daugiakriterinės sprendimų paramos metodus ir informacines technologijas.

Disertaciją sudaro įvadas, keturi skyriai, išvados, naudotos literatūros ir autoriaus publikacijų disertacijos tema sąrašai ir trys priedai.

Įvadiniame skyriuje aptariama tiriamoji problema, darbo aktualumas, aprašomas tyrimų objektas, formuluojamas darbo tikslas bei uždaviniai, aprašoma tyrimų metodika, darbo mokslinis naujumas, darbo rezultatų praktinė reikšmė, ginamieji teiginiai. Įvado pabaigoje pristatomos disertacijos tema autoriaus paskelbtos publikacijos ir pranešimai konferencijose bei disertacijos struktūra.

Pirmame disertacijos skyriuje apžvelgiama mokslinė literatūra. Pateikiama gyvenamosios aplinkos (angl. *Built and human environment*) samprata, apžvelgiami Lietuvos ir pasaulio mokslininkų atlikti tyrimai ir jų rezultatai gyvenamosios aplinkos atnaujinimo srityje, analizuojami įvairių autorių siūlomi teoriniai modeliai ir sistemos. Skyriaus pabaigoje formuluojamos išvados ir tikslinami disertacijos uždaviniai.

Antrame disertacijos skyriuje pateikiamas autorės sukurtas koncepcinis gyvenamosios aplinkos integruotos analizės modelis.

Trečiame disertacijos skyriuje autorės sukurtas modelis ir daugiakriterinės analizės metodai pritaikomi sprendžiant praktinį uždavinį – vertinami Bulgarijos kultūros paveldo atnaujinimo projektai. Projektų paraiškos buvo pateiktos Europos ekonominės erdvės ir Norvegijos dotacijoms gauti. Sukurta hierarchinė vertinimo kriterijų sistema, nustatyti kriterijų svoriai, vertinamų projektų parametrai. Siekiant nustatyti geriausias projektų alternatyvas, daugiakriterinis vertinimas atliktas taikant žinomus daugiakriterinio vertinimo metodus SAW, TOPSIS ir COPRAS bei naujai sukurtą metodą ARAS.

Ketvirtame disertacijos skyriuje pristatoma sukurta kompiuterinė gyvenamosios aplinkos atnaujinimo sprendimų paramos sistema, pateikiamas išsamus jos elementų aprašymas. Aptartas darbas su sistema ir išspręstas praktinis uždavinys.

Disertacijos tema paskelbta 13 straipsnių: du – žurnaluose įtrauktuose į Thomson ISI Web of Science sąrašą, vienas – recenzuojamame mokslo žurnale; keturi – konferencijų medžiagose, referuotose Thomson ISI duomenų bazėje, trys – recenzuojamoje tarptautinių konferencijų medžiagoje bei trys – respublikinių konferencijų medžiagoje. Disertacijos tema perskaityta 10 pranešimų Lietuvos bei kitų šalių konferencijose.

Notations

Symbols

A^- – negative-ideal solution (TOPSIS method);

A^+ – ideal solution (TOPSIS method);

a_j – j^{th} alternative;

a_o – optimal alternative;

CI – Consistency Index;

C_i – i^{th} criteria group;

c_i – i^{th} criterion;

CR – Consistency Ratio;

$F(X)$ – cumulative distribution function;

IR – Random Consistency Index;

k – number of respondents;

K^* – optimal criterion (SAW method);

K_j – relative closeness to the ideal solution (TOPSIS method);

L_j^- – separation to the negative-ideal solution (TOPSIS method);

L_j^+ – separation to the ideal solution (TOPSIS method);

M – median;
m – number of attributes;
n – number of alternatives;
N_j – utility degree of the j^{th} alternative (COPRAS method);
N_j^* – utility degree of the j^{th} alternative (ARAS method);
P – initial decision-making matrix;
$\overline{P}$ – normalized decision-making matrix;
$\hat{P}$ – normalized weighted decision-making matrix;
Q – vector of criteria weights;
q_i – significance (weight) of the i^{th} criterion;
Q_j – efficiency index of the j^{th} alternative (COPRAS method);
r – rank;
R_j – effectiveness index (ARAS method);
S – total square deviation;
S_{+j} – sum of maximizing attributes (COPRAS method);
S_{-j} – sum of minimizing attributes (COPRAS method);
$S_{\text{-min}}$– minimal sum of minimizing attributes (COPRAS method);
T_k – index of reiterated ranks;
v – degree of freedom;
W – concordance coefficient;
x_{ij} – attribute value of the j^{th} alternative;
x_{ij}^* – value of minimized attribute (ARAS method);
α – level of significance;
λ – eigenvalue;
χ^2 – significance of the concordance coefficient;
χ_{tbl}^2 – critical tabular value of χ^2.

Abbreviations

AHP – Analytic Hierarchy Process;
ANC – Average of Normalized Columns;
ARAS – Additional Ratio Assessment;
CIB – International Council for Research and Innovation in Building and Construction;
COPRAS – A Method of Multiple Criteria Complex Proportional Evaluation;
COST – Cooperation in the Field of Scientific and Technical Research;
CP – Compromise Programming;

CREDIT – Construction and Real Estate – Developing Indicators for Transparency;
DSS – Decision Support System;
DSS-BHER – Computer-Aided Decision Support System for Built and Human Environment Renovation;
EEA – European Economic Area;
ELECTRE – Elimination and (et) Choice Translating Reality;
EMT – Ecological Modernization Theory;
EPSRC – Physical Sciences Research Council;
GDP – Gross Domestic Product;
HQE²R – Sustainable Renovation of Buildings for Sustainable Neighbourhoods;
IABHER – Integrated Analysis of Built and Human Environment Renovation;
IDCOP – Innovation in Design, Construction & Operation of Buildings for People;
MADM – Multi-Attribute Decision Making;
MCDM – Multiple Criteria Decision Making;
MEW – Multiplicative Exponential Weighting;
MODM – Multi-Objective Decision Making;
NGM – Normalization of the Geometric Mean of the Row;
NRA – Normalization of Row Averages;
R&D – Research and Development;
SAW – Simple Additive Weighting;
SUE – Sustainable Urban Environment;
SUREURO – Sustainable Refurbishment Europe;
TOBUS – Decision Making Tool for Office Building Upgrading;
TOPSIS – Technique for Order Preference by Similarity to an Ideal Solution;
VDA – Verbal Decision Analysis.

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Introduction

The Investigated Problem

The renovation of built and human environment as a whole has been analyzed insufficiently worldwide. The research problem considers increasing the efficiency of built and human environment renovation from holistic perspective by using multiple criteria decision support methods and information technologies.

Importance of the Thesis

The renovation industry has received increasing attention and grown hugely in the last years, because of the change in economic conditions and the emphasis on sustainable development. Although the renovation projects are relatively small, in some developed countries, the total turnover of the renovation market reaches almost a half of the total construction output (Davidson and Leather 2000). The degree and rate of degradation of the built environment in Europe is of enormous economic and technical importance, since the value of the built environment represents approximately 50% of the national wealth of most countries (Long *et al*. 2001).

The built environment refers to all the human-made spaces designed with a purpose to meet stakeholders' needs of living, working, resting and performing other activities. Furthermore, it is affected by various micro, meso and macro level factors. Due to the complex nature of the built environment, renovation decisions must be considered avoiding narrow approach of renovation assessment of single buildings. Renovation of the built and human environment renovation must be considered instead, the holistic approach used and the complex renovation of living areas performed including various types of buildings (i. e. housing, commercial, industrial, public), cultural heritage objects, infrastructure objects, the surroundings (i. e. parks, leisure zones), etc.

Holistic approach in built and human environment renovation assessment is relevant by following aspects:

1. Helps to satisfy the needs of all the stakeholders participating in the built and human environment renovation process.
2. Increases energy efficiency of buildings and reduces negative environmental effects as pollution, climate change, etc.
3. Helps to select the most valuable and efficient renovation measures, at the same time saves the resources of government and citizens.
4. Allows upgrading the built and human environment in avoidance of costly alternatives of demolition.
5. Increases the comfort and attractiveness of neighbourhoods by increasing value, prestige and potential rental income.
6. Facilitates maintenance and operation of the built and human environment objects, as well as reduces operating costs and the negative impacts on the environment.
7. Helps to develop the necessary infrastructure for the built and human environment and increases the security of the residential areas.
8. Encourages the socialization of communities and increases their interest to the surrounding environment, its administration and maintenance, value retention and management.
9. Partly helps to solve current problems of the construction sector caused by economic crisis – provides new activities and jobs to the participants of construction industry.

Holistic view to built and human environment renovation can be regarded as a kind of state competitiveness. It shows the capacity to carry out complex long-term and costly projects in collaboration of public authorities, business and social organizations. These projects require a combination of each individual resident's needs to the wider public interest: to use less of energy resources, indeed to live in safe, healthy and comfortable environment.

The Object of Research

The object of research integrates the renovation process of built and human environment, participating stakeholders' groups with specific aims and the external micro, meso and macro environments as a whole.

The Goal of the Thesis

The goal of the thesis is the evaluation and enhancement of the effectiveness of the built and human environment renovation through the application of the established Conceptual Model for the Integrated Analysis of Built and Human Environment Renovation (IABHER), multiple criteria evaluation methods and the developed Computer-Aided Decision Support System for Built and Human Environment Renovation (DSS-BHER).

The Tasks of the Thesis

In order to reach the goal, the following tasks must be solved:

1. To review research studies of scientists from various countries in the field of the built and human environment renovation.
2. To develop the Conceptual Model for the Integrated Analysis of Built and Human Environment Renovation.
3. To propose and practically apply multiple criteria assessment methodology for evaluation of the built and human environment renovation projects' alternatives.
4. To develop Computer-Aided Decision Support System for Built and Human Environment Renovation and to test the effectiveness of the developed system by practical task solution.

Research Methodology

Research methodology is based on analysis of publications by Lithuanian and foreign scientists in the field of renovation. Questionnaire surveys, expert analysis, multiple criteria analysis, comparative analysis, logics and synthesis methods are applied in the performed research.

The preparation the thesis was based on scientific publications, encyclopedia directories, specialized dictionaries, statistical publications, statistical data of various countries on the internet, other scientific and informational publications of Lithuanian and foreign scientific institutions.

Importance of Scientific Novelty

Preparation of the thesis revealed the following new results:

1. A unique Conceptual Model for the Integrated Analysis of Built and Human Environment Renovation facilitating integrated analysis of renovation process, participating stakeholders' groups and affecting macro, meso and micro environment was developed.
2. The hierarchically structured system of criteria fully describing the built and human environment renovation was offered, weights of criteria determined by the specified AHP method based algorithm proposed by author.
3. The multiple criteria analysis methodology for renovation projects assessment was proposed and practically applied in order to evaluate alternatives of renovation projects.
4. The original Computer-Aided Decision Support System for Built and Human Environment Renovation was developed and tested; it enables to perform an integrated analysis of the renovation process, its components, participating stakeholders' groups and the affecting environment factors as a whole.

Practical Significance of Achieved Results

The achieved research results can be used for efficient decision-making in the built and human environment renovation in national and international contexts, scientific projects as well as in an educational process of Vilnius Gediminas Technical University.

The research results were practically applied in ES ERABUILD programme project "Construction and Real Estate – Developing Indicators for Transparency" (CREDIT) as well as for Bulgarian cultural heritage projects applications assessment supported for European Economic Area (EEA) and Norway Grants. The results are also used during Construction economics lectures for undergraduate (bachelor) students.

The Defended Statements

1. In order to make and implement efficient renovation decisions, renovation of the built and human environment should be analyzed from the holistic perspective.
2. The holistic assessment of the built and human environment renovation projects can be performed basing on the hierarchically structured system of criteria, multiple criteria evaluation methods and information technologies.
3. Projects of the built and human environment renovation can be evaluated by the traditional multiple criteria evaluation methods SAW and COPRAS and the newly developed method ARAS.
4. The developed original Computer-aided Decision Support System for Built and Human Environment Renovation facilitates automatic evaluation of renovation projects alternatives in holistic perspective; it helps to determine efficiency and utility degree of alternatives in comparison to the optimal alternative and to select the best alternative.

Approval of the Results

The main statements of the thesis were published in 13 scientific articles: two articles – in the Thomson ISI Web of Science register (Mickaitytė *et al*. 2008; Tupėnaitė *et al*. 2010), one article – in reviewed scientific journal (Tupėnaitė *et al*. 2008a), four articles – in the proceedings in Thomson ISI data base (Kaklauskas *et al*. 2007; Kaklauskas and Tupėnaitė 2008; Tupėnaitė and Kanapeckienė 2007; Zavadskas *et al*. 2008a), three articles – in the reviewed proceedings of international conferences (Raslanas *et al*. 2006; Tupėnaitė 2006a; Tupėnaitė *et al*. 2008b) and three – in other editions (Tupėnaitė 2006b; Tupėnaitė 2007; Tupėnaitė and Kanapeckienė 2008).

The main statements of the thesis were discussed during ten international and national scientific conferences and seminars:

- one – in the 25th International Symposium on Automation and Robotics in Construction (ISARC 2008), held in Vilnius, 2008;
- two – in the International Conference on Reliability and Statistics in Transportation and Communication (RelStat), held in Riga, 2007–2008;
- one – in the 9th International Conference on Modern building materials, structures and techniques, held in Vilnius, 2007;
- one – in the 7th International Conference on Environmental Engineering, held in Vilnius, 2008;
- one – in the International Conference on Buildings Energy Efficiency in the Baltics (BENEFIT-2006), held in Riga, 2006;
- one – in the 5th International Conference on Riga Forum 2006: Investment in the Baltic Metropolitan Regions, held in Riga, 2006;
- three – in the Conference of Lithuanian Young Scientists "Lithuania without science – Lithuania without Future", held in Vilnius, 2006–2008.

Dissertation Structure

The thesis consists of Introduction, 4 Chapters, Conclusions, References, List of Publications and 3 Annexes. The structure of the thesis is presented in Figure 1.

The volume of the thesis is 129 pages, excluding annexes, 39 numbered formulas are used, 18 pictures and 24 tables. Thesis prepared basing on 216 references.

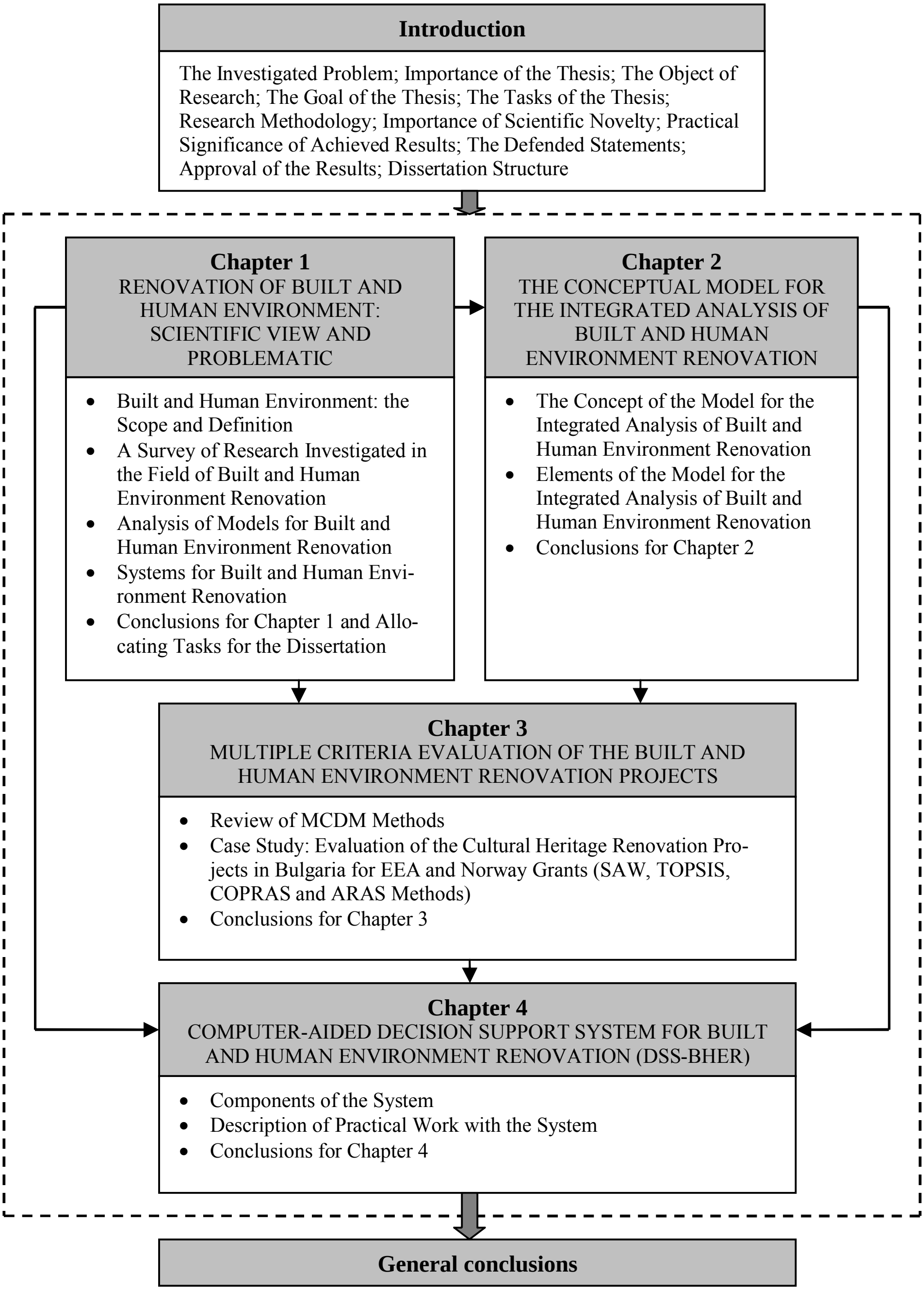

Fig. 1. The structure of the doctoral thesis

1

Renovation of Built and Human Environment: Scientific View and Problematic

In this chapter the scope and definition of the built and human environment is presented, a survey of research investigated in the field of built and human environment renovation performed, developed renovation models as well as computer-based systems discussed.

On the thematic of this chapter 12 publications (Mickaitytė *et al*. 2008; Zavadskas *et al*. 2008a; Tupėnaitė *et al*. 2008a,b; Tupėnaitė 2006a,b, 2007; Tupėnaitė and Kanapeckienė 2007, 2008; Kaklauskas and Tupėnaitė 2008; Kaklauskas *et al*. 2007; Raslanas *et al*. 2006) were published.

1.1. Built and Human Environment: the Scope and Definition

The notion of *built environment* is relatively recent. In common was started to be used in the literature since the mid-1970s. The origin is clearly in anthropological and behavioural studies concerning the influence of form and space on the individual and social behaviour (Rapoport 1976). The concept has evolved in anthropology and in more recent research the built environment was understood as the result of a process of social construction (Lawrence and Low 1990).

The term *built environment* came into widespread use in the 1990s (Crowe 1997). In common parlance, the built environment generally refers to the "man-made surroundings that provide the setting for human activity, ranging from the large-scale civic surroundings to the personal places" (Moffatt and Kohler 2008). Indeed there is still no unified view and definition of this concept in the scientific literature. Various authors analyzed built environment from the different perspectives, research goals and activity spheres.

Broad understanding of the built and human environment was given by Bartuska *et al*. (2007). Author suggests defining the built environment by four interrelated characteristics. First, it is extensive; it is everywhere; it provides the context for all human endeavors. More specifically, it is everything humanly created, modified, or constructed, humanly made, arranged, or maintained. Second, it is the creation of human minds and the result of human purposes; it is intended to serve human needs, wants, and values. Third, much of it is created to help human deal with, and to protect human from, the overall environment, to mediate or change this environment for human comfort and well-being. Last, an obvious but often forgotten characteristic is that every component of the built environment is defined and shaped by context; each and all of the individual elements contribute either positively or negatively to the overall quality of environments both built and natural and to human-environment relationships. These impacts are almost always local, and more and more are experienced at every scale, including global and even planetary (Habraken and Teicher 2000).

The discussed view is visualized in Figure 1.1. According to author, "the variety and scope of the built environment, its diverse content can be summarized into seven interrelated components: products, interiors, structures, landscapes, cities, regions, and the Earth". The sum of the seven defines the scope of the total built environment (Bartuska *et al*. 2007).

The term *built environment* is an integral part of the new definition of landscape architecture approved in 2003 by the International Federation of Landscape Architects. Tasks considered to be central to their work include the "planning, design, management, maintenance and monitoring of functional and aesthetic layouts of built environments" and "identifying and developing appropriate solutions regarding the quality and use of the built environment in urban, suburban and rural areas" (*Definition…* 2003).

Moffat and Kohler (2008) conceptualized the built environment as the social – ecological system (Fig. 1.2). In the given model the nested hierarchy grows from the building footprint or parcel, through block, cluster, neighbourhood, city and region.

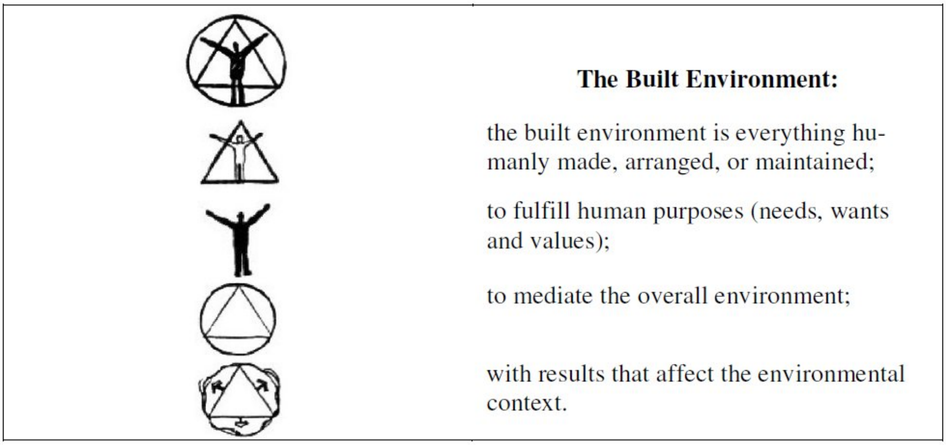

Fig. 1.1. Definition of the built environment and its four interrelated characteristics
(Bartuska *et al*. 2007)

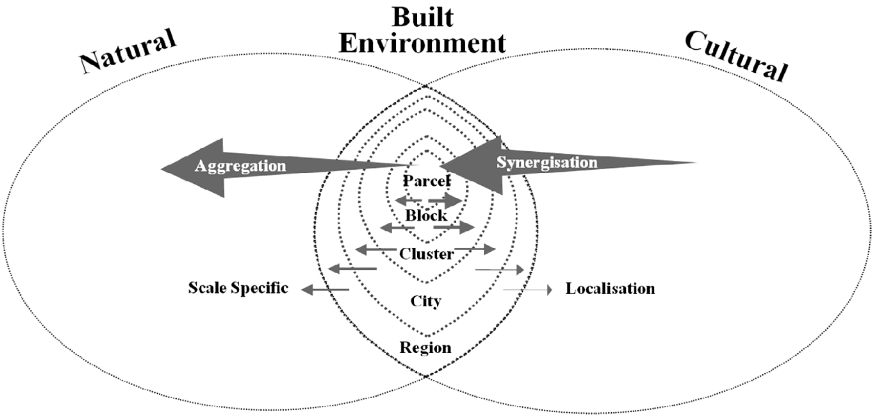

Fig. 1.2. Built environment as social – ecological system
(Moffat and Kohler 2008)

As spatial scales change, some physical effects are aggregated, while others are scale specific; some decision-making begins at the most local scale and seeks to maximize self-reliance, while other decision-making begins at the macro-scale and seeks to enable positive synergies (Moffatt and Kohler 2008).

Numerous behavioral theories and models include *environment* as a construct. From this view, the built environment consists of the neighborhoods, roads, buildings, food sources, and recreational facilities: the places in which human live, work, are educated, eat, and play (Glanz and Kegler 2007). Research to understand the impact of neighborhoods on health has grown significantly over the past decade as public health has more fully embraced a social ecological perspective. Neighborhood effects have been documented for a broad range of health and social outcomes, including birth weight, injury, mental health, and physical activity, among others (Diez-Roux 2001; Leventhal and Brooks-Gunn 2003; Hoehner *et al*. 2005). For example, research on physical activity and neighborhood environments indicates that people are more physically active in neighborhoods with recreational facilities, a mixture of land uses, connected streets, higher residential density, and enjoyable scenery (Humpel *et al*. 2002; Saelens *et al*. 2007). Walkable, mixed-use neighborhood designs can encourage the development of social capital (Leyden 2003).

Another concept states that the *built environment* includes all buildings and living spaces that are created, or modified by people. In addition to the buildings and spaces themselves, it also includes the infrastructural elements such as waste management, transportation and utility transmission systems put in place to serve this building space (Sarkis *et al*. 2008). From this point of view, the *built environment* addresses all buildings, housing, infrastructures, fixed equipment and communities.

The *built environment* refers to human – made spaces that they live and work in. A built environment is designed with a purpose, typically to meet some optimal set of organizational, customer, and employee needs. These needs often contradict each other and complicate decision-making about the built environment. The built environment is the result of design – organization, employee, and customer needs are designed into the space (Mallak *et al*. 2003).

Furthermore, it can be stated that buildings relate to people, and *vice versa*. Buildings affect people, and people respond to buildings. To an extent buildings also respond to people. For instance, technology exists that will turn on or turn up heating when a sensor detects the presence of people and/or low temperature – the so-called intelligent (or more accurately automated) building. The performance of a building can be measured, monitored and controlled. But this tends to be limited, for instance, measuring and controlling energy use per square meter, or space used per occupant or per hour. The building attracts users and visitors who may be customers or tourists, users of shops, cafes, restaurants, cinemas and theatres in the vicinity: the social and commercial "infrastructure". The building both supports and is supported by its context (Kaklauskas and Zavadskas 2009; Wood 2006).

The summary of the analyzed built environment definitions is provided in Table 1.1.

Considering the evolution of built environment definitions it can be concluded that the built environment is not constructed in empty place and relates to people in positive or even negative ways; on the other hand, built environment is directly affected by people. During the built environment life cycle – brief, designing, construction, maintenance, facility management, renovation, demolition and utilization – buildings are also affected by various micro, meso and macro level factors.

Table 1.1. Definitions of built environment

Author	Definition
Lawrence and Low (1990)	Built environment – the result of a process of social construction.
Crowe (1997), Moffatt and Kohler (2008)	Manmade surroundings that provide the setting for human activity, ranging from the large-scale civic surroundings to the personal places.
Gaining… (2003) Bartuska *et al*. (2007)	Built environment relates to four interrelated characteristics and seven interrelated components: products, interiors, structures, landscapes, cities, regions, and the Earth.
Moffat and Kohler (2008)	Built environment as social – ecological system. The nested hierarchy grows from the building footprint or parcel, through block, cluster, neighbourhood, city and region.
Glanz and Kegler (2007)	The built environment consists of the neighborhoods, roads, buildings, food sources, and recreational facilities: the places in which human live, work, are educated, eat and play.
Sarkis *et al*. (2008)	The built environment addresses all buildings, housing, infrastructures, fixed equipment and communities. It also includes the infrastructural elements such as waste management, transportation and utility transmission systems put in place to serve building space.
Mallak *et al*. (2003)	Human – made spaces where they live and work in.
Wood (2006) Kaklauskas and Zavadskas (2009)	Environment in which buildings relate to people, and *vice versa*.

The built environment is developed in order to satisfy the requirements of its residents (Kaklauskas and Zavadskas 2009). Human needs can be physiological or social and are related to security, respect and self-expression. People want their built environment to be aesthetically attractive and to be in an accessible place with a well-developed infrastructure, convenient communication access and good roads, and the dwelling should also be comparatively cheap, comfortable, with low maintenance costs and have sound and thermal insulation of walls. People are also interested in ecologically clean and almost noiseless environments, with sufficient options for relaxation, shopping, fast access to work or other destinations and good relationships with neighbours. The built environment can affect the whole of society or specific groups of people and individuals. For example, poor dwellings are non-aesthetic, uncomfortable and can be sources of various diseases or pose acute social problems such as a dirty or crime-ridden environment. These factors affect neighbourhoods from various perspectives. Although the most serious problems of built environments, e.g. unemployment, vandalism, lack of education, robberies, are not always related to the direct physical structure of housing. Increasing investment into the development of social and recreational centers, such as athletic clubs, physical fitness centers, and family entertainment centers, the infrastructure, a good neighbourhood and better education of young people, can solve such problems (Kaklauskas and Zavadskas 2009).

Provided examples allow coming to the conclusion that various stakeholders usually would prefer the concept of a *built and human environment* to the concept of a built environment. This proposition is especially true, when not only the built environment, but also the surrounding micro, meso or macro environment as well as stakeholders' needs, is considered as a research object. From this perspective the renovation is analyzed in this thesis – the holistic approach is used. Accordingly, the integrated renovation of the built and human environment is researched.

1.2. A Survey of Research Investigated in the Field of Built and Human Environment Renovation

In achieving sustainable development of the modern built and human environment, the building industry is a key player. It has impact on all three aspects of sustainability: economic development, social development and environmental protection (*UN Report*... 2002). Indeed building investments represent 10% of the GDP in western economics, the environmental impact of building activities – as it uses more raw materials than any other sector' (*Enterprise*... 2006) – is important as well. Moreover, buildings operation stands for one-third of Europe's primary energy demand, contributing to a large extent to greenhouse gas emissions. For the USA, similar findings have been reported (Der-Petrossian and Johansson 2000; De Meester *et al.* 2009, Kaluarachchi *et al.* 2005).

Buildings are also a major pollution source. They account for about half of sulphur dioxide emissions, a quarter of nitrous oxide emissions, about 10% of particulate emissions and about 35% of carbon dioxide emissions which are closely related to climate change, while construction wastes have a major impact on landfills. Building practices in the past have not properly addressed the current concerns about the optimum use of energy in buildings or the minimization of the environmental effects. In addition, ageing installations and facilities result in an even grimmer scenario. Existing buildings are often energy costly to operate, with serious indoor environmental quality problems (*Annual Bulletin*...2008).

However, buildings constitute a huge investment in natural and human resources, and the building stock is an enormous pool of private and public investment. According to studies carried out by the *European Cooperation in the field of Scientific and Technical Research* (COST), the estimated value of European Urban Heritage amounts to about 40 trillion Euro for the housing stock alone.

The existing building stock in Europe is estimated at 150 million dwellings (*Annual Bulletin*...2008), whereas only around 2 million are built every year. About 70% of the residential building stock is over 30 years old and about 35% are more than 50 years old. Lower quality of these buildings is directly related to obsolescence problems. Seeley (1983) has distinguished six types of obsolescence:

- *physical obsolescence*: while all buildings experience natural decay over time, accelerated deterioration leads to reduced physical performance and obsolescence. Natural decay is not considered an attribute of obsolescence but rather of age;
- *economic obsolescence*: the period of time over which ownership or use of a particular building is considered to be the least cost alternative for meeting a business objective governs investor interest and obsolescence based on economic criteria. Economic obsolescence can also include the need for locational change;
- *functional obsolescence*: change in owner objectives and needs leads to possible functional change from the purpose for which a building was originally designed. Many clients of the building industry, particularly in manufacturing industries, require a building for a process that often has a short life span;
- *technological obsolescence*: this occurs when the building or component is no longer technologically superior to alternatives and replacement is undertaken because of expected lower operating costs or greater efficiency;

- *social obsolescence*: fashion or behavioural changes (e.g. aesthetics, religious observance) in society can lead to the need for building renovation or replacement;
- *legal obsolescence*: revised safety regulations, building ordinances or environmental controls may lead to legal obsolescence.

Number of parameters like the quality of construction and materials, the local weather conditions or the lack of maintenance, can greatly influence obsolescence process. Air pollution can damage building materials because of their long life (Rabl 1999). Man-made pollutants have greatly increased the degradation rate of buildings. Of particular importance are corrosion caused by acid rain (especially due to SO_2) and soiling caused by particles (especially soot) (Balaras *et al*. 2005). Numerous studies have quantified the effects of air pollution on corrosion and erosion on different building materials like natural stone decay (Torfs and Van Grieken 1997; Moropoulou *et al*. 1995), wood (Morrell 2002), finishing surface coats (Ali *et al*. 2000), and various other building materials (Crammond 2002).

Exterior building surface degradation is one of the major concerns for building owners that tend to decide on exterior renovation actions on the basis of the general appearance of a building. Air pollution damage to buildings (Rabl 1999) includes expenditures to restore the original condition of the damaged object (i. e. cleaning), preventive measures (i. e. the extra cost of paint with enhanced resistance to pollution), and loss of amenity (i. e. aesthetic loss as a building becomes dirty). In a study for calculating the damage cost of French buildings caused by individual sources of pollution, it was found that the amenity loss is approximately equal to the renovation cost.

Numerical models describing the deterioration process of masonry subjected to an aggressive environment, in order to predict time taken to reach a given damage level has been presented by Pavani *et al*. (2003). Efforts have also been made to describe the deterioration process of building materials and components and to predict the future degradation state of a building, for example, the probable date of repair or replacement, since this is directly connected to higher refurbishment costs (Flourentzou *et al*. 2000).

The service life of a building element is defined as the period of time, measured in years, after installation during which all properties meet or exceed the minimum acceptable values when routinely maintained. Service life prediction or demand for durability has been treated in several national standards and building codes (Rudbeck 2002).

Buildings are major assets and form a significant part of facility management operations. Although buildings are long lasting they require continual maintenance and restoration. Eventually, buildings can become inappropriate for their original purpose due to obsolescence, or can become redundant due to change in demand for their service. It is at these times that change is likely: demolition to make way for new construction or some form of refurbishment or reuse (Langston and Lauge-Kristensen 2002) or, in general terms, *renovation*.

The concept *renovation* is usually divided under two categories: retrofit and refurbishment. The concept *retrofit* is generally used to identify actions that are required to bring a building into the framework of new requirements. The purpose of *refurbishment*, instead, is to bring a building back to its original state (Flourentzou and Roulet 2002).

Refurbishment can of itself take many forms, ranging from simple redecoration to major retrofit or reconstruction. Sometimes the buildings are in good condition but the services and technology within them are outdated, in which case a retrofit process may be undertaken. If a particular function is no longer relevant or desired, buildings may be converted to a new purpose altogether. This is *adaptive reuse* (Langston and Lauge-Kristensen 2002).

Older buildings may have a character that can significantly contribute to the culture of a society and conserve aspects of its history. The preservation of these buildings is important and maintains their intrinsic heritage and cultural values. Facility managers are frequently faced with decisions about whether to rent or buy, whether to extend or sell, and whether to refurbish or construct. Usually these are financial decisions, but there are other issues that should bear on the final choice, including environmental and social impacts (Langston *et al*. 2008).

Johnson (1996) indicates that society has advanced and its use of buildings has become more temporal. He states that "advances in technology and commerce, including the growth of industrial and office automation, and user demands for more comfortable environments for work and leisure have led to large numbers of buildings becoming obsolete or redundant and these changes have provided an abundance of buildings suitable for rehabilitation and reuse".

In addition to the above, environmental obsolescence is relevant to today's society. Environmental issues are assumed to be within technological obsolescence, but as the marketplace becomes more environment-conscious both social and legal obsolescence will also reflect environmental actions. For these reasons, buildings can become obsolete long before their physical life has come to an end. Investing in long-lived buildings may be sub-optimal if their useful life falls well short of their physical life. It is wise to design future buildings for change by making them more flexible yet with sufficient structural integrity to support alternative functional use (Langston *et al.* 2008).

The renovation industry has received increasing attention and grown hugely in the last decade, because of the change in economic conditions and the emphasis on sustainable development (Egbu 1999). Global organizations have invested plentiful resources in creating sustainable renovation environments (Hartkopf and Loftness 1996). Although a renovation projects are relatively small, in some developed countries, the total turnover of the renovation market reaches almost a half of the total construction output (Davidson and Leather 2000). The degree and rate of degradation of the built environment in Europe is of enormous economic and technical importance, since the value of the built environment represents approximately 50% of the national wealth of most countries (Long *et al.* 2001).

It is now time for Europe to have an ambitious renovation programme to accelerate the shift towards a low carbon and resource efficient economy while increasing housing quality, improving energy and water efficiency and citizens' health, creating new jobs and skills in the construction sector of the 27 EU Member States. In the US, the Department of Energy's "Rebuild America's Housing" program aims to partner with public and private housing organizations throughout the nation to make building improvements and provide solutions to housing needs while saving energy and reducing utility costs (*Rebuilding Europe's Housing*...2008).

In view of the French Presidency of the EU, stakeholders in the construction sector making purchases, investments, setting standards and rating performance have started to rally to ensure the implementation of the EU 2020 objectives in the field of sustainable development and climate change (reduction of GHS, increase of energy and resource efficiency and renewables). The European Council indeed called for an ambitious response from the business world and "interested parties" to activate "market-based levers" in order to ensure the implementation of these objectives. A wide range of initiatives are already set in motion by the different construction companies however, there is a need for convergence and coordination of efforts to encourage synergies with suppliers of environmental materials and technologies and other stakeholders on common criteria to help achieve the 2020 objectives (*Rebuilding Europe's Housing*...2008).

Renovation of the built environment, however, is usually characterized by complex and heterogeneous natures that require various specialties to integrate in highly variable conditions (Egbu 1999). Furthermore, a thorough building's renovation evaluation is quite difficult to undertake, because a building and its environment are complex systems e.g., technical, technological, ecological, social, comfort, esthetical, etc., where every sub-system influences the total efficiency performance and where the interdependence between sub-systems adopts a critical role (Kaklauskas *et al.* 2005). For these purposes the renovation processes should be evaluated in the more integrated way – considering the problem of the built and human environment renovation as a whole, resisting the narrow approach of single (isolated) buildings renovation.

The cyclical nature of the construction industry, the fact that the built environment is aging at a fast rate, the overall reduction in new building construction and the increasing awareness for sustainability, open new opportunities for expanding the refurbishment and reconstruction of buildings (Shaurette 2008). A recent report outlined a set of challenges that may cause construction markets to change direction in the near future. The first challenge outlined indicated that "aging infrastructure in nearly every market segment is at or beyond its current useful life…representing trillions of dollars in necessary spending over the next 10 to 20 years to upgrade and replace these assets" (*Annual Bulletin* …2008). These asset upgrades include change in use, upgrade of mechanical or electrical systems, restoration of deteriorated building envelopes, repair of structural damage, renovations to reduce service ability problems, changes to satisfy government mandates, repair of original construction and corrections to previous renovation errors. In spite of challenges due to being more difficult and requiring less qualified workers than new construction, maintenance and refurbishment activities are implemented by owners to maintain or raise the value of a building, thus decreasing its wear and obsolescence (Zavadskas *et al*. 1998).

Building renovation is often considered as a technical matter that concerns technical experts and engineers. However, every renovation operation modifies the human living environment. A narrow technical or financial vision can deteriorate people's living environment, while a global approach can upgrade it to current comfort standards, ecological requirements, and optimal energy performance (Genre *et al*. 2000).

There is a wealth of literature on a number of related topics covering renovation subjects including:

- depreciation of building components over time and the need of upgrading to maintain property value (Robinson and Reed 2002; Gyourko and Saiz 2004; Yau *et al*. 2008; Vijverberg 2001);
- minimization of life-cycle cost of buildings caused by implementation of retrofit measures (Gustafsson 2002; Ortiz *et al*. 2009; Ozela and Kohlerb 2004);
- associated benefits on building condition and property value after renovation of energy saving measures (Gorgolewski 1995; Martinaitis *et al.* 2004, 2007; Cakmanus 2007; Papadopoulus *et al.* 2002; Stankevicius *et al.* 2007; Hong *et al*. 2006; Roberts 2008; Raslanas *et al*. 2006[*]; Tupėnaitė 2006a[*],b[*]);
- timing of renovation (Rosenfeld and Shohet 1999); and
- rehabilitation versus new construction of housing (Johnstone 1995, 1997; Shah and Kumar 2006; Power 2008).

[*] The reference is given in the list of publications by the author on the topic of the dissertation

Furthermore, renovation benefits can be classified as economic, social and environmental (Tupėnaitė 2008*; Kaklauskas *et al.* 2007*). These are discussed in more detail.

Economic benefits. Firstly, the financial – economic aspect of renovation should be mentioned, which could be characterized as *real estate value enhancement*. It is usually agreed that renovation would enhance the market value of the property, but there are few empirical studies on it. Theoretical models can be traced back to Sweeney (1974), Dildine and Massey (1974). They have developed models on the opposing impacts to the rate of depreciation of maintenance, on the premise that renovation produced net value enhancement. Recent research works analyzed renovation investments estimation problems. Wong (2000) valued the refurbishment cycle by cost and timing criteria, Mansfied (2000) defined renovation as housing investment category, while Chau *et al.* (2003), Zavadskas *et al.* (2004a) used hedonic model for multiple-ownership buildings renovation investment valuation. Kangwa and Olubodun (2007) performed a survey of owners' satisfaction of renovation works. They conclude that "when all the notable variations in the satisfaction rating on follow-on maintenance strategies and expectations are considered together, it is the perceived increase in the value of a property – ensued from improvement works under the urban renewal programme – that stands out as the main influencing criteria". Hui *et al.* (2008) research results in Hong Kong provided strong evidence that rehabilitation has significant contributions in increasing property values of old, rehabilitated residential buildings. Empirical evidence shows that the price of renovated apartments increase about 10 percent (Chau *et al.* 2003) and this has positive effect on total built environment.

Martinaitis *et al.* (2004, 2007) propose the coefficient of a building element's rehabilitation as one of the possible methods of how, when taking into account both the energy saving and the improvement of building's elements condition, it would be possible to involve the benefit of the rehabilitation of elements into the energy saving projects for a buildings' renovation. This indirectly expressed benefit appears as the avoidance of a reduction of the total value of a building through the rehabilitation of the technical characteristics of a building's elements with regard to their functionality and safety.

Rehabilitated space can be created more quickly than new space, unless extensive structural reconstruction is required. Johnson (1996) suggests that rehabilitation typically takes half to three-quarters of the time necessary to demolish and reconstruct the same floor area. The shorter development period reduces the cost of financing and the effect of inflation on construction costs, so organizations that wish not to relocate have less disruption to operations and cash flow, reducing temporary accommodation expenses (Langston *et al.* 2008).

Despite the time advantages, the cost of converting a building is generally less than new construction because many of the building elements already exist. Given there are no expensive problems to overcome, like asbestos removal or foundation subsidence, the reuse of structural elements is a significant saving. Older buildings, however, may not comply with present regulations, particularly in the area of fire safety, which may generate some structural changes or additional protective measures. It is essential that any building being considered for major refurbishment have a thorough survey undertaken to confirm its structural and constructional quality, and its compliance with building ordinances (Langston *et al*. 2008).

Although there is a large body of literature focusing on the effects of the neighbourhood quality on the property value (i. e. Colwell *et al*. 2000; Boyle and Kiel 2001), studies on the aesthetical impact of the surrounding environment on property value are not rich. Among these studies, most showed that the visual quality of the surrounding environment posed great influence on property value. For instance, Benson *et al*. (1998) found that various qualities and types of water view commanded different premiums for waterside properties in the United States. Hamilton and Schwann (1995) found that the removal of visually unpleasant high voltage electric transmission line towers from adjacent properties in the United States increased their property value significantly by 5.7%.

However, only few studies focused on the quality of neighbourhood buildings on property value. Bourassa *et al*. (2004) by studying property transactions in New Zealand found that the presence of attractive buildings in the neighbourhood of a property added 37% to its value. By the same token, poorly maintained buildings should depress the value of neighbourhood properties. Negative externalities are created by the unsightliness of the poor properties. Refurbishing these poor buildings should reduce or even counter the externalities to their neighbourhoods.

Social benefits. Older buildings sometimes provide social benefits such as intrinsic heritage values. They can retain attractive streetscapes, add character, and provide status and image to an organization through the use of massive and highly crafted materials. Older buildings are often in advantageous locations in city centers and close to transport making reuse (where appropriate) more viable. They add to a sense of community and are often appreciated as comfortable working environments by occupants. Reduction in vacant or derelict buildings potentially adds vibrancy to communities, reduces crime and other unsocial behaviour, and raises living standards through added investment and revitalization (Langston *et al*. 2008). However, issues of legislative compliance, fire safety, disabled access and heritage constraints (such as a requirement for facade retention) are possible disadvantages that should be properly explored.

The study performed by Hong *et al.* (2008) analyzed the impact of the Warm Front energy efficiency scheme on domestic thermal comfort based on field surveyed data collected from a large sample of low-income households in England. The evidence showed that the introduction of insulation and central heating leads to increased indoor temperature and improved thermal comfort clearly demonstrating the process of take-back.

According to Hui (2005) projects and renovation works are initiated to:

- satisfy the latest requirements with regard to statutory compliance;
- satisfy tenant requirements;
- optimize space utilization;
- improve security, health and safety; and
- upgrade building services systems for better energy efficiency and indoor air quality.

Environmental benefits. Ecological modernization theory (EMT) is a theory for environmental innovation that has been offered as a possible solution to the conflict between industrial and commercial development and environmental protection (Sarkis *et al.* 2008).

Environmental benefits from rehabilitation arise through the recycling of materials, reuse of structural elements and the reduction in generated landfill waste. These translate into cost advantages to the owner, but have much wider environmental implications. Older buildings sometimes were constructed using a range of quality materials that typically display a useful life well in excess of their more modern counterparts (e.g. use of solid stone walls, slated roofs, marble floors, etc.).

Furthermore, many older buildings employ massive construction in their external envelope, which can reduce energy consumption in heating and cooling and deliver long-term operational efficiencies. Opening windows, natural ventilation and natural lighting are all desirable qualities where external noise and pollution are not issues.

Low-rise structures also eliminate the need for expensive vertical transportation systems. The reuse of existing public infrastructure, like telecommunications, water, gas, sewerage and drainage, can relieve demands on local authorities to extend infrastructure and to reclaim natural landscapes for sprawling urban development (Langston *et al.* 2008).

Recent research has shown that 40% of energy consumption could be saved, provided that using energy efficiently. Furthermore, every reduction in energy-usage has a significant influence on environmental protection and CO_2 emissions (Cakmanus 2007).

The issues of integral sustainable renovation of buildings have been intensively tackled for years in the countries of central Europe, and among others: Austria, Switzerland, Germany, and the Netherlands. Scandinavian countries though, have already developed different strategies of integral renewal in Denmark, Sweden, etc. The area of renewal of housing structures is taking a central place in the efforts for integral renovation and revitalization of larger areas, especially in larger housing estates (Ruano 2002). Among the most typical approaches can be included development models for energy efficient renovation, which through the use of new materials and the testing of new techniques also support different branches of the construction industry. In the aforementioned countries, the state financial stimulations, education, research, and accordingly adjusted policy of city authorities brought numerous positive results and experiences (Bueren 2006).

Sitar *et al*. (2006) emphasize the following integrated sustainable renovation principles:

- improvement of living conditions and provision of user-friendly apartments, increasing flexibility of the whole building concept and its parts, according to the current and future needs of inhabitants;
- decrease energy use and related building operational expenses;
- increased use of environment-friendly materials and renewable energy sources;
- economically favorable and innovative planning, building and using measures.

The aforementioned definitions and factors state that sustainable renovation is mostly related to technical – ecological aspects of building life cycle. Definitely it also involves satisfaction of social (healthy housing and environment, etc.) and economic (energy saving, low maintenance costs, etc.) needs. Integration of these needs makes the concept of *Sustainable Development* implemented (Kaklauskas *et al*. 2007[*]).

From the reviewed researches results it can be summarized that there is still a lack of empirical studies with the complex view to built environment renovation and it affecting macro, meso and micro environment factors as a whole.

1.3. Analysis of Models for Built and Human Environment Renovation

Much of the empirical work on renovation is based on *simple optimization models* in which a homeowner or landlord chooses the level of capital investment to maximize some objective function. For instance, Mayer (1981) presents a capital stock adjustment model to study rental housing rehabilitation, Za-

[*] The reference is given in the list of publications by the author on the topic of the dissertation

vadskas *et al*. (2004a) – a mathematical model for evaluation of investments into housing renovation.

Other proposed models can be defined as the *process-based models*. For instance, Hassanien and Losekoot (2002) propose the basic model of hotel renovation process. This model consists of four fundamental interrelated phases, which are common to any type of renovation: pre-planning, planning, implementation, and evaluation.

More complex models deal with *Building Life Cycle Analysis and costs management* (Shabha 2003; *Gaining…* 2006; Kaklauskas 1999; Zavadskas *et al*. 2001a,b). Figure 1.3 describes the different steps in a refurbishment process: diagnosis, brief, design, construction and the operation of the refurbished building.

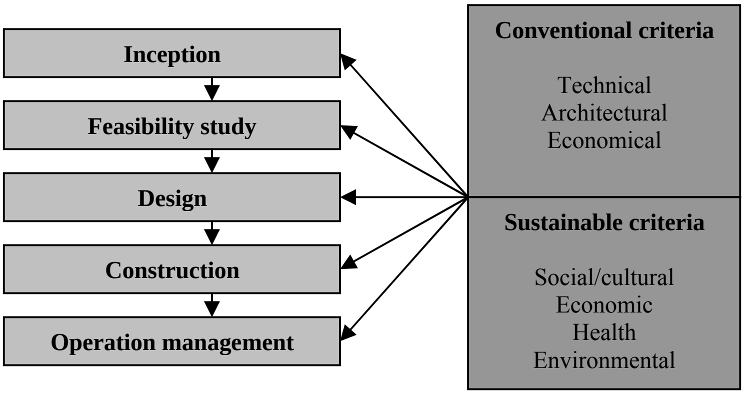

Fig. 1.3. Five steps of a refurbishment process (*Integrated Planning*... 2005)

According the model, all along the refurbishment process, integrated planning has to deal with various criteria that can be divided into two categories:

Conventional criteria:

- architectural (organization of spaces, aesthetics, functionality, flexibility);
- technical (law, regulation and standards, safety, durability, performance, maintenance);
- economical (investment cost, operation and maintenance costs, life-cycle costs).

Sustainable criteria:

- environmental protection (rational use of natural resources, reduction of air and water pollution, reduction of nuisance during the construction phase);

- human health and well-being (hydro-thermal, acoustic and visual comfort, indoor air and water quality);
- economic life and cultural concerns.

Flier and Thomsen (2005) have presented the National Renovation Award (Nationale Renovatie Prijs, NRP) Analytical model. The model starts from the NRP definition of renovation as "transformation (process) of the physical, functional, financial, architectural and ecological characteristics of a building or project (product) to realize a comprehensive and useful extension of the lifespan". It takes two steps. The first one is a description of the initial situation and the objectives of the participants and a description of the renovation process and product. Second step is an assessment of the results by means of the evaluation criteria effectiveness of the process (goal attainment), efficiency of the product (cost-benefit relation) and legitimacy of both process and product (support and acceptance from participants).

Recently much attention has been paid to *sustainable renovation issues*. It reflects in scientific models proposed by various researches as well as in the projects funded by the European Commission, i. e. SUREURO (Bueren *et al*. 2006), TOBUS (Caccavelli and Gurgerli 2002), Brita in Pubs (*Bringing*…2004), HQE^{2}R (Mørck *et al.* 2004).

Sustainable Renovation of Buildings for Sustainable Neighbourhoods (HQE^{2}R) project was partly funded by the European Commission under the Fifth Framework Research and Development (R&D) Programme. In the HQE^{2}R project 14 neighbourhoods and 10 research institutes in 7 European countries were cooperating to provide methods and tools for use by local municipalities and their partners: government agencies, planners, landlords, local citizens and other users in sustainable urban renewal projects. The objectives of the HQE^{2}R project were to promote sustainable development and quality of life in urban neighbourhoods. The methodology describes 4 main phases (inventory, identifying priorities, defining and assessing scenarios and finally setting up an action plan) and is based on a set up of sustainable development targets (Mørck *et al.* 2004).

In 2003 the European Commission also initiated the Fifth Framework project *Sustainable Refurbishment Europe* (SUREURO). SUREURO has developed models and systems that provide housing organizations, interested parties, local authorities, town planners, construction companies etc., opportunities to perform refurbishment processes within a normal time schedule and budget. In proposed sustainable refurbishment model Sustainable Process Management connects the key topics Property and Facility Management, Strategic Management and Cooperation and Participation Management and follows principles of sustainable development: social, cultural, environmental and economic (Bueren *et al*. 2006) (Fig. 1.4).

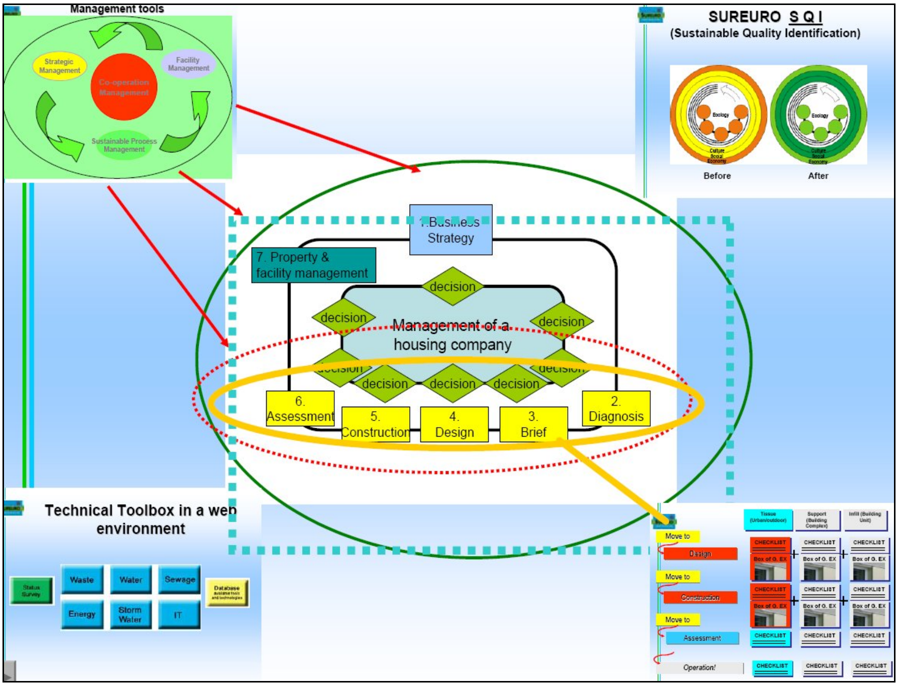

Fig. 1.4. SUREURO model for sustainable renovation (*SUREURO*…2003)

Basing on the *European diagnosis and decision-making tool for office building upgrading* (TOBUS), in decision-making model the general state of the office building is diagnosed and the actions for improvement are defined. The decision-making procedures are applied at the retrofitting scenario level. The result of the TOBUS method is a proposal for a retrofit strategy, the corresponding global actions along with their typical cost and impact on energy savings and the improvement (Caccavelli and Gurgerli 2002). Zavadskas *et al*. (2008a*) improved this model for the purpose of sustainable housing refurbishment. The sustainable buildings refurbishment decision-making model proposed by authors integrates economic, technical, social and ecological needs of stakeholders, helps to choose the best energy efficient refurbishment alternatives basing on multiple criteria methods.

Several more publications deal with the *decision-making* process and models in buildings renovation. Reddy *et al*. (1993) offer a frame-based decision support model for buildings renovation. These and other previous works foster a

* The reference is given in the list of publications by the author on the topic of the dissertation

modular approach to cope with the multitude facets of building renovation, and encourage the use of computer aided tools for the various modules.

Recently Juan *et al*. (2009a) proposed a decision-making model for housing refurbishment. Model conducts the housing condition assessment and offers optimal refurbishment actions considering the trade-off between cost and quality. Two refurbishment models are developed to explore the relationship among the life cycle cost, restoration cost and improved quality. A structured process is developed to assist users in diagnosing housing conditions and acquiring refurbishment decision support. Eight steps, as it is depicted in Figure 1.5 are established in this process.

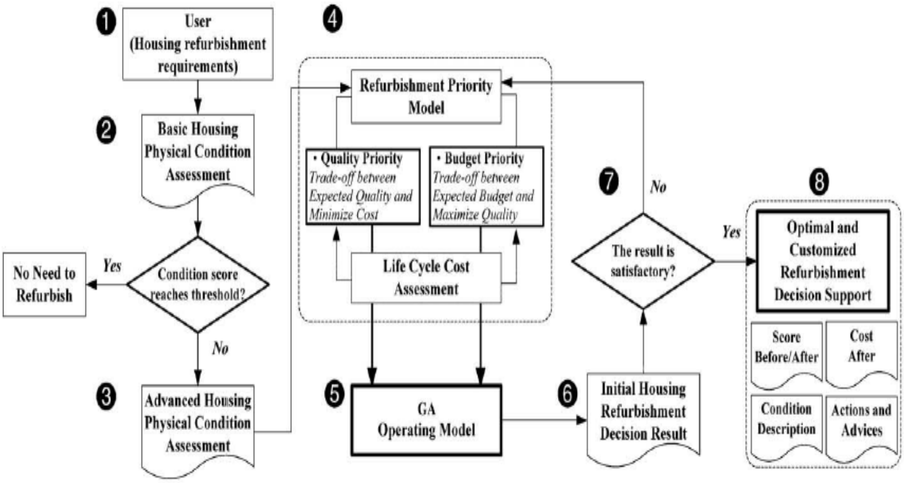

Fig. 1.5. Decision support process model for housing refurbishment (Juan *et al*. 2009a)

Bana e Costa and Oliveira (2002) proposed the design and construction process model to assist the Lisbon Municipality to assign priorities to renovation activities. The MACBETH (multiple criteria) approach was used for this purpose. The model starts by defining the degree of urgency of every single potential building job, and, later on, to assign it to one, and only one, of four ordered urgency categories: “absolute urgency”’, “urgent”, “medium priority”, and “low priority”.

The analyzed models are summarized in Table 1.2.

Table 1.2. Summary of the analyzed renovation models

Author	Model	Description	Application area
1	2	3	4
Mayer (1981) Zavadskas *et al.* (2004a)	Capital stock adjustment models	The choice of capital investment level into renovation	Rental housing rehabilitation, housing renovation, etc.
Hassanien and Losekoot (2002)	Basic model of hotel renovation process	Four fundamental interrelated phases analyzed: pre-planning, planning, implementation, and evaluation	Hotel renovation
Integrated Planning... (2005), Kaklauskas (1999) Zavadskas *et al.* (2001)	Models of Life Cycle Analysis and costs management	Analysis of refurbishment process: diagnosis, brief, design, construction and the operation of the refurbished building	Buildings refurbishment
Flier and Thomsen (2005)	National Renovation Award Analytical model	Renovation project evaluation performed in two steps: (1) a description of the initial situation and (2) assessment of the results by means of the evaluation criteria.	Renovation project
HQE²R project (Mørck *et al.* 2004)	HQE²R model for sustainable renovation	Four main described and sustainable development targets concerned	Buildings renovation
Sustainable refurbishment project SUREURO (Bueren *et al.* 2006)	SUREURO model for sustainable renovation	Connects the key topics of Property and Facility Management, Strategic Management and Cooperation and Participation Management and follows principles of sustainable development	Buildings refurbishment

Table 1.2 continued

1	2	3	4
Caccavelli and Gurgerli (2002)	TOBUS decision – making process model	Decision-making process for a retrofit strategy selection	Office buildings retrofit
Mickaitytė *et al.* (2008A)	Decision-making model for sustainable buildings refurbishment	Helps to choose the best energy efficient refurbishment alternatives by multiply criteria methods	Buildings refurbishment
Juan *et al.* (2009a)	Decision support process model for housing refurbishment	Performs housing condition assessment and offers optimal refurbishment actions	Housing refurbishment
Bana e Costa and Oliveira (2002)	The priority assignment model for renovation activities	Defines the degree of urgency of every single potential building job in renovation	Buildings renovation

Analysis of the scientific models revealed that renovation process is discussed by many authors from different perspectives. Much attention is paid on renovation processes, decision-making, sustainable renovation principles, macro and sometimes micro environment factors. Indeed these models are oriented to particular processes or objects (housing, hotels, commercial buildings, etc.) renovation. There is no model presented in which the built and human environment renovation is evaluated as a whole, considering all the elements of built and human environment renovation process, stakeholders' needs and affecting macro, meso and micro level factors.

1.4. Systems for Built and Human Environment Renovation

Contemporary decision-making problems in the field of construction and engineering are associated with a diversity of structures and processes, incommensurable variables, conflicting development objectives and constraints.

A causative relationship between the dependent variables and independent factors in construction solutions could be determined by applying a multiple regression analysis (Skitmore 1998, 2003; Drew *et al.* 2001). Also, different stakeholders with different interests and values that are interacting with each other make the decision-making process much more complicated. If we are to look for a solution to the problem, we must face a multi-dimensional approach.

Therefore, multiple criteria techniques seem to be an appropriate tool in ranking or selecting one or more alternatives from a set of available variants with respect to multiple, often conflicting criteria. Modern scientists apply multiple criteria analysis to solve construction and siting problems (Zavadskas *et al*. 2002; Ustinovicius and Stasiulionis 2001; Larichev and Olson 2001), as well as to optimize the building's envelope with respect to cost and energy performances during the sketch design (Azar and Hauglustaine 2001), to rate or rank buildings and retrofit scenarios of the same building according to a list of parameters (Roulet *et al*. 2002), and to optimize the building's thermal design and ventilation (Wright *et al*. 2002; Blondeau *et al*. 2002). One of the most important tasks at the design development stage of a building's design is the selection of the appropriate building units that are to be used in the various parts of the building, and to do so this is solved with the help of the multiple criteria decision-making (MCDM) technique (Nassar *et al*. 2003). Multiple criteria analysis is offered to determine effective investment mechanisms and efficient lenders (Zavadskas *et al*. 2004b), for selecting construction project contractor (Topcu 2004; Hatush and Skitmore 1998) and for facility management (Vilutiene and Zavadskas 2003), etc. The reconstruction of buildings in historical places of cities was analyzed in a similar way (Ustinovicius and Jakučionis 2000; Larichev *et al*. 2003; Zavadskas and Antuchevičienė 2004).

Currently, a built environment is characterized by the intensive creation and use of information, knowledge and automation applications (software, knowledge, expert and decision support systems, and neural networks). It is commonly agreed that use of these applications will significantly speed up built environment processes, improve the quality of the built environment and the value of decisions made and decrease the overall cost of a built environment's life cycle. For this purpose recent papers adopt decisions on economically efficient renovation to new technology methods: Adeli (1988) applies general theories and techniques of expert systems to construction, Henket (1990) suggests a theoretical model of several modular stages in the decision process, Reddy *et al*. (1993) offer a frame-based decision support model for building renovation, Alanne (2004) proposes a multi-criteria "knapsack" model to help designers select the most feasible renovation actions in the conceptual phase of a renovation project, indeed the only technological aspects and economical benefits are estimated in these systems.

Zavadskas *et al*. (2001a,b), Zavadskas *et al*. (2008a*,c), Kaklauskas (1999), Mickaitytė *et al*. (2008*), Tupėnaitė *et al*. (2008a*,b*), Kaklauskas and Tupėnaitė (2008*) integrate various IT supported knowledge management, decision support, expert models for buildings' life cycle management as well as renovation projects' assessment and optimization.

Dascalaki and Balaras (2004) proposed the XENIOS methodology and software for the refurbishment of hotels which can be used for a preliminary audit and a first assessment of where and how to integrate the most cost-effective energy efficient renovation practices, technologies and systems.

Bana e Costa and Oliveira (2002) have created a multiple criteria analysis (MACBETH) based decision support system for renovation priorities selection in Lisbon municipality.

Selih (2007) presented a *Computer supported multi-criteria decision support system* for the selection of a portfolio of renovation actions with highest cumulative utility score. A financial constraint can be imposed upon the solution. Mathematically, the model is based on the knapsack problem.

Perng *et al*. (2007) proposed *Quality Improvement Dynamic Decision Support System for Refurbishment Contractors*. The system adopts the system dynamics approach as the construction model for continuous improvement of service quality. On the basis of quantitative management, a cyclic procedure is developed, including current assessment, issue investigation, strategy-making, execution performance, feedback and improvement. Aided by feedback loop analysis in the dynamic system and longitudinal case simulation for all related scenarios, the decision-maker may constantly achieve optimal strategies.

Bueren *et al.* (2006) presented *The Sureuro Gaming Exercise* – a management game designed to show managers of housing companies how sustainable urban renewal involves organizational change in addition to different operational decisions.

Juan *et al*. (2009a) presented the *Genetic Algorithm-Based Online Decision Support System (DSS)* to help residents easily conduct the housing condition assessment and offers optimal refurbishment actions considering the trade-off between cost and quality. Two refurbishment models are developed to explore the relationship among the life cycle cost, restoration cost and improved quality.

Zavadskas *et al*. (2004) proposed the *Multiple Criteria Decision Support Web-Based System for Building Refurbishment*. System is based on multiple criteria analysis methodology, estimates many factors as well the needs and existing financial capability of tenants.

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* The reference is given in the list of publications by the author on the topic of the dissertation

Brandon and Ribeiro (1997) created a multi-strategy knowledge-based framework as well as computerized system for assessment of house renovation grant system applications.

Many useful renovation assessment and decision support tools were proposed by IDCOP (*Innovation in Design, Construction & Operation of Buildings for People*) – a multi institutional research programme funded under the Engineering and Physical Sciences Research Council (EPSRC) Sustainable Urban Environment (SUE) programme in UK. The aim of the IDCOP consortium is to find new ways to improve the performance of building envelopes over the whole building life cycle. The proposed tools are a façade rating system, a decision-making model using an Analytic Hierarchy Process (AHP) approach, a knowledge base and key performance indicators for the study of building façades, a Multiple Criteria Decision-Making (MCDM) tool for sustainable maintenance in social housing.

The major players in a building's renovation can use various purpose decision support systems, created under the projects EPIQR, TOBUS, INVESTIMMO, Brita in Pubs, etc.

EPIQR is a decision tool that combines financial, technical, energy, and comfort analysis. The EPIQR research program has successfully developed the EPIQR methodology for assessing cost effective energy related improvements for refurbished apartment buildings. In addition the methodology has been developed into a marketable computer based multi-media program suitable for use by a wide range of building professionals. The EPIQR methodology addresses the need for building owners, operators, surveyors, architects, and engineers to carry out cost effective refurbishment and retrofit projects within apartment buildings (Jaggs and Palmer 2000; Caccavelli and Genre 2000; Genre *et al.* 2000; Balaras *et al.* 2000).

TOBUS as a systematic method is based on multiple criteria analysis and a constructivist approach, which helps an expert in designing retrofit scenarios. This approach includes several steps and follows an iterative process. The associated computer tool takes charge of tedious tasks such as calculating the associated costs, performing an energy balance, and checking for coherence between actions; and presents various viewpoints to the expert. It also helps the user in quickly creating various scenarios. The expert can then interact with this information and makes the decision for selecting the final scenario. This interactive approach brings together expert intuition and rational systematic verification (Flourentzou and Roulet 2002). The problem of TOBUS is that it is dedicated to office buildings only.

Following on the footsteps of EPIQR and TOBUS the *Decision-Making Tool for Long-Term Efficient Investment Strategies in Building Maintenance and Retrofit* – INVESTIMMO was developed. It is a new method and software to assess residential building renovation and refurbishment processes, for selecting long-term financial investment strategies and setting priorities for a large building stock. The user can create and evaluate several retrofit scenarios and perform a cost analysis, taking into account building physical and functional state of deterioration, future deterioration of building elements, occupants' quality of life, energy and water consumption as well as the environmental impact from building's operation and retrofit actions, reduction of operating costs and the overall time effectiveness of the investment (Balaras *et al*. 2000).

SINDEX is a recent software tool that uses multiple criteria to calculate a sustainability index, and has the potential to completely replace conventional net present value methodologies for ranking and selecting projects. Wealth is measured as a benefit–cost ratio and includes all aspects of life cycle cost (e.g. maintenance, durability, future replacement). A weighted evaluation matrix (criteria and performance) is used to measure utility in a quantitative manner (Gallus and Langston 2006).

Since the condition assessment and refurbishment for a building deal with fairly complicated systems, stakeholders such as the clients, contractors, architects, suppliers and financial institutions involved in building refurbishment projects may want to utilize neural networks, genetic algorithms, fuzzy systems, knowledge-based decision support system, etc. for performing complex analysis in various ways and selection of the most suitable refurbishment actions (Zavadskas *et al*. 2006).

Many various-purpose neural networks can be used for renovation purposes (Kaklauskas 1999; Tupėnaitė and Kanapeckienė 2007[*]; Tupėnaitė 2007[*]). Recent research in building and related artificial intelligence topics have shown that "smart control techniques" such as fuzzy systems and neural networks can contribute to the reduction of energy consumption while maintaining indoor comfort in acceptable margins.

It can be concluded that there is a number of methods and models developed to assess conditions and support decisions pertaining to buildings renovation. However, so far, relatively little attention was paid to tackling with multiple criteria analysis and formation of alternative variants for the whole built and human environment, taking in account all the affecting macro, meso and micro environment factors. For instance, a large number of built and human environment renovation alternative versions that each has detailed information in various criteria can be created for the most efficient alternative selection when adopting multiple criteria analysis methods and multiple criteria decision support system that enable users to mathematically appreciate the effect of changes with the aim of project benefits and costs.

[*] The reference is given in the list of publications by the author on the topic of the dissertation

1.5. Conclusions for Chapter 1 and Allocating Tasks for the Dissertation

1. Provided examples allow coming to the conclusion that various stakeholders usually would prefer the concept of a built and human environment to the concept of a built environment. From this perspective the renovation is analyzed in this thesis – the holistic approach is used. Accordingly, the integrated renovation of the built and human environment is researched.
2. From the reviewed researches results it can be summarized that there is still a lack of empirical studies with the holistic view to built environment renovation and it affecting macro, meso and micro environment factors as a whole.
3. Renovation process is discussed in various scientific models from different perspectives. Much attention is paid on renovation processes, decision-making, sustainable renovation principles, macro and sometimes micro environment factors. Indeed these models are oriented to particular processes or objects' (housing, hotels, commercial buildings, etc.) renovation. There is no model presented in which the built and human environment renovation is evaluated as a whole, considering all the elements of the built and human environment renovation process, stakeholders' needs and affecting macro, meso and micro level factors.
4. There is a number of computer-aided systems developed to assess conditions and support decisions pertaining to buildings renovation. However, little attention is paid to tackling with multiple criteria analysis and formation of alternative variants for the whole built and human environment renovation, taking in account all the affecting macro, meso and micro environment factors.
5. It can be concluded that the integrated built and human environment renovation as a whole has been analyzed only in small scale worldwide; scientists insufficiently apply multiple criteria analysis methods and computer-aided systems in order to increase the efficiency of renovation. These will be the tasks for research of this thesis.

2

The Conceptual Model for the Integrated Analysis of Built and Human Environment Renovation

In this chapter the Conceptual Model for the Integrated Analysis of Built and Human Environment Renovation (IABHER) is developed. The model analyses the renovation process of the built and human environment, participating stakeholders' groups with specific aims and renovation process affecting external macro, meso and micro environment factors, as a whole.

On the thematic of this chapter 2 publications (Mickaitytė *et al*. 2008; Tupėnaitė *et al*. 2010) were published.

2.1. The Concept of the Model for the Integrated Analysis of Built and Human Environment Renovation

Following a category-based presentation of renovation strategies potentially applicable to all built and human environment, whole-system design is critical. The categories and strategies are interdependent; none stand in isolation. Decisions made in one area may affect the performance in the other. A single design improvement might simultaneously improve several building systems' performances; for example, careful decisions on building shape and window placement that take into account both prevailing wind and sun angles may not only enhance a building's thermal performance but can also result the improved day lighting. On the other hand, consideration of one single building with no regard to other structures may result in poorer performance of the built environment; for example, upgrading of one single building without solving infrastructure problems would only slightly increase the quality of living in the particular area and the maximal benefits of renovation will not be achieved. Any conflicts among categories should be resolved by using an integrated design approach; careful decisions should be made to select the type of design that can trigger multiple savings or other benefits. It is essential that all stakeholders work together and consider all sustainability categories in order to be aware of the influence of their decisions on the overall sustainability performance of the building in each category.

Based on the discussed principles the *Conceptual Model for the Integrated Analysis of Built and Human Environment Renovation* (IABHER) was developed by author (Fig. 2.1).

The model consists of these main elements:

1. Macro environment factors affecting built and human environment renovation.
2. Meso environment factors affecting built and human environment renovation.
3. Micro environment factors affecting built and human environment renovation.
4. Stakeholders participating in renovation process.
5. Renovation cycle, consisting of four interrelated phases: information collection and analysis, decision modelling, solution selection, and implementation.

The main purpose of this model is to improve the condition of the built and human environment through efficient decision-making in renovation supported by multiple criteria evaluation methods; considering all the macro, meso and micro environment factors as well as stakeholders' needs as a whole.

Holistic view to the built and human environment renovation can be regarded as a kind of state competitiveness. It shows the capacity to carry out complex long-term and costly projects in collaboration of public authorities, business and social organizations. These projects require a combination of each individual resident‘s needs to the wider public interest: to use less of energy resources, indeed to live in safe, healthy and comfortable environment.

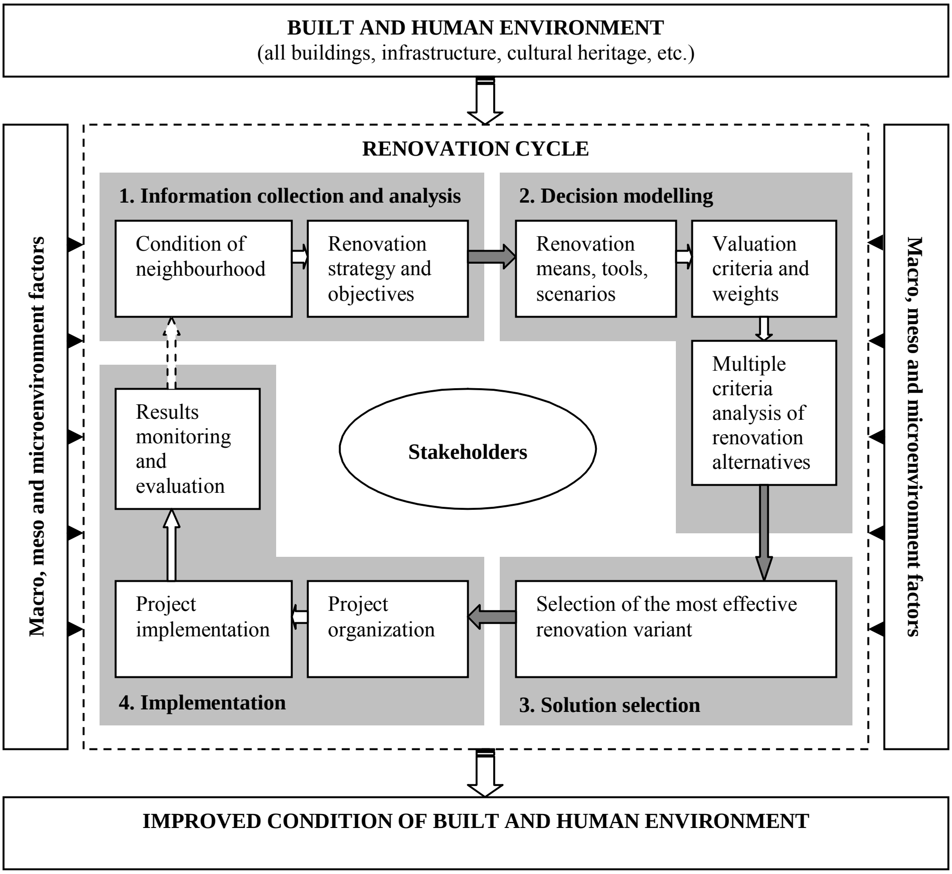

Fig. 2.1. Conceptual Model for the Integrated Analysis of a Built and Human Environment Renovation

Integrated renovation of the built and human environment is relevant by following aspects:

1. Helps to satisfy the needs of all the stakeholders participating in the built and human environment renovation process.
2. Increases energy efficiency of buildings and reduces negative environmental effects as pollution, climate change, etc.
3. Helps to select the most valuable and efficient renovation measures, at the same time saves the resources of government and citizens.
4. Allows upgrading the built and human environment in avoidance of costly alternatives of demolition.
5. Increases the comfort and attractiveness of neighbourhoods by increasing value, prestige and potential rental income.
6. Facilitates maintenance and operation of the built and human environment objects, as well as reduces operating costs and the negative impacts on the environment.
7. Helps to develop the necessary infrastructure for the built and human environment and increases the security of the residential areas.
8. Encourages the socialization of communities and increases their interest to the surrounding environment, its administration and maintenance, value retention and management.
9. Partly helps to solve current problems of the construction sector caused by economic crisis – provides new activities and jobs to the participants of construction industry.

The elements of the model are discussed below.

2.2. Elements of the Model for the Integrated Analysis of Built and Human Environment Renovation

2.2.1. Macro Environment Factors Affecting Built and Human Environment Renovation

The highest level influencing built and human environment as well as its renovation efficiency is macro level. In this level the built and human environment renovation is influenced by economic, social, cultural, scientific and technological, natural and ecological, political other factors. In some circumstances each group of the mentioned factors can be crucial and renovation project can fail. In order to avoid negative impacts, it is important not to separate built and human environment renovation consideration processes from environmental conditions and their changes. For instance, the slow down of economy had huge impact on investments into renovation in Lithuania – renovation projects had stacked because of lack of funding. On the other hand, growing energy prices and heating costs will increase interest of habitants in energy consumption reducing measures. All these impacts must be considered in renovation decision-making.

National economic environment has a direct influence on the built and human environment as well as its renovation. It is determined by the policy of national authorities on taxes and money, capital movement, investment environment, loan granting and interest rates. Economic environment is also determined by such factors as demand, supply, competition, pricing, etc. (Zavadskas *et al.* 2004a).

The main economic indicators, which define development of the economy, are the following: development cycles, inflation and unemployment. They also affect change of other indicators (GDP change, consumer income, level of savings, prices of goods, opportunities to get loans). Economic development is irregular-cyclic. Most often renovation is funded through loans; therefore, the amount of construction work and possibilities to renovate the built environment depend on interest rates.

Social factors (living conditions and standards, educational background, labour force regulating legal acts, health protection, public organizations, media, citizens' attitudes to renovation, innovations in renovation process etc.) are influencing stakeholders' aims and their capabilities. Implementation of the built and human environment renovation is closely related to interests of country and society (implementation of economic, social, environment protection and other requirements in country, regional and municipality levels).

Culture (literacy, cultural traditions, religion, cultural needs, quality and working conditions requirements, etc.) is directly influencing stakeholders' requirements to the built environment and their aims.

Science and technologies (fundamental and utilitarian researches development level, information technologies and computerization level, industrial and manufacturing technologies level, communication, etc.) influence efficiency of the built and human environment renovation process and state requirements to its participants.

While institutions, legislation and improved practice in the construction sector can go some way to reducing emissions and energy consumption, a step-change in performance will require the integration of new technologies in both energy supply and demand. As a result of a sustained research effort over the last two decades, many technology options are available that could help bring about this step-change, including: smart façades, solar energy collection/conversion (Porteous and MacGregor 2005), building integrated renewables, such as photovoltaic components and encased wind turbines (Born *et al*. 2001), heat and power systems (Berntsson 2002; Harvey 2006), electrical appliances, internet energy services, design tools (Clarke *et al*. 2004, 2008), smart metering (Darby 2000), etc.

Natural and ecological factors (temperature, precipitation, humidity, landscape and topography, natural resources, water, water resources and soil quality, sanitary requirements to environment, nature protection, ecological conditions and their changes, etc.) are influencing renovation efficiency because the requirements to the particular stages should be considered.

Political decisions (regional cohesion programmes, preferential credits, governmental orders, dotations, subsidies, construction activities regulating documents, law changes, etc.) have huge influence on the renovation efficiency of the built and human environment. To achieve even first steps towards sustainability will require that government play an active role not only in regulation of behaviour of companies and individuals, but also in expanding knowledge and understanding of the demand side of the built environment renovation. This requires policy initiatives in two spheres, in particular research and regulation (Kincaid 2000).

Supply-side policies that reduce construction costs could have a considerable impact on the built and human environment renovation in areas with relatively large fractions of structures still priced near replacement costs. The fate of many neighborhoods' housing stocks could depend upon such intervention (Gyourko and Saiz 2004).

2.2.2. Meso Environment Factors Affecting Built and Human Environment Renovation

The changing role of the construction sector, with a focus on the service rendered by buildings, coupled with developing functions of construction firms in terms of diversification and vertical integration with particular emphasis on supply chain control, calls for a new approach of a mesoeconomic framework to assess the importance and scope of the construction sector beyond the narrow definition of construction activity (Ruddock 2009).

In addition, the case for a new approach to the valuation of construction activity has come from two other areas. Firstly, the International Council for Research and Innovation in Building and Construction (CIB) presented *Revaluing Construction Agenda* focuses on improving the value of final construction output and requires that the totality of activities involved in the production of the built environment is reviewed (see Ruddock (2007), Ruddock and Lopes (2006) for a holistic assessment of construction). Secondly, Carassus (2004) proposes a framework (or mesoeconomic) system approach for understanding the construction sector. The rationale for this approach is based on the view that the role of the construction sector should be viewed in a wider context than that of the narrowly defined *International Standard Industrial Classification* (ISIC) definition of the industry.

The requirements of sustainable development focus on the need to deal with longer-term consequences, not only regarding the production of buildings but also the management of the building product over the whole life cycle. This focus on the service means that a new approach is needed to analysis of the function of the construction sector, with emphasis on the "management of the service rendered by such works all along their life-cycle" (Carassus 2004, Carassus *et al*. 2006).

Analysis has to take into account such recent evolution and all the actors involved in the life cycle of built and human environment structures (not only procurement, design and production but also operation, maintenance, refurbishment and demolition). Renovation analysis needs to go beyond just the construction firms to include the industry's professions and the materials industry as well as the service aspects, stock management organizations and the real estate sector.

2.2.3. Micro Environment Factors Affecting Built and Human Environment Renovation

The third level factors may be considered as the micro level and these depend upon those at the macro and meso level.

The level of efficiency and the scope of activities of the renovation industry depend on the following micro variable factors:

- suitability of contractor to perform particular works;
- organization structure of contractor enterprise;
- sources of company finance;
- information system of construction;
- education and training of employees;
- know-how;
- types of contracts, etc.

Renovation projects are usually characterized by complex, small-scale and highly labour-intensive renovation tasks (Okoroh and Torrance 1999). For instance, special characteristics of housing renovation include site-driven works undertaken in an existing building (Daoud 1997), intensified uncertainty (Clancy 1995), long turn-round time and many simultaneously operating workers in a restricted space (Glardon *et al.* 1995). These unique characteristics render it more difficult to standardize the delivered service, compared to new construction, and the outcome of the renovation performance will be highly dependent on a contractor's capability and experience.

Renovation can be categorized as a service industry (Holm 2000a,b). Providing what customers expect, such as customized products or services, is a key to reach customer satisfaction in service management as well as to decrease a gap between customers' quality perceptions and suppliers' service delivery (Juan *et al.* 2009b).

In order to give an accurate assessment of above mentioned micro efficiency level factors, it is necessary to develop a system of criteria fully describing each of them. For example, the micro level factors characterizing renovation project efficiency will be considered under the type of contract. The type of contract can be selected by taking into account numerous factors which influence its efficiency (Kaklauskas 1999):

- owner's corporate policy on contracting;
- availability of in-house experienced personnel;
- time needed to get the project designed and constructed;
- desire of owner to control elements of project;
- importance of cost to owner;
- amount of risk owner wants to contract out;
- availability and suitability of contractors;
- local construction climate;
- experience of contractor;
- degree of confidence in contractor;
- pre-contract period (long, short);
- consultants (chosen by contractor or employer);
- sub-contractors (domestic, nominated);
- valuation of variations (expensive, at cost, cheap).

The efficiency of each of above micro factors can also be assessed by a system of criteria adequately describing it.

2.2.4. Stakeholders

There are many stakeholders participating in the built and human environment renovation process:

- municipal technical personnel (usually named building administrators);
- municipal technical supervisors;
- buildings designers;
- contractors;
- buildings users;
- politicians;
- society, etc.

For instance, the survey of renovation projects in West Midlands (UK), distinguished the main groups of participants (Fig. 2.2).

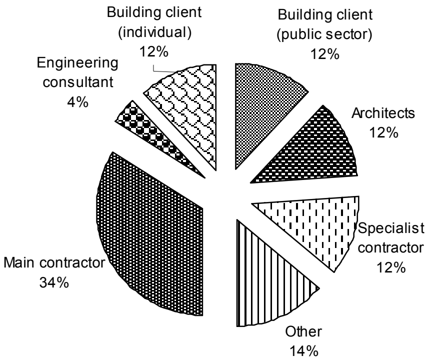

Fig. 2.2. Organizations working in the renovation market (*Gaining*... 2006)

The aforementioned groups are making renovation decisions; hereby their dissemination about built and human environment renovation (as a whole) principles is very important. Also it is crucial to ensure this information to reach them. Some research reveals that one of the severest challenges of renovation projects is asymmetric information between contractors and residents in a renovation process (Holm 2000a). Residents with inadequate knowledge in renovation usually lack the judgment ability on cost, quality and service provided by contractors. Disreputable contractors who propose deceitful cost estimation, unpredicted quality, and unstable service usually affects customers' satisfaction and project performance. Asymmetric information results are in the gap between expectation and perception, and it may lead residents to be in vulnerable conditions (Juan *et al.* 2009b).

Renovation of the built and human environment must fully satisfy the requirements of stakeholders' groups. For instance, the sustainable needs expressed by the communities about the use of the space can be as follows: meeting points for young and old people, security, green areas, services and technological functionality of open spaces and surrounding buildings. The design solution in this case can be formulated as follows:

- the individuation of a organic system of open spaces characterized by different functions, but at the same with a central role given to the historic places;
- the localization of main urban functions and services to increase the attractiveness of the neighbourhood and to favor social mix;
- the creation a pedestrian paths, and the flexible use of spaces;

- the elimination of traffic pollution which represent a damage for pedestrian, residents and buildings;
- the creation of security, by changing a neglected space to a new reference point for the built environment;
- the support to socialization;
- the creation of places for children, youth, old people;
- the creation of a green space;
- the increase of accessibility;
- the increase of aesthetical and comfortable living and working environment;
- the activation of economic processes, etc.

2.2.5. The Cycle of the Built and Human Environment Renovation

In order to design and implement the built environment renovation basing on the sustainable development principles it is necessary to follow these principles from idea till implementation. Suitable decisions must be made starting from the projecting stage. Furthermore, information character should change in dependence on decision-making phase – one type of information is needed in the initial information collection stage and another at the end of decision implementation stage.

The process of the built and human environment renovation, starting from the idea and ending with implementation, is quite durable and can be divided into four main phases.

First phase. Data and information collection, aims and tasks determination, problem formulation. At the initial phase the purposes, tasks, expected results of renovation, main project participants, their aims and their relations are determined, neighbourhood condition assessed and analysis of renovation necessity performed. The reasons for renovation can be various – physical, economic depreciation of buildings, failure of standards and requirements, aims to reduce energy consumption, improve external and internal environment quality, etc.

When renovation reasons are clarified, further activities to achieve the main tasks are discussed. Renovation can of itself take many forms, ranging from simple redecoration to major retrofit or reconstruction. Sometimes the buildings are in good condition but the services and technology within them are outdated, in which case a retrofit process may be undertaken. If a particular function is no longer relevant or desired, buildings may be converted to a new purpose altogether. This is adaptive reuse.

It is obvious, however, that aims determination and projecting stages decisions also influence construction and usage stages, their processes and decision-making. For this reason in this phase various decision-making groups' dissemination is crucial. In this phase the general information about energy saving, technical information about innovative technologies and information about costs is needed the most (the *Project BRITA in PuBs* 2006).

Decision modelling phase. After renovation aims and the need for renovation defined, the next and very important phase is decision modelling. Information is analyzed, models formed, evaluation criteria selected and alternatives are distinguished in this phase.

Decision-making means the selection of the best alternative from numerous alternatives. Analysis of the built and human environment renovation and decision-making is sophisticated because of many possible alternatives appearing in aims establishment, projecting, and construction, usage stages. These alternatives sometimes even not interact. In order to create optimal renovation strategy needs of all renovation stakeholders' groups must be considered. Accordingly, renovation alternatives must be analyzed basing on many criteria (Zavadskas *et al*. 2001a,b; Banaitiene *et al*. 2008). In this phase the information about already implemented renovation projects, best practice examples, strengths and weaknesses of the projects is needed.

Decision selection phase. The main aim of this phase is to select correct alternative, evaluate expected results and make the final decision. In order to choose the best decision (alternative), methods of multiple criteria analysis as well as experts' decisions and advances can be applied. In order to optimize the best decision (alternative) selection, intelligent technologies and systems should be used: decision support systems, expert systems, best practice data bases, etc.

Implementation phase. Implementation phase is the last phase of decision-making process. The decision is transferred to implementers and the examination if the best alternative was selected is made.

The project should be evaluated from time to time during the development process as well as after finishing the programme to see how the actual situation is, when compared with the expected plans. This evaluation should be based on subjective criteria (e.g. feedback from any stakeholders, such as customers, contractors, government institutions, etc.).

2.3. Conclusions for Chapter 2

1. The Conceptual Model for the Integrated Analysis of Built and Human Environment Renovation (IABHER) was developed. The main purpose of this model is to improve the condition of built and human environment through efficient decision-making in renovation basing on multiple

criteria evaluation methods, considering all the macro, meso and micro environment factors as well as stakeholders needs as a whole.

2. The model of the Integrated Analysis of Built and Human Environment Renovation suggested by the author differs from other scientific models by the object of analysis (assumes built and human environment renovation as a whole) and by the idea of multiple criteria evaluation methods application.
3. The main interrelated components of the model are macro, meso and micro level environmental factors affecting renovation, the participating stakeholders' groups with specific aims, and the process of the renovation.
4. The impact of the macro, meso and micro level environmental factors on renovation of the built and human environment can be assessed by the adequate system of evaluation criteria.
5. There are many stakeholders participating in the built and human environment renovation process (municipality, contractors, building users, society, etc.). Renovation of the built and human environment must fully satisfy the requirements of all stakeholders' groups. For this purpose, it is essential that all stakeholders work together and consider all the renovation decisions in sustainable way.
6. The main interrelated phases of the built and human environment renovation process, distinguished in the model, are data and information collection, aims and tasks determination, problem formulation, decision modelling, decision selection and implementation. In order to make and implement efficient decisions in renovation process it is proposed to use the multiple criteria evaluation methods and computer-aided systems.

3

Multiple Criteria Analysis of the Built and Human Environment Renovation Projects

In this chapter the developed Conceptual Model for the Integrated Analysis of Built and Human Environment Renovation (IABHER) as well as multiple criteria decision-making methods are applied in assessment of the *Cultural Heritage Renovation Projects in Bulgaria* applied for European Economic Area (EEA) and Norway Grants. The hierarchically structured system of evaluation criteria is developed, weights of criteria determined, assessment and calculations of the attributes performed. Renovation projects alternatives are assessed basing on the traditional multiple criteria analysis methods SAW, TOPSIS, COPRAS as well as the newly developed method ARAS in order to select the best project alternative for granting.

On the thematic of this chapter 3 publications (Tupėnaitė *et al*. 2010; Tupėnaitė *et al*. 2008b; Zavadskas *et al*. 2008a) were published.

3.1. Review of the Multiple Criteria Decision-Making Methods

As it was discussed and concluded in the previous chapters of the thesis, multiple criteria decision-making (MCDM) approach use to be the most advantageous for decision-making in built and human environment renovation field.

MCDM is a set of methods which allow the aggregation of several evaluation criteria in order to choose, rank, sort or describe a set of alternatives (i. e. renovation projects). It also deals with the study of the activity of decision aid to a well identified decision maker (i. e. individual, firm, organization, etc.). Its principal objective is to provide the decision maker with tools that enable him to advance in solving a decision problem (i. e. the selection of the renovation projects for granting), where several, often conflicting multiple criteria must be taken into consideration (Zopounidis 1999; Triantaphyllou 1998 *et al.*; Triantaphyllou 2000 and others).

In particular, formulation of a multi-objective multiple-participant decision problem (i. e. renovation granting or implementation) is based on the following basic components:

- a set of potential alternatives;
- a set of objectives or criteria;
- a number of decision makers;
- a preference structure or weights; and
- a set of performance evaluations of alternatives for each objective or criteria.

According to many authors (Zimmermann 2001; Triantaphyllou 1998 *et al.*; Triantaphyllou 2000; Bernroider and Stix 2007, etc.), MCDM is divided into multi-objective decision-making (MODM) and multi-attribute decision-making (MADM). MODM studies decision problems in which the decision space is continuous. A typical example is mathematical programming problems with multiple objective functions. On the other hand, MADM concentrates on problems with discrete decision spaces. In these problems the set of decision alternatives is predetermined. However, very often the terms MADM and MCDM are used to mean the same class of models (i. e. MCDM) (Triantaphyllou 2000) as it is considered in this thesis.

The MCDM problem needs to be solved by one of the many methods available. Solving can imply the aggregation of utilities into an overall evaluation for each alternative leading to a final ranking. As each method has its own characteristics, there are many ways to classify them (Smith and von Winterfeldt 2004; Hwang and Yoon 1981; Poh 1998, etc.).

One classification method is based on the type of data and considers either deterministic, stochastic (Lahdelma *et al.* 2003; Prato 1999) or fuzzy methods

(Carlsson and Robert 1996; Yeh 2004). However, there may be situations which involve combinations of all the above (such as stochastic and fuzzy data) data types (Triantaphyllou 2000). An alternative way to classify methods pertains to the number of decision makers involved in the decision-making process, i. e. focusing on supporting group decisions (Kim and Han 1999). The methods can be classified further according to the type of information. One of the possible approaches is based on the classification made according to the type of information received from the decision maker (Larichev 2002). It includes:

- methods based on quantitative measurements. This group consists of widely known methods from multiple criteria utility theory (Keeney and Raiffa 1976; Zavadskas *et al*. 1995) and some new methods (Hwang and Yoon 1981; Triantaphyllou 2000; Zavadskas *et al*. 2004a; Brauers 2004; Ustinovichius 2004);
- methods based on initial qualitative assessments, the results of which later take a quantitative form. This group consists of analytic hierarchy method (Saaty 1994), as well as the methods based on fuzzy sets (Zadeh 1965; Peldschus and Zavadskas 2005);
- methods based on quantitative measurements but using a few criteria to compare the alternatives (comparison preference method). This group consists of preference comparison methods (Roy 1996; Slowiński *et al*.; Greco and Matarazzo 2002; Ustinovichius and Stasiulionis 2001);
- methods based on qualitative data not using a transformation to quantitative variables. This group comprises verbal decision analysis (VDA) (Larichev *et al*. 1995; Larichev *et al*. 2003, etc.).

One more classification approach is to distinguish classical and technical methods (Zavadskas and Kaklauskas 1996). Classical methods are based on low priority principle in order to evaluate the importance of criteria. In this case it is possible to determine priorities of alternatives and to select the rational one. Technological methods are outranking and fuzzy-set methods. They are not based on the low priority principle.

A further classification is often made within MCDM methods into compensatory and non-compensatory methods. Compensatory in this context means that a lower value in one criterion can be compensated for by a higher value in another criterion, meaning values can therefore be combined across different criteria. With non-compensatory methods, combination of criteria is not possible in this way (Hwang and Yoon 1981).

The availability of a wide selection of methods for solving MCDM problems, however, generates the paradox that the selection of an MCDM method for a given problem leads to an MCDM problem itself (Triantaphyllou 2000). A phenomenon known as the inconsistent ranking problem can be caused by different MCDM methods (Yeh 2003). This implies that the choice of a specific method in general influences the ranking outcome. The validity of ranking outcomes remains a problematic issue in MCDM as it was concerned by Bernroider and Stix (2007).

There is the great diversity of literature in which MCDM methods are compared (Geoffrey 1988; Goodwin and Wright 1996; Urli and Nadeu 1999; Zavadskas and Kaklauskas 1996; Zavadskas *et al*. 2001a,b; Ustinovicius *et al*. 2007 and others). Mahmoud and Garcia (2000) have compared five MCDM methods: SAW, PROMETHEE II, compromise programming (CP), ELECTRE II and AHP. The sensivity of results, clarity of methods as well as additional information needed to apply the method were researched. Authors conclude that the most advantageous method for the selected task was SAW.

A simulation by Zanakis *et al*. (1998) evaluated eight MCDM methods: SAW; multiplicative exponential weighting (MEW); TOPSIS; elimination and (et) choice translating reality (ELECTRE); and four AHPs. The rank-reversal dimension indices in the simulation disclosed the following performance order for these eight methods: SAW and MEW performed the best, followed by TOPSIS and AHPs. The ELECTRE method performed the worst. In addition, Chang and Yeh (2001) confirmed the superiority of SAW in an empirical study of the three evaluation methods (SAW method, weighted product and TOPSIS). The findings of these studies suggest that simpler evaluation techniques are often superior. Furthermore, according to Dyer *et al*. (1992) and Kaliszewski (2004), the complexity of most methods as perceived by real decision makers prevents their application in practice.

Triantaphyllou (2000) performed the sensitivity analysis of WSM, AHP, and revised AHP, WPM, and TOPSIS methods. Author concludes that it is doubtful that the “perfect” MCDM approach will ever be found, it is always a prudent idea for the user to be aware of the main controversies in the field. Although the search for finding the best MCDM method may never end, research in this area of decision-making is still critical and valuable.

Although there are many comparative studies presented in literature, it must be stated that the actual procedures for finding a method vary greatly depending on the structure of the underlying decision problem. In this thesis, methods are examined with respect to their suitability for finding a solution to a matching problem for a renovation decisions. For this reason only those methods that appear promising and the most popular are discussed in greater detail: SAW, TOPSIS and COPRAS as well as the newly developed method ARAS. The selected quantitative multiple criteria evaluation methods differ in their intrinsic logic (concept), type of data normalization as well as the way of combining the data and the criteria weights into the criterion of method evaluation, variation range of the criteria values and the influence of the initial data, i. e. the criteria values and weights in the evaluation result. For this purpose more detailed analysis is performed in order to select the most suitable method for renovation projects assessment.

Simple Additive Weighting (SAW) method was summarized by MacCrimmon (1968). Its major principles were also described in the papers of Churchman and Ackoff (1954) and Klee (1971).

SAW is a widely-used method for aggregating several criteria. The method involves adding together criteria values for each alternative and applying weights to individual criteria. Criteria must be maintained using the same scale for this to be possible. Once values for all alternatives have been aggregated, the alternative with the highest (or lowest) value is then selected as the comparatively optimal solution.

Calculations are carried out according to algorithm SAW shown in Figure 3.1.

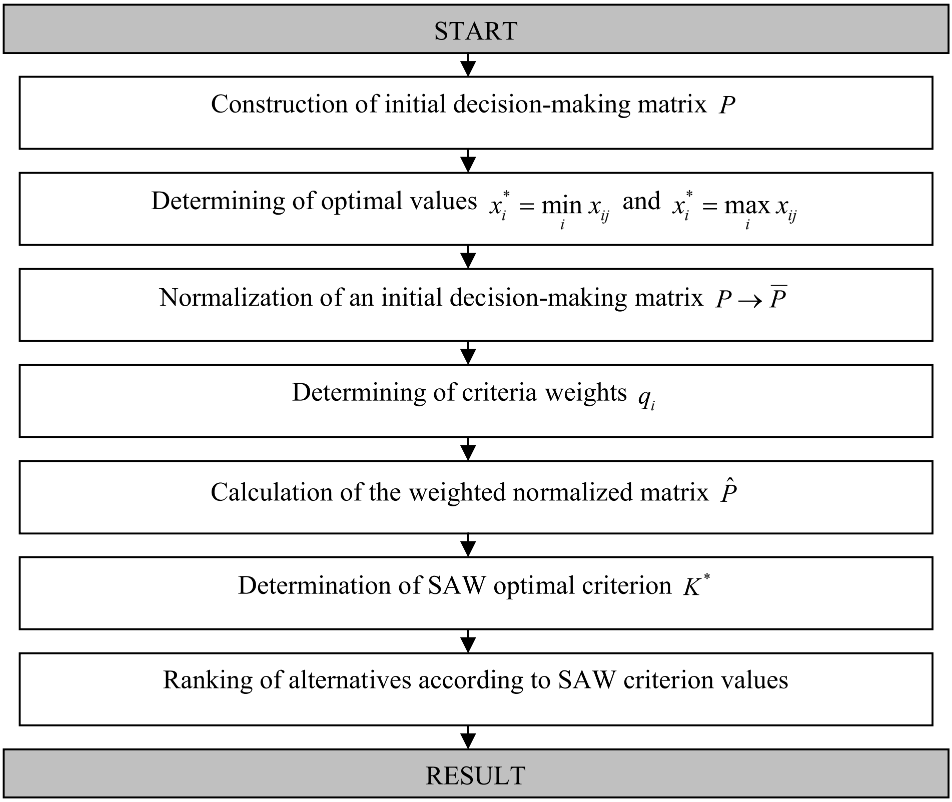

Fig. 3.1. Algorithm of the SAW method (Shevchenko *et al*. 2008)

Stage 1. Forming of decision-making matrix:

$$P = \begin{matrix} & a_1 & a_2 & \cdots & a_n \\ \begin{matrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{matrix} & \left[\begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix}\right] \end{matrix}; \; i = \overline{1,m}; \; j = \overline{1,n}, \tag{3.1}$$

where: n – number of alternatives; m – number of attributes; x_{ij} – the attribute value of the j^{th} alternative.

Here also the best values of each parameter are determined according to the formula (3.2):

$$x_i^* = \min_i x_{ij}, \text{ if preferable is minimum of } i^{th} \text{ attribute;} \tag{3.2}$$

$$x_i^* = \max_i x_{ij}, \text{ if preferable is maximum of } i^{th} \text{ attribute.}$$

Stage 2. Performing normalization of the decision-making matrix. The normalized values of normalized decision-making matrix $\overline{P}$ are calculated according to the formula (3.3):

$$\bar{x}_{ij} = \frac{\min_i x_{ij}}{x_{ij}}, \text{ if preferable is minimum of } i^{th} \text{ attribute;} \tag{3.3}$$

$$\bar{x}_{ij} = \frac{x_{ij}}{\max_i x_{ij}}, \text{ if preferable is maximum of } i^{th} \text{ attribute.}$$

Stage 3. Defining weighted normalized matrix. Values of the matrix are calculated by multiplying values of $\overline{P}$ matrix by corresponding weights of significances of each attribute:

$$\hat{P} = \begin{bmatrix} q_1\bar{x}_{11} & q_1\bar{x}_{12} & \cdots & q_1\bar{x}_{1n} \\ q_2\bar{x}_{21} & q_2\bar{x}_{22} & \cdots & q_2\bar{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ q_m\bar{x}_{m1} & q_m\bar{x}_{m2} & \cdots & q_m\bar{x}_{mn} \end{bmatrix}; \; i = \overline{1,m}; \; j = \overline{1,n}. \tag{3.4}$$

Stage 4. Defining efficiency criterion for each j^{th} alternative:

$$K_j^* = \sum_{i=1}^{m} \hat{x}_{ij}; \; i = \overline{1,m}; \; j = \overline{1,n}. \tag{3.5}$$

Optimum variant and ranks of the alternatives are established by size K^*:

$$K^{*}=\left\{a_j \middle| \max_j \sum_{i=1}^{m} q_i \bar{x}_{ij}\right\};\ i=\overline{1,m};\ j=\overline{1,n};\ \sum_{i=1}^{m} q_i=1\,. \tag{3.6}$$

Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) (Hwang and Yoon 1981). The basic principle is that the chosen alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution.

The TOPSIS procedure consists of the seven stages, the algorithm is presented in Figure 3.2.

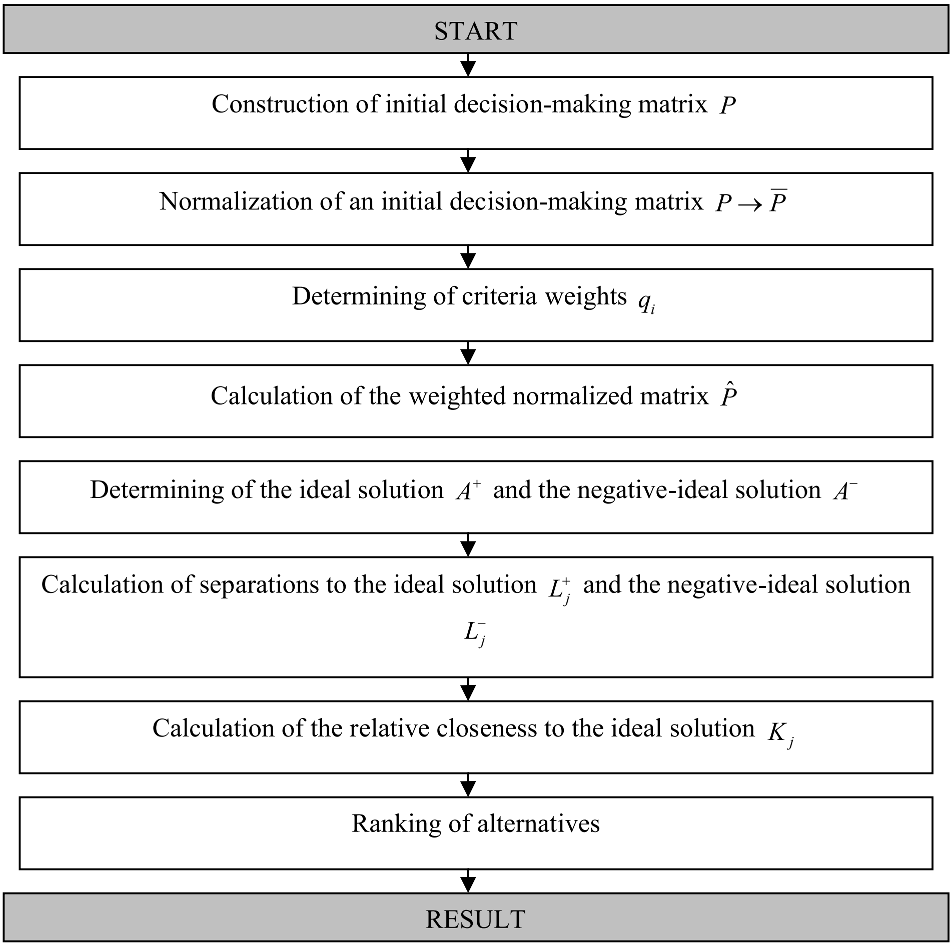

Fig. 3.2. Algorithm of the TOPSIS method

Stage 1. Forming of decision-making matrix:

$$P = \begin{matrix} & a_1 & a_2 & \cdots & a_n \\ x_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ x_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{matrix}; \; i = \overline{1,m}; \; j = \overline{1,n}, \tag{3.7}$$

where: n – number of alternatives; m – number of attributes; x_{ij} – the attribute value of the j^{th} alternative.

Stage 2. Calculation of the normalized decision matrix. The normalized value $\bar{x}_{ij}$ is calculated as:

$$\bar{x}_{ij} = x_{ij} \Big/ \sqrt{\sum_{j=1}^{n} x_{ij}^2}; \; i = \overline{1,m}; \; j = \overline{1,n}, \tag{3.8}$$

where: n – number of alternatives; m – number of attributes; x_{ij} – the attribute value of the j^{th} alternative.

Stage 3. Calculation of the weighted normalized decision matrix. The weighted normalized value is:

$$\hat{x}_{ij} = q_i \bar{x}_{ij}; \; i = \overline{1,m}; \; j = \overline{1,n}, \tag{3.9}$$

where q_i is the weight of the i^{th} attribute or criterion, and $\sum_{i=1}^{m} q_i = 1$.

Stage 4. Determination of the ideal and negative-ideal solution:

$$A^+ = \{\hat{x}_1^+, ..., x_n^+\} = \left\{ \left(\max_j \hat{x}_{ij} \middle| i \in J' \right), \left(\min_j \hat{x}_{ij} \middle| i \in J'' \right) \right\}, \tag{3.10}$$

$$A^- = \{\hat{x}_1^-, ..., \hat{x}_n^-\} = \left\{ \left(\min_j \hat{x}_{ij} \middle| i \in J' \right), \left(\max_j \hat{x}_{ij} \middle| i \in J'' \right) \right\}, \tag{3.11}$$

where J' is associated with maximized criteria, and J'' is associated with minimized criteria.

Stage 5. Calculation of the separation measures, using the n dimensional Euclidean distance. The separation of each alternative from the ideal solution is given as:

$$L_j^+ = \sqrt{\sum_{i=1}^{n} \left(\hat{x}_{ij} - \hat{x}_i^+ \right)^2}; \; j = \overline{1,n}. \tag{3.12}$$

$$L_j^- = \sqrt{\sum_{i=1}^{n} \left(\hat{x}_{ij} - \hat{x}_i^- \right)^2}; \; j = \overline{1,n}. \tag{3.13}$$

Stage 6. Calculation of the relative closeness to the ideal solution. The relative closeness of the alternative a_j with respect to K_j is defined as:

$$K_j = \frac{L_j^-}{L_j^+ + L_j^-};\ j = \overline{1,n};\ K_j = [0,1]. \quad (3.14)$$

Stage 7. Ranking of the preference order.

A Method of Multiple Criteria Complex Proportional Evaluation (COPRAS) was developed by Zavadskas and Kaklauskas in 1996. This method assumes direct and proportional dependence of significance and priority of investigated alternatives on a system of attributes. The system of attributes is determined and experts calculate their values and initial weights. The interested parties, taking into consideration their goals and the existing capabilities, can check and correct all this information.

The determination of significance and priority of alternatives is carried out in four stages, according to algorithm depicted in Figure 3.3.

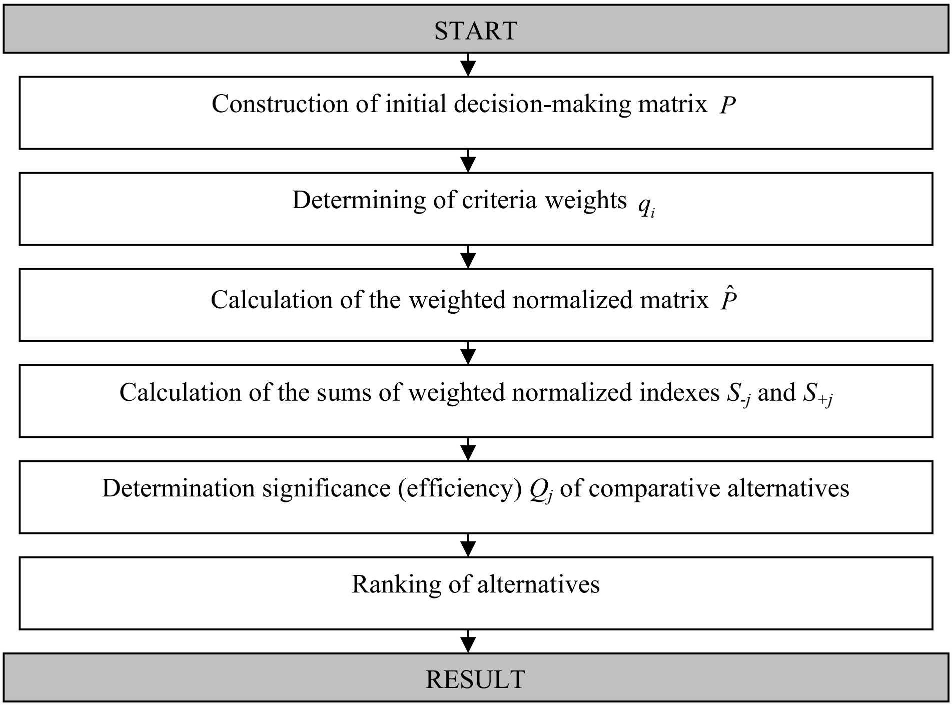

Fig. 3.3. Algorithm of the COPRAS method

Stage 1. The weighted normalized decision-making matrix $\hat{P}$ is constructed. The purpose of this stage is to receive dimensionless weighted values of the attributes. All attributes, originally having different dimensions, can be compared when their dimensionless values are known. The following equation is used:

$$\hat{x}_{ij} = \frac{x_{ij} \cdot q_i}{\sum_{j=1}^{n} x_{ij}}; \; i = \overline{1,m}; \; j = \overline{1,n}, \tag{3.15}$$

where n – number of alternatives; m – number of attributes; x_{ij} – the attribute value of the j^{th} alternative; q_i – significance (weight) of i^{th} criterion.

The sum of dimensionless weighted index values $\hat{x}_{ij}$ of each criterion is always equal to the significance q_i of this criterion:

$$q_i = \sum_{j=1}^{n} \hat{x}_{ij}; \; i = \overline{1,m}; \; j = \overline{1,n}. \tag{3.16}$$

In other words, the value of significance q_i of the investigated criterion is proportionally distributed among all alternative versions a_j according to their values x_{ij}.

Stage 2. The sums of weighted normalized indexes describing the j^{th} alternative are calculated. The options are described by minimizing attributes S_{-j} and maximizing attributes S_{+j}. The sums are calculated according to the formula:

$$S_{+j} = \sum_{i=1}^{m} \hat{x}_{+ij}; \; S_{-j} = \sum_{i=1}^{m} \hat{x}_{-ij}; \; i = \overline{1,m}; \; j = \overline{1,n}. \tag{3.17}$$

In this case, the values S_{+j} (the greater is this value, the more satisfied are the interested parties) and S_{-j} (the lower is this value, the better is goal attainment by the interested parties) express the degree of goals attained by the interested parties in each alternative. In any case the sums of "pluses" S_{+j} and "minuses" S_{-j} of all alternative projects are always respectively equal to all sums of significances of maximized and minimized attributes:

$$S_{+} = \sum_{j=1}^{n} S_{+j} = \sum_{i=1}^{m} \sum_{j=1}^{n} \hat{x}_{+ij},$$

$$S_{-} = \sum_{j=1}^{n} S_{-j} = \sum_{i=1}^{m} \sum_{j=1}^{n} \hat{x}_{-ij}; \; i = \overline{1,m}; \; j = \overline{1,n}. \tag{3.18}$$

In this way, the calculations made may be additionally checked.

Stage 3. The significance (efficiency) of comparative alternatives is determined on the basis of describing positive (pluses) and negative (minuses) characteristics. Relative significance Q_j of each alternative a_j is found according to the formula:

$$Q_j = S_{+j} + \frac{S_{-\min} \cdot \sum_{j=1}^{n} S_{-j}}{S_{-j} \cdot \sum_{j=1}^{n} \frac{S_{-\min}}{S_{-j}}}; \; j = \overline{1,n}. \tag{3.19}$$

Stage 4. Determining the priority order of alternatives. The greater the Q_j, the higher is the efficiency of an alternative.

The analysis of the method presented makes it possible to state that one can easily apply it to evaluating the alternatives and selecting the most efficient one, while being completely aware of the physical meaning of the process. Moreover, the method allows the formulation of a reduced criterion Q_j that is directly proportional to the relative effect of the compared values x_{ij} and weight q_i on the final result.

In order to visually assess alternative efficiency the utility degree N_j can be calculated. The degree of utility is determined by comparing the alternative analyzed with the most efficient alternative. In this case, all the utility degree values related to the alternative analyzed will be ranged from 0% to 100%. The formula used for the calculation of alternative a_j utility degree is given below:

$$N_j = \frac{Q_j}{Q_{\max}} \cdot 100\% \cdot \tag{3.20}$$

The newly developed *Additional Ratio Assessment* (ARAS) method is based on ratio sums of alternatives. The best alternative is considered as the alternative which is closest to the optimal alternative (Zavadskas and Turskis 2010; Tupėnaitė *et al*. 2010*). Calculations are carried out according to algorithm presented in Figure 3.4.

Stage 1. Construction of initial decision-making matrix P:

$$P = \begin{array}{c} \\ x_1 \\ x_2 \\ \vdots \\ x_m \end{array} \begin{array}{c} \begin{array}{cccc|c} a_1 & a_2 & \cdots & a_n & a_o \end{array} \\ \left[\left(\begin{array}{cccc} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{array} \right) \begin{array}{|c} x_{1o} \\ x_{2o} \\ \vdots \\ x_{mo} \end{array} \right] \end{array}; \; i = \overline{1,m}; \; j = \overline{1,n}, \tag{3.21}$$

where n – number of alternatives; m – number of attributes; x_{ij} – the attribute value of the j^{th} alternative; a_o – optimal alternative.

If values of attributes are minimized (the minimum value preferred), they should be converted into maximized values as follows:

* The reference is given in the list of publications by the author on the topic of the dissertation

$$x_{ij} = \frac{1}{x_{ij}^*}; \; i = \overline{1,m}; \; j = \overline{1,n}, \tag{3.22}$$

where x_{ij}^* – values of the minimized attributes.

In this stage the attributes of the possibly optimal alternative A_o are also determined. The possibly optimal alternative A_o has the best possible values of attributes (i. e. the minimal possible costs and the maximum possible benefits preferred by stakeholders).

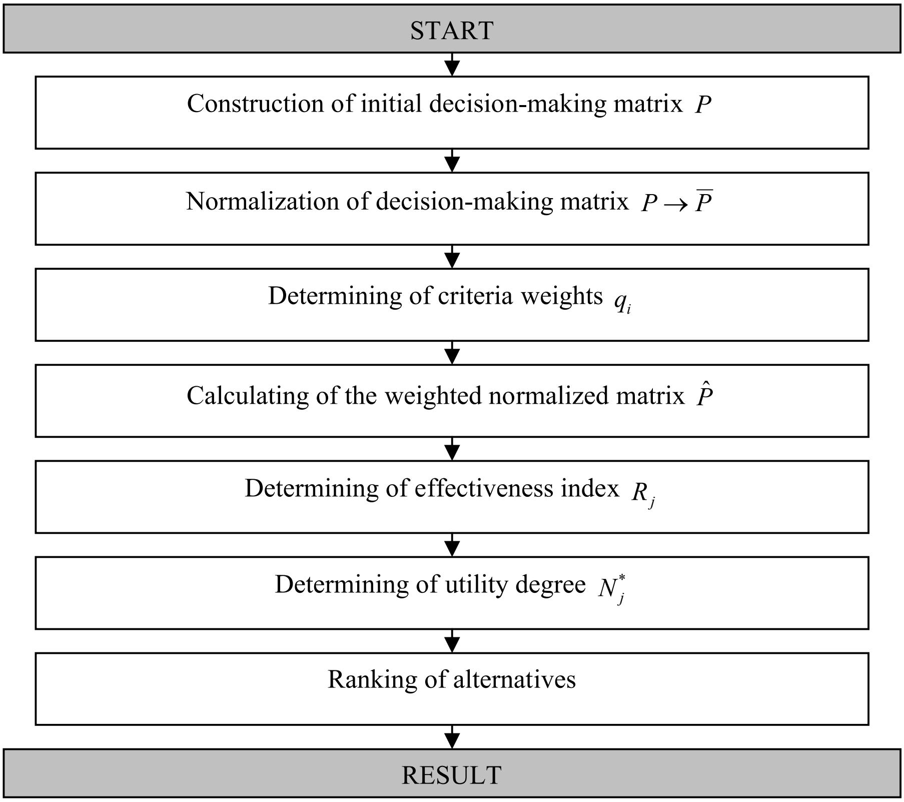

Fig. 3.4. Algorithm of the ARAS method

Stage 2. Normalization of the decision-making matrix. The values of normalized decision-making matrix $\overline{P}$ are calculated according to the formula:

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}}; \; i = \overline{1,m}; \; j = \overline{1,n}. \tag{3.23}$$

Stage 3. Defining weighted normalized matrix $\hat{P}$. Values of the matrix are calculated by multiplying values of $\overline{P}$ matrix with corresponding weights of significances of each attribute q_i:

$$\hat{P} = \left[\begin{array}{cccc|c} q_1\overline{x}_{11} & q_1\overline{x}_{12} & \cdots & q_1\overline{x}_{1n} & q_1 x_o \\ q_2\overline{x}_{21} & q_2\overline{x}_{22} & \cdots & q_2\overline{x}_{2n} & q_2 x_o \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ q_m\overline{x}_{m1} & q_m\overline{x}_{n2} & \cdots & q_m\overline{x}_{mn} & q_m x_o \end{array}\right]; \ i = \overline{1,m}; \ j = \overline{1,n}. \tag{3.24}$$

Stage 4. Defining the effectiveness index R_j for each alternative as follows:

$$R_j = \sum_{i=1}^{m} \hat{x}_{ij}; \ i = \overline{1,m}; \ j = \overline{1,n}. \tag{3.25}$$

Stage 5. Calculating the utility degree N_j^* for each alternative as follows:

$$N_j^* = \frac{R_j}{R_o} \cdot 100\%, \tag{3.26}$$

where R_o – the effectiveness index of optimal alternative.

Utility degree N_j^* of alternative a_j indicates satisfaction degree of demands and goals pursued by the interested parties – the greater is the N_j^* the higher is the efficiency of the alternative. In this case, the utility degree N_o of the optimal alternative will always be the highest (equal to 100%). The utility degrees of all remaining alternatives are lower as compared with the optimal one. This means that total demands and goals of interested parties will be satisfied to a smaller extent than it would be in case of the optimal alternative. The best alternative will be the one closest to the optimal alternative.

Stage 6. Ranking of the alternatives according to the utility degree N_j^* in descending order.

The discussed methods are further compared in Table 3.1.

Table 3.1. Comparison of the analyzed MCDM methods

	SAW	TOPSIS	COPRAS	ARAS
1	2	3	4	5
Requirements to attributes	The same scale	Different scales	Different scales	Different scales
Normalization	Linear	Vector	Linear (proportional)	Linear

Table 3.1 continued

1	2	3	4	5
Compensation function	Compensatory	Compensatory	Compensatory	Compensatory
Ranking index	Score (based on additive weighting of alternatives)	Ranking index including the distances from the ideal point and negative-ideal point	Significance Q_j which is directly proportional to the effect of the compared criteria values and significances on the end result	Utility degree N_j^* in comparison to the optimal value of alternative
Result	The highest ranked alternative has the optimum score comparing to other alternatives	The highest ranked alternative is the best in terms of the ranking index: closest to the ideal point	The highest ranked alternative is the best in terms of the ranking index Q_j and has the highest utility degree N_j.	The highest ranked alternative has the highest utility degree N_j^* and is closet to the optimal alternative
Utility degree in percentage	Not available	Not available	Available	Available
Simplicity	Very simple	Simple	Simple	Simple

The described methods are further applied in the practical case study.

3.2. Case study: Evaluation of the Cultural Heritage Renovation Projects in Bulgaria for EEA and Norway Grants

3.2.1. Background

History has left the countries of Central and Southern Europe with a rich and diverse heritage. Cultural heritage has a character that can significantly contribute to the culture of a society and conserve aspects of its history as well as to encourage the economic growth of particular district. From this perspective cultural heritage is an integral part of the built and human environment. Indeed, with strained public finances, limited interest from private investors, and scarce EU funding for the cultural heritage sector, financing care and maintenance of cultural relics and monuments has often proved hard.

By making protection of cultural heritage one of the European Economic Area (EEA) and Norway Grants' core priority sectors, Iceland, Liechtenstein and Norway help to alleviate this lack of funding and contribute to securing cultural heritage for future generations.

European cultural heritage is a priority sector in all countries, and is the largest priority sector under the EEA and Norway Grants in terms of funding size. Around two thirds of the approved cultural heritage projects contribute to the renovation of immovable cultural heritage in the shape of historical buildings, fortresses, manor houses, religious monuments and historical urban areas. Projects also aim to revitalize buildings by providing public access and developing venues for the performing arts. Thus the projects contribute to the development of the regions, spread of culture and can be considered as part of built and human environment renovation.

Grants aimed at conservation and renovation of European cultural heritage have been made available to a broad range of applicants through close to 30 highly popular open calls across Central and Southern Europe. The beneficiary states have steered much of the grant support towards this sector and to date more than 20 percent of all approved grants have been made towards cultural heritage projects.

The project portfolio includes protection of World Heritage sites in Poland, restoration of manor houses in Estonia and Lithuania, renovation of wooden buildings in Latvia and urban regeneration and revitalization of historic centers in Portugal and Spain. Slovenia, Slovakia and the Czech Republic have supported several small-scale projects involving a wide array of building styles.

Recently the support is given to the new countries – Romania and Bulgaria. As granting funds are limited not all the projects can be granted. Accordingly, it is very important evaluate and select the most efficient and reasonable projects for granting. In order to ensure the transparency, projects are evaluated by experts from foreign countries. The case study of Bulgarian projects assessment for granting purposes is analyzed in this chapter. VGTU professor A. Kaklauskas and author of thesis have participated as experts in this assessment.

3.2.2. Development of the Criteria System for Evaluation of the Projects

In order to evaluate the cultural heritage renovation projects, a system of criteria must be developed. Basing on the main concept of this thesis, projects must be evaluated with respect to whole possible effects on the built and human environment – the holistic approach used. For this purpose macro, meso and micro-environment factors, renovation process as well as the needs of stakeholders should be considered.

The system of renovation projects' evaluation criteria was developed by author basing on the EEA Financial Mechanism and the Norwegian Financial Mechanism Appraisal Manual (2009), outcomes of Nordic-Baltic project *Construction and Real Estate – Developing Indicators for Transparency* (CREDIT) (in which author is participating) as well as on the research results provided in Chapters 1 and 2.

The purpose of the renovation projects' evaluation is to verify and assess their performance in the following areas:

1. The suitability of the applicant.
2. The relevance of the operation in a holistic context.
3. The choice and efficiency of methodology, approach and technical solution.
4. A risk control.
5. The economic and financial aspects and feasibility of the operation.
6. The cross-cutting issues (sustainable urban development, gender equity, good governance).
7. The bilateral relations.
8. The main quantitative indicators of the projects.

These eight assessment areas are described by specific assessment criteria. As the projects are evaluated basing on 48 criteria and the evaluation problem is sophisticated, the hierarchical structure of criteria groups and subgroups was developed (Fig. 3.5).

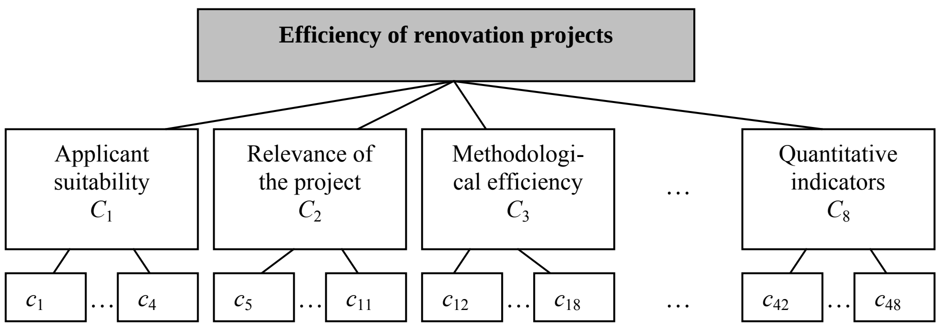

Fig. 3.5. Hierarchical model of renovation projects evaluation criteria

All the criteria groups and subgroups are described below in detail.

Applicant suitability (C_1). This group of criteria focuses on the applicant, including the organization and project management. The information relating to the applicant must be assessed in respect of credibility and applicant suitability. Criteria describing the applicant suitability are presented in Table 3.2.

Table 3.2. Criteria for applicant suitability assessment

Criteria		Description
c_1	Suitability of the applicant to implement the project	Is the applicant sufficiently committed to implement the project in line with relevant terms and requirements?
c_2	Suitability of the project partners	Any partners must be checked for background, etc. Their commitment and relevant competence/capacity should be verified.
c_3	Suitability of the organizational resources / structure	The applicant's resources and competence regarding its ability to manage the project must be examined. Verification of whether the management structure is clear and whether roles and responsibilities are clearly allocated should be made. Is the institutional capacity sufficient, e.g. does the body responsible for management and implementation of the project have the necessary staff, experience and know-how to ensure its efficient implementation?
c_4	Adequateness of the publicity plan for the operation	The publicity plan given in the application should be examined and verified regarding suitability for the purpose and the objectives of the financial mechanisms.

Relevance of the project (C_2). The focus of this criteria group is on the assessment the project's place in the overall strategic and legal context. This is necessary in order to understand how the project will contribute to the overall objectives and development at a regional or national level. The innovative character of the project and the contribution to implementing EU law is also covered by this section. Criteria are described in Table 3.3.

Methodological efficiency (C_3). This criteria group is on methodology, approach and technical solution addresses whether or not the chosen project presents the appropriate solution or approach to the problem and how well this can be measured. This group also covers the necessary element of capacity building, human resources development and the planning for post completion operation and maintenance of the project results. Criteria are presented in Table 3.4.

Table 3.3. Criteria for the assessment of relevance of the project

Criteria		Description
c_5	Justification of the project	The background and justification of the project should be confirmed by one or more independent sources: local or national bodies, etc.
c_6	Public consensus about the project	Public opinion about the project.
c_7	Relevance of the overall project objective	The relevance of the overall objective needs to be considered: 1) How does the overall objective fit into the national strategic plans for the relevant sector in the beneficiary state? 2) How significant is the project's potential contribution to the overall objective?
c_8	Meeting of the purpose of the project to the needs expressed by the applicant	The defined purpose of the project should be compared with the needs expressed by the applicant in the background and justification. To what extent does the proposed project meet these needs?
c_9	Purpose contribution in a national or regional perspective	The purpose must be considered from a local, regional and national perspective. It is important to form an opinion about how the project contributes to solving the problem or the issue in a broader perspective.
c_{10}	Innovativeness of the project	The project's degree of innovativeness, providing it with a potential to become a demonstration project, should be considered whenever relevant. Such demonstration may later be used to solve the same or similar problems on a larger scale with resources from others. This is of particular importance because the EEA Grants cover many, broad sectors, and can therefore in many cases only contribute to solving parts of the needs. The potential for implementing the learning from the given project into other projects must therefore be considered. The greater this potential, the more likely it is that other resources may be allocated to the same focus area and contribute further to the overall objective of the project.
c_{11}	Implementation of EU legislation	The project must be in accordance with EU legislation. The appraisal must evaluate the verification.

Table 3.4. Criteria for the assessment of methodological efficiency of the project

Criteria		Description
c_{12}	Effectiveness of the proposed solution compared to alternative solutions to the same problem	This section on methodology, approach and technical solution addresses whether or not the chosen project presents the appropriate solution or approach to the problem and how well this can be measured. This section also covers the necessary element of capacity building, human resources development and the planning for post completion operation and maintenance of the project results.
c_{13}	The choice of technology in a best available technique context	The choice of technology should, when relevant, be defended in a best available technique context. Whenever possible, the efficiency of the project in terms of cost per unit of result/purpose should be assessed.
c_{14}	Clarity and feasibility of the time schedule	The realism of the schedule is important for the success of the project and must therefore be considered. The proposed work programme should be assessed according to coherence between objectives, activities and time table.
c_{15}	Relevance of the division into separate project activities	The clarity of the work programme must be assessed. The milestones included must be definable and measurable. They must also be appropriate and practical for monitoring, reporting, disbursement, etc.
c_{16}	Suitability of the proposed indicators	The result indicators shall illustrate key, direct results of a project. Ideally, results indicators can also be used as progress indicators during the project implementation. All the indicators for result and purpose must be quantified.
c_{17}	Capacity building and human resources development	The institutional capacities and possible needs for human resource capacity strengthening need to be considered for different types of projects. Have the necessary elements of capacity building, training of existing personnel, etc. been sufficiently integrated into the project?
c_{18}	Operation and maintenance	The capacity to ensure the post completion operation and maintenance is an essential element for long term success. It is part of the appraisal to review how the applicant foresees handling operational and maintenance related aspects.

Risk control (C_4). Risks that may reduce the benefit of the project, or even cause the project to fail, should be assessed. The applicant must have identified and analyzed the risks, and developed a proper response plan, but there may also be risk factors not recognized by the applicant.

The target is to verify that the risks have been considered and that adequate risk management has been developed. A risk assessment must identify and analyze the risks, including likelihood and impact considerations as a basis to determine how the risks should be managed. It will typically include, but not be limited to, the relationship between risks and objectives, judgment of critical risks and determination of actions to mitigate risks. Criteria are presented in Table 3.5.

Table 3.5. Criteria for the assessment of risk control of the project

Criteria		Description
c_{19}	Control of the managerial risks	Examples of managerial risks are lack of qualifications, mismanagement, fraud, etc. These and other managerial risks that relate to the project should be assessed.
c_{20}	Control of the technical risks	Technical risks may among other things be related to risk of accidents, lack of technical suitability, etc.
c_{21}	Control of the financial risks	Examples of financial risks are lack of co-financing, lack of fiscal strength, inappropriate expenses, etc.
c_{22}	Control of the legal risks	Legal risks may be those that relate to not obtained, but required permits, legal disputes, changing legislation, etc.
c_{23}	Suitability of the management and control of risk	The purpose of the risk management is to identify, control and minimize the risk factors as well as to secure an efficient response in order to minimize the consequences.

Economic feasibility (C_5). The economic feasibility is about whether or not the project has a sound financial and economic foundation to become successful in both the short-term (during implementation), and in the long-term (following implementation). Criteria are presented in Table 3.6.

Contribution to cross-cutting targets (C_6). The contributions to cross-cutting targets address various aspects of the project relevant for all priority sectors, and are important in relation to the quality and sustainability of the proposals. They may also form an essential part of the overall project rationale. Cross-cutting targets are addressed to sustainable urban development, gender equity guarantees, and good governance.

Table 3.6. Criteria for the assessment of economic feasibility of the project

Criteria		Description
c_{24}	Feasibility of the budget	The budget must be assessed for its relevance regarding both unit prices and number of units needed for the project.
c_{25}	Revenue generation and additional benefit	If the project has a revenue generating component, this must be evaluated. The additional benefit information should be assessed.
c_{26}	Co-financing feasibility	The co-financing source(s) must be assessed regarding likelihood of delivering the required financing according to schedule throughout the project.
c_{27}	Applicant's control of any in-kind contributions	Any in-kind contribution must, as far as practically possible, be checked for its existence and availability to the project.
c_{28}	Cost-effectiveness of the project	The cost-effectiveness of the project should be examined. This analysis must take all relevant costs and benefits of the project into consideration over the lifetime of the project in a net present value consideration. An attempt must be made to quantify all relevant effects of the project, including ecological, social and other benefits to society.
c_{29}	Economic life and post completion financing	A project's economic life is related to the long-term financing of operation and maintenance of the result in order to maintain the purpose following the termination of the implementation period. For all types of projects an effort must be made to create an economic life after the completion of the project. The appraisal should determine whether or not the possibilities for creating the financing for such economic life have been utilized effectively. Regarding maintenance for projects including capital investments, it is important to determine whether or not the applicant has a sound plan for how to fund future maintenance costs in a secure way.

Sustainable development requirements are implemented in the financial mechanisms in different ways. Some project will have a sustainable development focus, whereas other projects will be part of sustainable development through the inclusion of sustainability aspects wherever appropriate. Certain three dimensions of sustainable development are assessed:

- *Environmental.* The issue regarding the environmental dimension is to determine whether or not the project has a positive environmental impact and how the key aspects of environment have been taken into account. Environmental protection may even be the purpose of the project.
- *Economic*. Although many economic aspects have been covered elsewhere, the task here is to discuss the economics of the project in the context of sustainable development. Among other things, it is important to determine that the economic drivers that influence the project are sustainable and whether or not the project in itself makes any kind of contribution to the establishment of economic tools for sustainable development and urban growth.
- *Social*. The social related checkpoints relate to the knowledge and conduct of the population, their health and integrated sustainable development management. Other parts of the social dimension relate to the other cross-cutting issues.

Gender aspects also should be reflected in all facets of a project, making the concerns and experiences of women as well as men an integral part of the planning, implementation, monitoring and evaluation of the project.

The information given on good governance should be checked and verified. Any information indicating possible non-compliance with elements of good governance must be considered.

Bilateral relations (C_7). It is of interest to know whether or not the project contributes or may contribute to bilateral or even multilateral relations between the donor states and the beneficiary state. Criteria are presented in Table 3.7.

Table 3.7. Criteria for the assessment of bilateral relations of the project

Criteria		Description
1		2
c_{38}	Partnership contribution to the quality or success of the project	A common way to contribute to bilateral relations is a partnership between the applicant and one or more partners in one or more of the donor countries
c_{39}	Good working relations between the partners	The relations between the partners and their quality must be assessed in order to guarantee successful implementation of the project.

Table 3.7 continued

1		2
c_{40}	Potential to develop the partnership beyond the project cooperation	The partnership beyond the project cooperation is estimated as a complementary benefit of the project.
c_{41}	Identification of the forms of bilateral relations other than partnerships	The other forms of bilateral relations than partnerships should be indicated and valuated.

Main quantitative indicators of the project (C_8). This group of criteria reflects the most important quantitative indicators of the project. Criteria are presented in Table 3.8.

Table 3.8. Main quantitative indicators of the project

Criteria		Description
c_{42}	Project budget (Euro)	Project budget must be evaluated basing on its feasibility, adequacy to the scope of works and current market prices. Lower rational budget is preferred.
c_{43}	Duration of the project (months)	The time for project implementation must be rational, consistent with volume of works.
c_{44}	Staff involved in the project management (number)	Staff involvement is about involving staff in all decisions that affect their working lives and the project implementation. Greater number of staff involved in the project management is preferred.
c_{45}	Average expenses of renovation (Euro per sq. m.)	Expenses of renovation work must meet the market prices. The lower price of renovation works is preferred.
c_{46}	Area of the newly developed infrastructure (sq.m)	Large developed area is evaluated as successful result of project implementation.
c_{47}	Visitors increase after project implementation (people)	Visitors increase is estimated as the economic result of the project implementation having positive effects to the rural economy development.
c_{48}	Number of conserved and/or protected items	Number of conserved and/or protected items during the project.

The weights of the developed criteria are determined in the next chapter.

3.2.3. Determining Weights of Criteria

The definition and the interpretation of criteria weights are different between authors. Because of the difficulties in measuring and interpreting the criteria weights, it is generally stated that criterion weight measures the importance of a criterion in the multiple criteria analysis problem under consideration. The roles of criteria weights are also different depending on multiple criteria analysis methods (Choo *et al*. 1999). Criteria weights determination is an important part of multiple criteria analysis as alternatives are selected based on several criteria and criterion weight.

Criteria weights are the key point in obtaining the total scores of alternatives and most importantly the conclusion of multiple criteria analysis problems. Most multiple criteria analysis methods use criteria weights to assess the overall scores of the alternatives.

The criteria weights determination methods could be classified into two main groups, namely objective approaches and subjective approaches. In the objective approaches, criteria weights are derived from information contained in each criterion through mathematical models (without decision makers intervention) (Diakoulaki *et al*. 1995).

In subjective approaches, criteria weights are derived form decision makers subjective judgment. In order to get the subjective judgments, analyst usually gives decision makers a set of designed questions. Subjective criteria weight determination is an uneasy task. It is the point where decision makers have to make compromise before taking final decision. It is often time consuming, especially when there is no agreement between decision makers of the problem under consideration (Diakoulaki *et al*. 1995).

There are many methods to derive subjective preference of decision makers regarding criteria weights in renovation projects evaluation. One of the most and widely applied method to derive criteria weights in multiple criteria analysis is *Analytic Hierarchy Process* (AHP) (Ramanathan 1997). This method is proposed to use in determining weights of the criteria in this thesis. AHP is becoming quite popular in research due to the fact that its utility outweighs other research methods (Cheng and Li 2001). The development of AHP could be traced back to the early 1970s in response to the scarce resources allocation and planning needs for the military (Saaty 1980). As the methodological procedure of AHP can easily be incorporated into multiple, objective programming formulations with interactive solution process (Yang and Lee 1997), it has received a wider attention in various fields. AHP considers both qualitative and quantitative approaches to research and combines them into a single empirical inquiry. It uses qualitative way to decompose an unstructured problem into systematic decision hierarchy (Cheng and Li 2001).

In AHP, decision makers are asked to compare the relative importance of two criteria. For example, in evaluating renovation projects' alternatives where the main goal is to reduce energy consumption, the typical question would be: "Of the two criteria, replacing windows or doors, which one is you consider more important, and by how many times, with respect to alternatives to reduce energy consumption in building?" The decision makers give their judgments based on the judgment scale shown in Table 3.9.

Table 3.9. Saaty's scale of measurement in pair-wise comparison (Saaty 1980)

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one to another
5	Strong importance	Experience and judgment strongly favor one to another
7	Very strong importance	An activity is strongly favored and its dominance is demonstrated in practice
9	Absolute importance	The importance of one over another affirmed on the highest possible order
2,4,6,8	Intermediate values	Used to represent compromise between the priorities listed above
Reciprocals of above non-zero numbers		If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j* , then *j* has the reciprocal value when compared with *i*

The judgments are then summarized in the pairwise comparison matrix. If equation 3.27 is a matrix $C = c_{ij}$, then:

$$C = \begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ c_{m1} & c_{m2} & \cdots & c_{mn} \end{bmatrix} = \begin{bmatrix} 1 & q_1/q_2 & \cdots & q_1/q_n \\ q_2/q_1 & 1 & \cdots & q_2/q_n \\ \vdots & \vdots & \cdots & \vdots \\ q_n/q_1 & q_n/q_2 & \cdots & 1 \end{bmatrix}. \quad (3.27)$$

Equation 3.27 is reciprocal matrix where all the elements are positive. It contains the derived pairwise comparison, $c_{ij} = q_i / q_j$ (q_i and q_j are the relative importance of criteria *i* and *j*, respectively, their reciprocals, $c_{ij} = 1/c_{ij}$, and unity as its diagonal elements $c_{ji} = 1$. Zahedi (1995) described that in general all diagonal elements in square matrix *C* are equal to unity and the triangle under the diagonal line are always the reciprocal of the corresponding triangle above the diagonal line. As a consequence, the number of pairwise comparison is $(m(m-1)/2)$, where *m* is the number of criteria. In other words, we do pairwise comparison only on half of the matrix (Saaty 1994a,b).

If we multiply matrix *C* with vector of weights, *Q*, (assuming that the vector of weights, *Q*, are known) yields in $CQ = mQ$ (a system of homogenous linear equations) where *q* is termed as a principal right eigenvector of *C* and *m* is therefore the eigenvalue of *C*:

$$(C - mI)Q = 0 \tag{3.28}$$

or

$$Cq = \begin{bmatrix} 1 & q_1/q_2 & \cdots & q_1/q_n \\ q_2/q_1 & 1 & \cdots & q_2/q_n \\ \vdots & \vdots & \cdots & \vdots \\ q_n/q_1 & q_n/q_2 & \cdots & 1 \end{bmatrix} \begin{bmatrix} q_1 \\ q_2 \\ \vdots \\ q_n \end{bmatrix} = m \begin{bmatrix} q_1 \\ q_2 \\ \vdots \\ q_n \end{bmatrix} = mq \,. \tag{3.29}$$

If decision makers judgments are perfectly consistent in which all pairwise comparisons are equal to $c_{ik} = c_{ij} \times c_{ji}$ (for *i*, *j* and *k*=1,2,3,…,*m*), then the principal right eigenvector of *C* is equal to *m* (Saaty 1990). However, perfectly consistent judgments (equation 3.29) are rarely happening in reality, so that the eingenvalue of *C* equal to *m* is also rarely happen. As consequence, the largest eigenvalue $(\lambda_{\max})$ will be always greater than or equal to *m* and equation (3.29) is transformed to:

$$CQ = \lambda_{\max} Q \,. \tag{3.30}$$

The system of linear equation (equation 3.30) can be used to determine the relative importance for all pairwise-compared elements. The vector of weights, *Q*, is obtained from normalizing the eigenvector connected to the largest eingenvalue $(\lambda_{\max})$ to sum 1. Because all columns of *C* differ by multiplicative constant, the solution of *C* of equation 3.30 is unique (Saaty 1980; Hwang and Yoon 1981).

Several methods have been developed in order to calculate the principal right eigenvector (Q) as well as its largest eingenvalue $\left(\lambda_{\max}\right)$ of the square matrix C. Those methods are *Eigenvalue* method, the *Average of Normalized Columns* (ANC) method, the *Normalization of Row Averages* (NRA) method, and the *Normalization of the Geometric Mean of the row* (NGM) method. Amongst those methods, the eingenvalue method has been found to be the best method (Saaty 1980). The NGM has an advantage that it is mathematically easy to apply. Equation 3.31 is the NGM method to estimate the principal right eigenvector (Q) and equation 3.32 is its largest eingenvalue.

$$q_i = \frac{\left(\prod_{j=1}^{m} c_{ij}\right)^{1/m}}{\sum_{k=1}^{m}\left(\prod_{j=1}^{m} c_{kj}\right)^{1/m}} \tag{3.31}$$

and

$$\lambda_{\max} = \sum_{i=1}^{m}\left\{\left(\sum_{j=1}^{m} c_{ij}\right) \times q_i\right\}. \tag{3.32}$$

The closeness between $\lambda_{\max}$ and m can be used to measure the degree of inconsistency of the square matrix C. The closer $\lambda_{\max}$ to m the more consistent is the square matrix C. Saaty (1980) established *Consistency Index* (*CI*) of the square matrix C:

$$CI = \frac{\left(\lambda_{\max} - m\right)}{\left(m-1\right)}. \tag{3.33}$$

In order to decide whether the *CI* is acceptable or not, Saaty (1980) also provided the *Random Consistency Index* (*RI*), which is the average *CI* of a randomly generated reciprocal matrices (500 sample size) with dimension n (see Table 3.10). The degree of inconsistency of the square matrix C can be measured by the ratio of *CI* to *RI*, which is called the *Consistency Ratio* (*CR*):

$$CR = \frac{CI}{RI}. \tag{3.34}$$

Saaty (1994b) has set the acceptable *CR* values for the different matrices‘ sizes:

- the *CR* value is 0.05 for a 3–by–3 matrix;
- 0.08 for a 4–by–4 matrix;
- 0.1 for larger matrices.

If the consistency level falls into the acceptable range, the weight results are valid.

Table 3.10. The averagely random consistent indicator *RI* of 1-10 matrix

The number of tiers	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.12	1.25	1.35	1.42	1.46	1.49

The described AHP method was applied in order to determine weights of the renovation projects‘ evaluation criteria (Tupėnaitė *et al*. 2010*). The calculations algorithm is presented in Figure 3.6.

Very important issue in this survey was to select the experts having appropriate experience in fields of projects assessment for granting purposes (i. e. EU structural funds, EEA grants) as well as experience in renovation projects' implementation. Seven experts fully satisfied the requirements and were selected for the survey. Two of experts are from VGTU Strategic analysis unit, three from VGTU Department of Construction economics and property management and two from private sector companies.

The questionnaires of judgment matrices where prepared and provided to experts. Judgment matrices, filled by experts were used for the calculations of criteria weights and the consistency ratio (*CR*) of each matrix was checked. Weights, determined by each expert are presented in Annex A.

Further weights provided by each of the experts were aggregated and assumed as distribution and the *medians* of these distributions were calculated in order to determine the final weights of criteria.

In probability theory and statistics, a median is described as the numeric value separating the higher half of a sample, a population, or a probability distribution, from the lower half. The median of a finite list of numbers can be found by arranging all the observations from lowest value to highest value and picking the middle one. If there is an even number of observations, then there is no single middle value, so one often takes the mean of the two middle values (Pfanzagl 1994).

For any probability distribution on the real line with cumulative distribution function *F* a median *M* satisfies the inequalities (Pfanzagl 1994):

$$P(X \le M) \ge \frac{1}{2} \text{ and } P(X \ge M) \ge \frac{1}{2} \qquad (3.35)$$

* The reference is given in the list of publications by the author on the topic of the dissertation

or

$$\int_{-\infty}^{m} dF(x) \geq \frac{1}{2} \text{ and } \int_{m}^{\infty} dF(x) \geq \frac{1}{2}. \tag{3.36}$$

Calculation of medians is a popular technique in summary statistics and summarizing statistical data, since it is simple to understand and easy to calculate, while also giving a measure that is more robust in the presence of outlier values than is the mean.

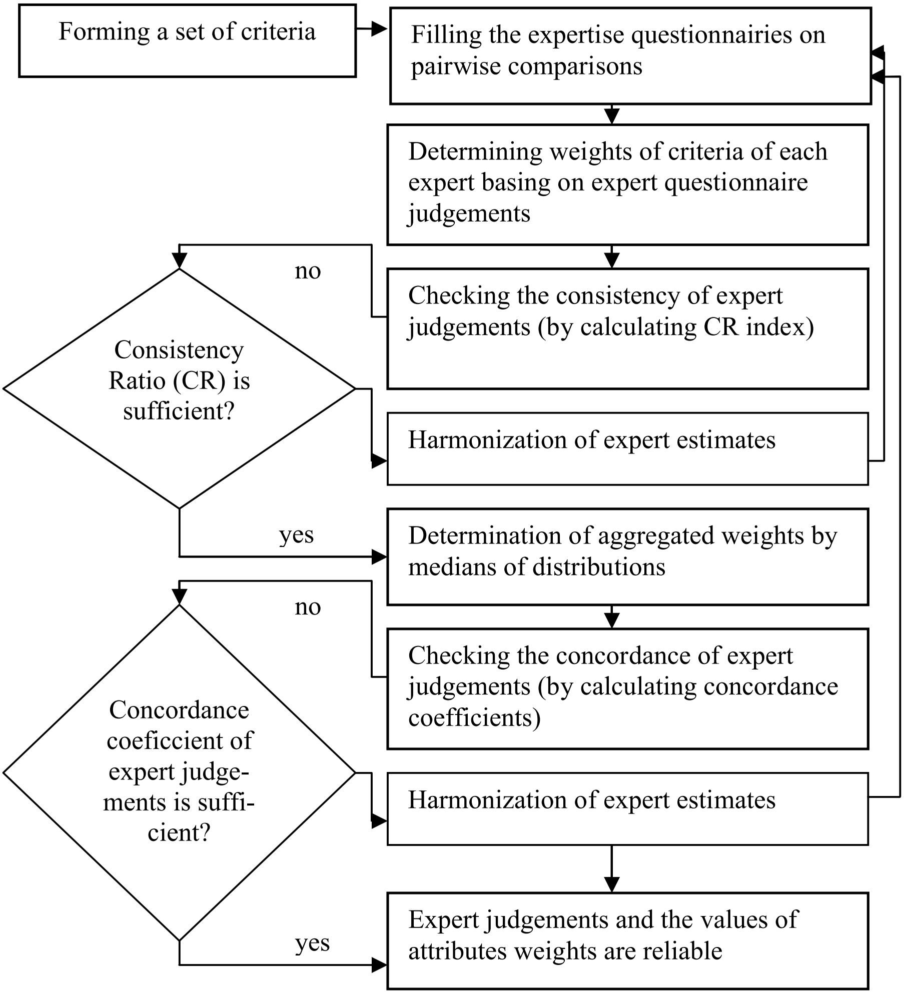

Fig. 3.6. Proposed algorithm for determination of weights of criteria by pairwise comparison

For example, the calculations of the weights of criteria in *Applicant suitability* criteria group are presented in Table 3.11.

Reliability of the data can be expressed by the coefficient of concordance (agreement) of the respondents' opinions by describing the extent to proximity of individual views. In cases with reiterated ranks for the same parameters, as in this case, the coefficient of concordance is (Kendall 1970; Podvezko 2005):

$$W = \frac{12S}{r^2(m^3 - m) - r\sum_{k=1}^{r} T_k}; \; W \in [0;1], \tag{3.37}$$

where S is the total square deviation of the rankings of each attribute, T_k –the index of reiterated ranks in the r rank, k – the number of respondents and m – the number of evaluation attributes.

Table 3.11. Determination of weights of criteria in criteria group assessing *Applicant suitability*

Expert (k_i)	Weights of criteria determined by AHP method			
1	0.2604	0.2570	0.3023	0.1803
2	0.2500	0.2500	0.2855	0.2145
3	0.2500	0.2510	0.2900	0.2090
4	0.2604	0.2570	0.3123	0.1703
5	0.2661	0.2260	0.3116	0.1962
6	0.2540	0.1981	0.2939	0.2540
7	0.2560	0.2821	0.2968	0.1651
q_i (Median)	**0.2560**	**0.2510**	**0.2968**	**0.1962**

Here $\sum_{i=1}^{m} q_i = 1$.

The deviation of the attribute ranking is calculated as follows:

$$S = \sum_{i=1}^{m} \left[\sum_{k=1}^{r} t_{ik} - \frac{1}{n} \sum_{i=1}^{m} \sum_{k=1}^{r} t_{ik} \right]^2, \tag{3.38}$$

where t_{jk} is the rank conferred by the k respondent to the i attribute.

However, the calculated value W is stochastic; and therefore, the significance of the concordance coefficient has to be calculated. Kendall (1970) has proved that, when $m > 7$, the significance of the concordance coefficient can be calculated by χ^2 criterion which has a distribution with degree of freedom $v = m - 1$, where m is the number of attributes considered. It has been proved that if the calculated value χ^2 is larger than the critical tabular value χ^2_{tbl} for the pre-selected level of significance (e.g. $\alpha = 0.05$ or $\alpha = 0.01$), then the hypothesis about the agreement of independent experts 'judgments' is not rejected.

The significance χ^2 of the concordance coefficient is calculated as follows:

$$\chi^2_{\alpha,v} = W \cdot r \cdot (m-1) = \frac{12S}{rm(m+1) - \frac{1}{m-1}\sum_{k=1}^{r} T_k}. \quad (3.39)$$

If the $\chi^2_{\alpha,v} > \chi^2_{tbl}$ the significance of concordance coefficient exists on α level, then the agreement of experts' opinions is satisfactory and group opinion is established. Otherwise, when $\chi^2_{\alpha,v} < \chi^2_{tbl}$ is obtained, the respondents' opinions are not in agreement, which implies that they differ substantially and the hypothesis on the rank's correlation cannot be accepted.

If number of attributes m is from 3 to 7 ($3 \le m \le 7$), the χ^2 distribution should be applied choicely. In some cases the critical tabular value χ^2_{tbl} can be higher than the calculated value χ^2, indeed the respondents' opinions are in agreement. In this case the probabilistic tables of concordance coefficient or tables of critical S values can be used (Podvezko 2005).

In practical case study concordance coefficients were calculated for each group of criteria. For example, the *Applicant suitability* assessment criteria group consists of 4 criteria. The calculations of concordance coefficient are following:

$$T_1 = (0.2500)^3 - 2.500 = 0.15625; \; T_2 = (0.2750)^3 - 0.2750 = 0.06605;$$

$$T_3 = T_4 = 0; \; \sum_{k=1}^{r} T_k = 0.08167.$$

$$W = \frac{12 \cdot 201.08}{7^2(4^3 - 4) - 7 \cdot 0.08167} = 0.821.$$

After the concordance coefficient is determined, the significance is calculated according to equation (3.39).

$$\chi^2 = 0.821 \cdot 7(4-1) = 17.241.$$

χ^2_{tbl} = 11.345 with degree of freedom 3 and pre-selected level of significance α = 0.01. As $\chi^2 > \chi^2_{tbl} = 17.241 > 11.345$ the agreement of experts' opinions is satisfactory.

Adequate calculations were performed in all groups of criteria. Results are presented in Annex A. Determined weights of criteria are presented in Table 3.12.

Table 3.12. Weights of criteria determined by AHP method

Group of criteria	Weight q_i	Criteria	Weight q_i
1	2	3	4
Applicant suitability	0.0592	Suitability of the applicant project	0.2560
		Suitability of the project partners	0.2510
		Suitability the organizational resources / structure	0.2968
		Adequateness of the publicity plan for the operation	0.1962
Relevance of the project	0.1567	Justification of the project	0.1531
		Public consensus about the project	0.0678
		Relevance of the overall project objective	0.1473
		Meeting of the purpose of the project to the needs expressed by the applicant	0.0502
		Purpose contribution in a national or regional perspective	0.2368
		Innovativeness of the project	0.1731
		Implementation of EU legislation *c*	0.1717
Methodological efficiency	0.1672	Effectiveness of the proposed solution compared to alternative solutions to the same problem	0.1599
		The choice of technology in a best available technique context	0.1420
		Clarity and feasibility of the time schedule	0.1631
		Relevance of the division into separate project activities	0.0496

Table 3.12 continued

1	2	3	4
		Suitability of the proposed indicators	0.1289
		Capacity building and human resources development	0.1445
		Operation and maintenance	0.2121
Risk control	0.1473	Control of the managerial risks	0.1078
		Control of the technical risks	0.2501
		Control of the financial risks	0.2501
		Control of the legal risks	0.1375
		Suitability of the management and control of risk	0.2545
Economic feasibility	0.1581	Feasibility of the budget	0.1904
		Revenue generation and additional benefit	0.0846
		Co-financing feasibility	0.1019
		Applicant's control of any in-kind contributions	0.0590
		Cost-effectiveness of the project	0.2739
		Economic life and post completion financing	0.2903
Contribution to cross-cutting targets	0.0420	Recovery of natural resources	0.1233
		Strengthening of financial tools for ecosystem protection	0.0685
		Increase of public understanding of sustainability and positive influence on citizens' sustainability behavior	0.1071
		Positive effects for public health	0.0722
		Contribution to poverty reduction	0.1040
		Promotion of women's participation within the project	0.0723
		Improvement of participation of civil society into decision making processes	0.3005
		Proactive approach to preventing and dealing with corruption	0.1521

Table 3.12 continued

1	2	3	4
Bilateral Relations	0.0700	Partnership contribution to the quality or success of the project	0.2540
		Indications development and good working relations between the partners	0.2540
		Potential to develop the partnership beyond the project cooperation	0.2939
		Identification of the forms of bilateral relations other than partnerships	0.1981
Main quantitative indicators of the project	0.1892	Project budget (Euro)	0.1520
		Duration of the project (months)	0.1245
		Staff involved in the project management (number)	0.0435
		Average expenses of renovation (Euro per sq.m.)	0.1801
		Area of the newly developed infrastructure (sq.m)	0.2155
		Visitors increase after project implementation (people)	0.1335
		Number of conserved and/or protected items	0.1509

Further the determined weights of criteria are used for the multiple criteria assessment of the renovation projects. The alternatives of the projects are discussed in the next chapter.

3.2.4. Description of the Evaluated Renovation Projects' Alternatives

In this case study five Bulgarian cultural heritage renovation projects were analyzed and evaluated:

1. Restoration and conservation of *Magura* historical complex (A_1).
2. Revival and preservation of traditional building techniques and skills used in Bulgaria (A_2).

3. Reconstruction of the *Onbashieva House* as part of the Vassil Levski National Museum in Karlovo and popularization of the life and deed of the Bulgarian national hero Vassil Levski as part of the European cultural heritage (A_3).
4. Opening of *Sofia Arsenal* museum for contemporary art in the monumental building (A_4).
5. Restoration and conservation of *Shumen Fortress* – cradle of the civilizations that lived in Bulgaria (A_5).

The selected projects for EEA and Norwegian Grants application are further described.

Alternative 1. Restoration and conservation of Magura historical complex. The project is connected to the realization measures for protection on the cultural historical heritage of the historical complex *Magura* and for the more attractive presentation and promotion on this invaluable wealth.

Magura Hill (also known as Rabisha Mound) is situated in the Northwest Bulgaria, 2.5 km from Belogradchik Town, 35 km from Vidin and 220 km from Sofia. Due to its rich cultural and historical heritage of high value it has been distinguished as a historical landmark of national significance.

The most valuable site in the whole complex in both cultural and historical aspect and in environmental aspect is the Magura Cave. It is formed in the Rabisha Mound (with carst origin) and is extraordinary both with its impressive underground halls and rock formations and with the found remains and relicts from the Neolithic times and Early Bronze times (Fig. 3.7).

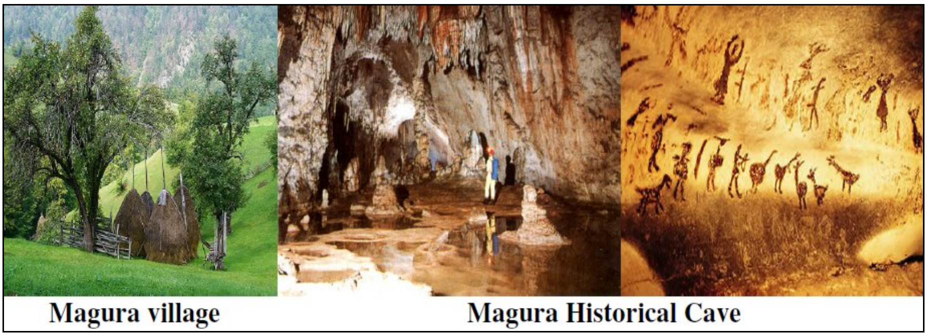

Fig. 3.7. Fragments of *Magura* historical complex

However, in order to preserve this ancient history for the future generation it is necessary to undertake additional measures connected to the better preservation of the sites and at the same time allowing this cultural heritage to receive wider public recognition.

The main aim of the project is preservation of the cultural and historical heritage on the territory of Belogradchik Municipality and its attractive presentation.

The specific aim of the project is preservation, improvement of the infrastructure, promotion and attractive presentation in the unique cultural and historical complex *Magura* in its wholes and its designation as a group cultural monument.

In this aspect the project envisages the realization of activities for preservation and presentation of the elements of the cultural and historic heritage, investment activities connected to the development of specialized tourist infrastructure, as well as promotion and marketing of the natural-historic complex as an attractive tourist destination. The main accent of the project is the activities for studying and conservation of the historical artifacts. These activities will be realized in the first phase of the project.

Archeological studies will be carried out at defined zones of the hill. In the cave an overall restoration study will be done of the cave paintings, whose aim will be to propose the most appropriate methods for their conservation. At the end of this first phase, on the basis of the archeological studies a procedure will be initiated for designation of the Magura Cave and Magura Hill as a group cultural monument. Based on the results of the archeological and restoration studies, a Management plan for the historical complex will be developed. This will contribute to the preservation of the unique cultural landmark in the long term. The investment aspect of the project includes internal and external development of Magura Cave and the hill above it.

The internal development includes construction of resting points, equipment of medical station, presentation of prehistoric animals which inhabited the cave and presentation of scenes from the life of people who inhabited the cave during the Neolith Age. A reliable communication system for connection between the administrative building and the points in the cave is also envisaged. The external development envisages improvement of the infrastructure at the cave entrance and exit, installation of the alley lighting, development of the parking at the Rabisha hotel, expansion of the administrative building through developing and equipping of an exhibition hall.

The promotion activities include development of promotional and information materials (leaflet, CD, website, information boards) and promotional campaign for the renewed historic complex as an attractive tourist site.

The activities will be implemented for two years.

Alternative 2. Revival and preservation of traditional building techniques and skills used in Bulgaria. The intangible cultural heritage, including traditional skills, crafts and old building techniques, represents a core part of the cultural and spiritual wealth of Bulgaria as well as on a European and global scale. The urbanization and the fast expansion of the modern building industry represent a real threat of losing the knowledge and skills of traditional building techniques. Moreover, living and action-borne skills disappear as the old practitioners of these crafts pass away. Thus, the revival and preservation of traditional construction techniques and skills are important issues both of national and European significance. In line with the Convention for the Safeguarding of Intangible Cultural Heritage, Bulgaria committed itself to take the necessary measures to ensure the safeguarding of the intangible cultural heritage present in its territory. The proposed project will contribute to fulfilling Bulgaria's obligations.

The project aims at revival and preservation of the traditional knowledge and skills in old building techniques applied in Bulgaria. A major part of the project activities are concentrated in the area of Vitosha Nature Park (Bulgaria) (Fig. 3.8).

Fig. 3.8. Vitosha Nature Park and Traditional Bulgarian building

The project will be implemented over 24 months and includes the following activities:

1. Study and research of traditional construction methods applied in Bulgaria - a review of the existing information, on-site survey, etc. The results will be: information on existing old buildings, master builders; pictures of existing constructions; spot-filming of characteristic elements; text materials.
2. Transfer of knowledge and exchange of best practices between Bulgaria and Norway.

3. Upgrade the existing technical design of an Educational Training and Exhibition Center.
4. Establishment of an ETE Center. This activity consists of: (1) Construction of the Center by applying old traditional building techniques and skills, following the detailed technical design, attached to this project proposal; (2) Establishment of a shelter-like construction presenting Norwegian traditions.
5. “Learning by doing” training in traditional building techniques. It will focus on passing on action-born knowledge activities and will include a series of 3 workshops (5 days each), which will take place on different stages of building of the Center. Students and people with special interest in old traditional construction methods will take part on volunteer basis and will be trained. Three students will pass “train the trainers” exercise.
6. Documentation. Spot-films and photos presenting every step of the construction of the ETE Center will be prepared and used for training purposes. A detailed book/manual with description of the building process, pictures, schemes and a terminology section will be prepared and published.
7. Exhibition activities: design and establish the first exhibition in the ETE Center. It will present selected old construction methods, natural materials, techniques and tools from Bulgaria and from Norway (input from National Maihaugen Open Air Museum). Traveling exhibition will be exposed at 10 park directorates and thus widely communicate the project goals and values.
8. Development of National programme, including an action plan and outline of the main steps in developing a network for safeguarding of traditional building techniques, skills and knowledge from different country regions.
9. Promotional activities, to: (1) raise awareness on the importance of safeguarding intangible cultural heritage, (2) provide stakeholders with information access; (3) ensure adequate communication of project goals, efficient participation and transparency.

Project approach:

- emphasis on stakeholder participation;
- creating favorable environment for fruitful cooperation;
- result-oriented and motivated project team;
- transparency and accountability.

This project proposal is a result of a newly established partnership between Vitosha Nature Park and NHU (Norwegian Crafts Development) and is a joint effort of both partners. Vitosha Nature Park Directorate will have the overall responsibility of the project management.

Alternative 3. Reconstruction of the Onbashieva House as part of the Vassil Levski National Museum in Karlovo and popularization of the life and deed of the Bulgarian national hero Vassil Levski as part of the European cultural heritage. The project shall be implemented on the territory of the Municipality of Karlovo and has a total duration of 24 months.

The overall objective of the project is to popularize the life and deed of the Bulgarian national hero Vassil Levski as part of the European cultural heritage. The specific purpose of the project is to reconstruct the Onbashieva house as part of Vassil Levski National Museum in Karlovo, by fully completing the Memorial Complex (Fig. 3.9).

Fig. 3.9. *Onbashieva House* in Karlovo (historical view)

With the present project the building shall be architecturally renovated and functionally adapted as part of the Memorial Complex and shall consists of basement of approximately 70 sq.m. (two small store rooms); ground floor of approximately 85 sq.m. (information center /library and reading-room); floor of approximately 90 sq.m. (meeting, presentation and conference room with multimedia and two working offices). The house is being reconstructed as per project of National Institute for Monuments of Culture for shaping the environment of Vassil Levski's birth house, approved by the National Council for Preservation of the Cultural Monuments at the Ministry of Culture in 1993.

The Onbashieva house was located in the North part of Karlovo next to Vassil Levski's house of birth. In architectural design the building is representative of the late Bulgarian Renaissance architecture, a two-storey house with nice windows and staircase leading to the second floor, basement, an impressive portico, open to the South towards the spacious cobble-stone yard. The house had existed in this form until 1981, when after a fire, it has been demolished. The name of the Onbashieva house derives from its first owner – a Turk. The house is a symbol of the good neighbour and purely human relations between the Bulgarian and Turk population in Karlovo. The reconstruction of the Onbashieva house is an important stage of the entire preservation of the environment of the Apostle's birth house. This shall be a reconstruction of a typical representative of the Bulgarian Renaissance house in Karlovo, which is also historically related to the family of Vassil Levski.

Main activities of the project are as follows:

1. Reconstruction design: electrical installation, water and waste water system, geodesy, energy efficiency, health and safety plan.
2. Reconstruction of the Onbashieva house: uncovering of preserved foundations, construction of the house, renovation of the fence walls, stone and cobble-stone yard pavement, shaping and planting of the yard according to the tradition of old houses in Karlovo, internal furnishing of the house.
3. Project development and construction of an architectural plastic composition at the entrance of the complex.
4. Establishment of a modern library and information center with internet access and Multimedia.
5. Development of an information database of materials /text, photographic, film and multimedia/ of 19^{th} Century Europe, the progress of democratic thought and the most prominent personalities – European democrats and revolutionaries from various nationalities: Garibaldi, Koshuth, Petofi, Velestinlis, Fridty of Nansen, Papaflesas, Herzen, Bakunin and others.
6. Development of an information database of materials of Vassil Levski and the attainments of his revolutionary and democratic thought in various languages;
7. Organization of an informational campaign for the popularization of the completed Memorial complex and the new services offered by Vassil Levski National Museum in Bulgaria.
8. Organization of an informational campaign for the popularization of the life and deed of the Bulgarian national hero Vassil Levski as part of the European cultural heritage in Norway.

Alternative 4. Opening of Sofia Arsenal museum for contemporary art. Contemporary art in Bulgaria has troubles in attracting audience. On its part, the potential audience is in growing difficulty finding works of contemporary art. Currently the biggest state owned art gallery in the country with the oldest and largest fund of classical works is the main partner in the artistic activities of contemporary art. Exhibition space is deficient. The fine arts are losing their once typical public popularity. Bulgaria does not have a contemporary art museum.

The proposed project is pursuing the common goal of conservation of the European cultural heritage by creating conditions for cultural socialization, educational and research work in the field of contemporary art.

The achievement of the common goal presupposes the accomplishment of the specific one – opening of a Contemporary Art Museum situated in a historical building from the end of the 19th century following an architectural reconstruction of the building and the surrounding area. The building is a three-storey one with total area of 1084 sq. m. It forms part of the Sofia Arsenal architectural complex, a monument of cultural heritage located in the South Park of Sofia (see Fig. 3.10). The building's intended purpose was to be used as an art gallery but instead it is used currently as a depository. The proposed reconstruction follows the principles of the sustainable architecture.

Fig. 3.10. Historical monumental building the South Park of Sofia

The work on the project will continue for a period of 22 calendar months. The preparatory stage includes consultations; preparation of the engineering and the contractor designs for the reconstruction; the bills of quantities; organization and holding of a procedure for selection of a contractor; receipt of a Permit for construction. Its duration is 4 months.

The next stage involves the equipment of the construction site with temporary external connections, which takes up to 1 month.

Following the performance of dismantling works within 1 month the reconstruction works starts: architecture and construction part; construction and installation works, including all systems and installations; external constructions. These activities are performed within 13 months.

The external connections and the green design of the surrounding area are completed. The appropriate acceptance committees and administrative procedures for commissioning of the site are held. Duration – 2 months.

Acceptance committees and administrative procedures are absolved within 1 month.

The museum is equipped with information and communication facilities and a digital archive is set up. The equipment is delivered and installed –1 month.

Two independently detached stages follow which are subordinated to a common subject: museum activity. The development of a museum's strategy presupposes holding of consultations, survey among the target groups; partnership seeking. An annual plan for the museum is prepared; a set of job descriptions are drafted, selection and appointment of staff is undertaken. An inauguration workshop is organized for selection of an International Museum Council for partnership and cooperation. A Council is elected; the museum and its first exhibition are opened while the initially evacuated museum fund is placed in a depository in advance. Total duration is 18 months, 7 of which during the first year and 11 – during the second year of the project's implementation. During the whole period the planned measures for publicity and visualization are fulfilled.

Alternative 5. Restoration and conservation of Shumen Fortress – cradle of the civilizations that lived in Bulgaria. The aim of the project proposal is conservation and restoration of Historical-Archaeological Reserve *Shumen Fortress* and transformation of the object into an attractive destination for Bulgarian and foreign visitors. The reserve is located near the modern city of Shumen (3 km away) (Fig. 3.11).

The current problems of this historical object are connected with a shortage of financial resources. The problem is fundamental to the upkeep of the fort and planning of future development interventions. As a result of insufficient resources, the fortress walls and infrastructure inside the fort have been destroyed through the ages and weather conditions and the artistic lighting is broken and outdated.

Completion and beautification of the Fortress must be accomplished through conservation and restoration activities.

The overall objective of the project is conservation of Shumen Fortress and uncovering possibilities for development of the object as a part of cultural heritage in Bulgaria.

Fig. 3.11. *Shumen Fortress* in Bulgaria

The purpose or direct effect of the realization of the project includes restoration of the fortress walls, basic infrastructure inside the fort and installation of artistic lighting. For the realization of these objectives, it is important to properly implement the following project activities:

1. Formation of the project management team, which will be responsible for good governance, monitoring and the accountability of project activities and for communication with National Focal Point and the Financial Mechanism Office.
2. Public procurement procedures for the restoration activities and for the equipment. The stages of this activity include – preparation of tender documentation, implementation of procedures under Public Procurement Law and official contract signing with a company chosen for project restoration activities and for delivery and installation of the equipment.
3. Restoration and conservation activities of the Shumen Fortress include silhouette building of the Southern fortress wall, silhouette building of the Eastern fortress wall, silhouette building of the Northern fortress wall, adaptation of the South-Eastern fortress tower for the lapidary museum, and completion of walking paths in the North-Western sector, etc.
4. Purchase, delivery, and installation of two equipment items – Temperature and humidity condition system for the preservation of archeological artifacts found in the Fortress and a device for visitor access – a Turnstile.
5. Publicity of the project. This activity includes implementation of a press-conference to announce the project's beginning, creation of com-

memorative plaques about the EEA Financial Mechanism contribution to the project, creation and distribution of project leaflets, creation of a website for the Shumen fortress, organization of a re-enactment of the historical battle between the army of King Vladislav and the Ottoman invaders, broadcasting of information about the project, and a final press conference regarding the project.

6. Realization of financial activities connected with preparation of interim and final external audit reports and payment of bank charges for opening and administering the project account.

7. Conclusion of the project with preparation of final technical and financial reports by the project management team.

The period of project realization is 24 months. Some of the activities mentioned above will be accomplished in first year, the rest in the second.

The main strengths and weaknesses of the described projects alternatives are presented in Table 3.13.

Table 3.13. Strengths and weaknesses of the analyzed projects

Project	Strengths	Weaknesses
1	2	3
Restoration and conservation of *Magura* historical complex – A_1	-Experienced applicant; -Scope of the project; -Reasonable project budget; -Sustainability of the project achievements; -The project is innovative; it offers the development of a motivated proposal which will be submitted to the UNESCO.	Unclear realistic of construction (external development of the entrance and exit of Magura Cave, etc.) costs due to crisis in the construction and real estate sector.
Revival and preservation of traditional building techniques and skills used in Bulgaria – A_2	-Experienced Applicant; -Scope of the Project; -Reasonable Project price; -Sustainability of the Project achievements.	The weaknesses of the project are liquidated after the reduction of the overall project budget from 472 072 Euro to 305 850 Euro and canceling (optimizing) some activities.

Table 3.13 continued

1	2	3
Reconstruction of the Onbashieva House – A_3	-Experienced Applicant; -Scope of the Project; -Reasonable project revised budget; -Sustainability of the project achievements; -The project is innovative; - It foreseen to carry out of scientific researches, comparative analyses of the activity and ideas of Vassil Levski.	Unclear realistic of the renovation of the Onbashieva House costs due to crisis in the construction and real estate sector.
Opening of *Sofia Arsenal* museum for contemporary art – A_4	-Experienced Applicant; -Scope of the Project; -Reasonable Project price; -Sustainability of the Project achievements; -Innovative solutions.	Because of the turbulences in the real property and construction sector it is quite difficult to estimate the final costs of the renovation works.
Restoration and conservation of *Shumen Fortress* – cradle of the civilizations that lived in Bulgaria – A_5	-experienced Applicant; -scope of the Project; -innovativeness of the Project; -sustainability of the Project achievements.	Vague real Southern fortress restoration costs due to crisis in the construction and real estate sector.

All the projects' alternatives are further assessed by the experts according to the system of criteria and the parameters of the projects are determined. For criteria groups C_1–C_7 the assessment of attributes is qualitative. Each project is assessed with a score „very poor“ (score 1), “poor” (2), “adequate” (3), “good” (4) or “very good” (5). For criteria group C_8 quantitative assessment is given basing on information provided in application forms. Thus the decision matrix for multiple criteria evaluation of the projects is prepared (see Annex B).

3.2.5. Multiple Criteria Evaluation of the Projects

Multiple criteria evaluation of the renovation projects' alternatives further is performed basing on the previously discussed methods SAW, TOPSIS, COPRAS and ARAS in respect to hierarchically structured system of evaluation criteria. For this purpose the calculations must be performed in two cycles – at first in lower hierarchy levels of criteria and after in the highest hierarchy level of criteria. This hierarchical evaluation is advantageous to experts or other decision makers – they can evaluate performance of each project in certain group of criteria as well as in all groups of criteria. For this reason the evaluation process becomes clear and visible.

Detail calculations in each group of criteria as well as in all groups of criteria are presented in Annex C. In this chapter only the final calculation results are presented.

The results obtained in all four methods application are presented in Table 3.14 and the ranks of the alternatives' priorities – in Table 3.15.

Table 3.14. Data obtained by calculating the efficiency of the alternatives by SAW, TOPSIS, COPRAS and ARAS methods

Method	Ranking index	Alternatives				
		A_1	A_2	A_3	A_4	A_5
SAW	K_j^*	0.81	0.86	0.89	0.78	0.95
TOPSIS	K_j	0.34	0.53	0.52	0.19	0.66
COPRAS	$N_j(\%)$	86.5	97.3	94.3	84.9	100
ARAS	$N_j^*(\%)$	58.41	63.18	64.43	54.94	71.51

Table 3.15. Rank of variants' priorities determined by SAW, TOPSIS, COPRAS and ARAS methods

Method	Rank of alternatives‘ priorities
SAW	$A_5 \succ A_3 \succ A_2 \succ A_1 \succ A_4$
TOPSIS	$A_5 \succ A_2 \succ A_3 \succ A_1 \succ A_4$
COPRAS	$A_5 \succ A_3 \succ A_2 \succ A_1 \succ A_4$
ARAS	$A_5 \succ A_3 \succ A_2 \succ A_1 \succ A_4$

Basing on the multiple criteria analysis performed by four methods – SAW, TOPSIS, COPRAS and ARAS – it can be stated that the best alternative (A_5)

determined by all the methods is the same. It means that the granting firstly should be supported to the project alternative A_5 (*Restoration and conservation of Shumen Fortress*) and later – to other projects basing on the priorities list, according to the available granting amounts.

It must be admitted that these results are obtained in analyzing only part of the projects applications. In order to make real granting decisions, all the projects applied for granting must be analyzed and their ranks calculated.

SAW, COPRAS and ARAS methods provided equal results (ranks of alternatives‘ priorities), indeed the rank of alternatives' priorities determined by TOPSIS method differs considering the performance of alternatives A_2 and A_3 – the alternative A_3 according to SAW, COPRAS and ARAS methods is the second best, indeed according TOPSIS method it is in the third place although its distance only to small extent differs from the alternative A_2. In order to select the best method for renovation projects evaluation the applied methods must be discussed in more detail and their advantages and disadvantages distinguished.

From the analysis results it can be stated that although SAW method is simple to apply and is widely used in the scientific research, some disadvantages should be noted. The major disadvantage of the SAW method is that it is only possible to compare attributes with a uniform scale. Many renovation projects have attributes with mixed data, making SAW unsuitable. Among the other disadvantages it can be mentioned absence of pairwise comparison abilities as well as determination of each alternative utility degree.

The MCDM method TOPSIS is based on an aggregating function representing "closeness to the ideal". The basic principle of the TOPSIS method is that the chosen alternative should have the "shortest distance" from the ideal solution and the "farthest distance" from the "negative-ideal" solution. The TOPSIS method introduces two "reference" points, but it does not consider the relative importance of the distances from these points (Opricovic and Tzeng 2004). Another disadvantage is that TOPSIS method uses vector normalization. For this purpose the normalized value may depend on the evaluation unit. From the discussed disadvantages it is doubtful if the renovation project alternative determined by TOPSIS method as the best is really the "ideal solution". For lack of accuracy TOPSIS should not be the most suitable method for renovation projects assessment.

COPRAS method seems to be very advantageous for built and human environment renovation projects assessment.

Two aspects that make the COPRAS method superior to the available MADM (MCDM) methods are as follows:

- This method may be used to estimate the utility degree of renovation alternatives, showing, as a percentage, the extent to which one alternative is better or worse than other alternatives taken for comparison;

- This method may be used to estimate the market value of renovation alternatives.

The COPRAS method was successfully used for solving various renovation problems in scientific research (Kaklauskas *et al*. 2005, 2006a,b; Zavadskas *et al*. 2008a*,d, 2009; Tupėnaitė 2008b*, etc.).

The COPRAS method was applied in practice during the Framework 5 project CONSTRINNONET and the Framework 6 project BRITA in PuBs. Zavadskas, together with Kaklauskas and other coworkers, used this method to develop different web-based intelligent and biometric systems for real-world applications, i. e. basing on this method *Multiple Criteria Web-Based Decision Support System for Refurbishment of Public Buildings* was created (Zavadskas *et al*. 2004; Zavadskas *et al*. 2008c).

Although the COPRAS method is proved to be the most suitable for renovation projects' assessment it should be admitted that in this thesis renovation of the built and human environment is analyzed as a whole. Author aims to develop the universal renovation projects' assessment methodology, applicable in various cases of built and human environment renovation. In COPRAS method the best alternative is selected from the existing set of alternatives in comparison with the best alternative from this set. For this purpose the utility degree of certain alternative can change if the new alternatives are added to the set. Accordingly, the best alternative can be "not the best" in all the cases. In order to avoid this disadvantage it is more convenient to compare the existing renovation projects' alternatives with the "optimal alternative" (alternative which fully satisfies the stakeholders' needs). For this purpose the newly developed method ARAS is recommended for renovation projects' assessment.

It must be noted that the projects assessment methodology proposed by author is universal and can be used for various renovation tasks solutions: housing, public buildings, commercial buildings, etc. renovation projects assessment or for the decision-making in integrated renovation of particular territories. Stakeholders' groups in particular cases can select the appropriate criteria by themselves as well as to determine their weights, assess the projects' parameters and to perform multiple criteria analysis basing on the proposed methodology.

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* The reference is given in the list of publications by the author on the topic of the dissertation

3.3. Conclusions for Chapter 3

1. MCDM methods were reviewed and four the most promising methods selected for the assessment of the renovation projects – SAW, TOPSIS, COPRAS and the newly developed method ARAS.
2. Four selected MCDM methods were practically applied in case study of five Cultural Heritage Renovation Projects in Bulgaria for EEA and Norway Grants.
3. In order to evaluate the cultural heritage renovation projects, a hierarchical system of criteria, consisting of 8 groups of criteria and 48 sub-criteria, was developed. Basing on this system projects are evaluated with respect to whole possible effects on built and human environment – the holistic approach is used, macro, meso and micro environment factors, renovation process as well as the needs of stakeholders considered.
4. The weights of criteria were estimated by experts and calculated by AHP method using the original methodology proposed by author. The agreement of experts' opinions was checked by concordance coefficient calculations.
5. SAW, COPRAS and ARAS methods provided equal results (ranks of alternatives' priorities), indeed the rank of alternatives' priorities determined by TOPSIS method differs considering the performance of alternatives A_2 and A_3 – the alternative A_3 according to SAW, COPRAS and ARAS methods is the second best, indeed according TOPSIS method it is in the third place.
6. Multiple criteria analysis results by four selected methods provided equal results in best and least alternative determination. Analysis revealed that the best alternative is *Restoration and conservation of Shumen Fortress* and the least alternative is *Opening of Sofia Arsenal museum for contemporary art*.
7. For further built and human environment renovation projects evaluation author suggests to apply the newly developed method ARAS. Method is based on additional ratio assessment. The best alternative is considered as the alternative which is closest to the optimal one.
8. The projects assessment methodology proposed by author is universal and can be used for various renovation tasks solutions. Stakeholders groups in particular cases can select the appropriate criteria by themselves as well as to determine their weights, assess the projects' parameters and to perform multiple criteria analysis of the projects.

4

The Computer-Aided Decision Support System for Built and Human Environment Renovation

The Computer-Aided Decision Support System for Built and Human Environment Renovation (DSS-BHER) is developed in this chapter. The chapter provides detailed description of the system's components: user interface, databases within the database module and models within the model base. The working principles with the system are explained and solutions to practical tasks provided.

4.1. Components of the Computer-Aided Decision Support System for Built and Human Environment Renovation

Basing on the Conceptual Model for the Integrated Analysis of Built and Human Environment Renovation (IABHER) and multiple criteria assessment method ARAS in order to determine most efficient versions of renovation projects Computer-Aided Decision Support System for Built and Human Environment Renovation (DSS-BHER) was developed. DSS-BHER consists of a database, database management system, model-base, model-base management system and user interface (Fig. 4.1). The system is available on the internet and can be found at the following address: http://iti.vgtu.lt/renovation.

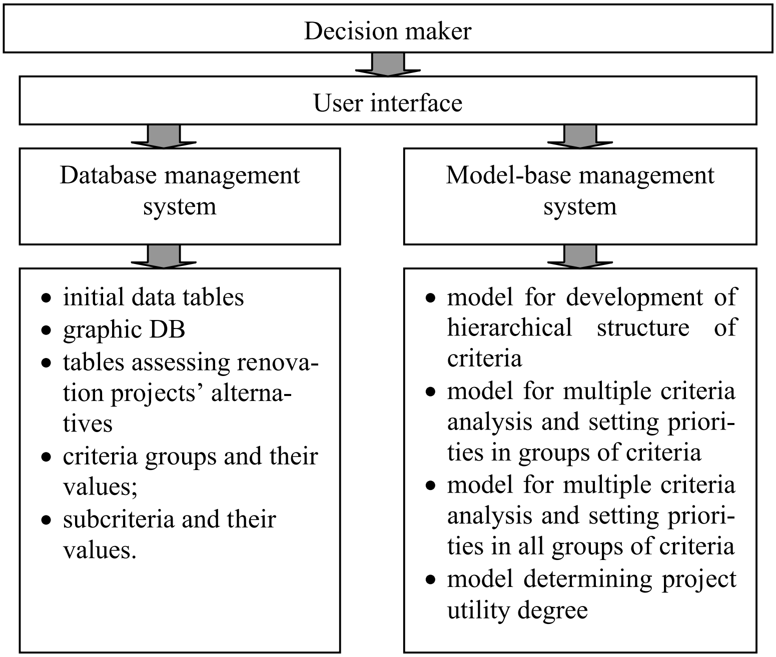


Fig. 4.1. Components of the Computer-Aided Decision Support System for Built and Human Environment Renovation

The system integrates databases and model-bases managed by system users via user interface. These components are closely interrelated and link smaller components of the system. The main components of the system are further discussed in detail.

4.1.1. Database and Database Management System

Built and human environment renovation involves a number of stakeholders' groups (i. e. clients, users, designers, contractors, suppliers, maintenance organizations, local authorities, government and its institutions, etc.) pursuing various goals as well as having different potentialities, educational level and experience. This leads to various approaches of the above groups to decision-making in this field. In order to thoroughly analyze the alternatives available and obtain an efficient compromise solution it is often necessary to define them on the basis of macro, meso and microenvironment describing information. This information should be provided in a most user-oriented way.

For instance, macro economic information on built and human environment renovation embraces the group of economic, social, legal, technological, ecological criteria to be considered. This information may be described in minor detail, especially when the particular projects are considered. In the analyzed case study (see Chapter 3.2), the renovation projects are assessed from the various aspects, considering macroenvironment issues: economic feasibility, cross-cutting issues as sustainable development, etc.

In a similar way, it is possible to demonstrate the need to possess some other information (i. e. data on comfort, aesthetics, etc.) related to the complex efficiency of analyzed alternative versions of the built and human environment renovation.

The presentation of information needed for decision-making in DSS-BHER system may be in conceptual (digital (numerical), textual, graphical (diagrams, graphs, drawings, etc), photographical, sound, visual (video)) and quantitative forms. Thus, quantitative information presentation involves criteria systems and subsystems, units of measurement, values and initial significances fully defining the alternatives provided. Conceptual information means a conceptual description of the alternative solutions, the criteria and ways of determining their values and significances, etc.

In this way, DSS-BHER system enables the decision maker getting various types of conceptual and quantitative information on built and human environment renovation from a database and a model-base allowing him to analyze the above factors and make an efficient solution.

The analysis of database structures in decision support systems according to the type of problem solved reveals their various utility. There are three basic types of database structures: hierarchical, network and relational (Kaklauskas 1999). DSS-BHER system has a relational database structure when the information is stored in the form of tables. These tables contain quantitative and conceptual information. Each table is given a name and is saved in the computer external memory as a separate file. Logically linked parts of the table make a relational model. The following tables make DSS-BHER system database:

- *Initial data tables*. These contain general facts about the renovation projects considered, actions planned, projects budget, etc.;
- *Graphic database*, containing conceptual information on projects considered, i. e. photographs of the objects, plans, etc.;

- *Tables assessing renovation projects alternatives*. They contain quantitative and conceptual information about alternative renovation solutions relating to applicant suitability, project feasibility, etc.;
- *Criteria groups and their values*. These contain the description of criteria groups and their weights both in quantitative and conceptual ways;
- *Sub-criteria and their values*. Sub-criteria are also described both in quantitative and conceptual forms, their dependence to the corresponding group of criteria is determined;
- *The tables of renovation project alternative assessment.*

The collection, processing and presentation of information for a database in the computer acceptable form is a complicated time-consuming process. The information collected in a database should be reliable, fully describing built and human environment renovation as well as enabling DSS-BHER system to perform an efficient multiple criteria analysis of renovation alternatives basing on hierarchically structured system of criteria.

To design the structure of a database and perform its completion, storage, editing, navigation, searching, browsing, etc. a database management system was used.

Tables of initial data contain the following information:

- general facts about the renovation projects analyzed;
- data on objects to be renovated (physical, economic, architectural, aesthetic, functional, legal, etc.);
- top priority and significances of renovation objectives;
- the amount of money intended for renovation;
- the duration of the projects implementation;
- the information about applicant;
- information about the optimal (mostly preferred) alternative.

The applicants seeking for granting of renovation projects should provide in tables of initial data exact information about the project, aims, actions, feasibility, budget, etc. as well as about their capacities to implement the project.

Graphic database contains conceptual information on projects considered, i. e. photographs of the objects to be renovated, plans, schedules, etc.

Tables assessing renovation projects alternatives for granting contain the evaluation data on projects in 8 areas, provided by experts:

- the suitability of the applicant;
- the relevance of the operation in a holistic context;
- the choice and efficiency of methodology, approach and technical solution;
- a risk control;
- the economic and financial aspects and feasibility of the operation;

- the cross-cutting issues (sustainable development, gender equity, good governance) ;
- the bilateral relations;
- the main quantitative indicators of the projects.

The tables of renovation project alternative assessment contain the project alternatives available and their quantitative and conceptual description as well as description of the optimal alternative. Quantitative description of the alternatives deals with the systems and subsystems of criteria fully defining the alternatives as well as the units of measurement and values and initial significances. Conceptual description defines the alternatives available in a commonly used language giving the reasons and providing grounds for choosing a particular criterion, calculation its value, significance and the like.

The process of drawing up the tables of renovation project alternative assessment consists of the following steps:

- collection and presentation of general information about the alternatives under consideration;
- collection and presentation of general information about the optimal alternative;
- establishment and conceptual description of the systems and subsystems of criteria;
- establishing of criteria for choosing the units of measurement;
- determination of the initial significances of the criteria.

Tables of criteria groups and their values contain the description of each criteria group and their weights both in quantitative and conceptual ways (text description, graphical information, measuring units, maximization or minimization, etc.);

Tables of sub-criteria and their values contain full description of the criteria both in quantitative and conceptual forms; also their dependence to the corresponding group of criteria is determined.

The values of the criteria used to describe the alternatives are obtained by analyzing the projects as well as using the expert, statistical and other methods, analogies, available recommendations and documents. The accuracy of information about the alternatives presented is of paramount importance, the objective character of the choice of the most efficient variant being largely dependent on it. It should be noted that quantitative information is sufficiently objective. Actual projects have actual costs and maintenance expenditures. The values of the qualitative criteria are usually rather subjective though the application of expert methods contributes to their objectivity. The initial significances of all criteria are obtained by using AHP method. In addition, based on various specifications and standards as well as expertise results and the granting requirements, some limitations on the criteria determining the rejection of the variants from further analysis in case the latter do not satisfy them can be established.

The *Financial Mechanism Office* for EEA and Norway grants, citizens, applicants have their specific needs. Therefore, every time when using DSS-BHER system they may make corrections of the database according to the aims to be achieved and the financial situation available. Also new projects for assessment can be added.

Uniform types of relational tables have been chosen to facilitate entering of appropriate data into the database. Such unified database also make it possible easily correct and introduce new information as well as efficiently carrying out computation.

The above tables are used as a basis for working out the matrices of decision-making. These matrices, along with the use of a model-base and models, make it possible to perform multiple criteria evaluation of alternative renovation projects resulting in the selection of most beneficial variants in respect to the closeness to the optimal (most preferred by stakeholders) alternative.

The DSS-BHER database management system allows users to analyze the renovation projects' alternatives by taking into account the hierarchically structured system of criteria.

4.1.2. Model-Base and Model-Base Management System

A model-base allows the DSS-BHER user to select the most beneficial renovation projects' alternatives by comparing the measures that promote the greatest value to all interested bodies and organizations.

Since the efficiency of a renovation project variant is determined in holistic approach taking into account macro, meso and micro environment factors a model-base of the DSS-BHER should include models enabling a decision maker to do a comprehensive analysis of the variants available and make a proper choice. The following models of model-base are aimed to perform this function:

- a model for development of hierarchical structure of criteria;
- a model for multiple criteria analysis and setting priorities in groups of criteria;
- a model for multiple criteria analysis and setting priorities in all groups of criteria;
- a model for determining project utility degree.

A model for development of hierarchical structure of criteria allows assigning each analyzed criteria to respective group of criteria.

A model for multiple criteria analysis and setting priorities in groups of criteria performs multiple criteria analysis of renovation projects alternatives and sets the priorities of them basing on the weighted criteria in each group of criteria. The methodology of the newly developed method ARAS is used for this purpose.

A model for multiple criteria analysis and setting priorities in all groups of criteria acquires data about each project performance in each criteria group and uses this data for multiple criteria analysis of renovation projects alternatives and sets the priorities of them basing on the weighted criteria of criteria groups. The methodology of the newly developed method ARAS is used for this purpose.

A model for determining project utility degree determines the utility degree of each renovation project in respect to the optimal alternative both in each group of criteria as well as in whole criteria groups. The quantitative value of utility degree is provided in percentage.

4.2. Work with the Computer-Aided Decision Support System for Built and Human Environment Renovation

In order to demonstrate the practical work with DSS-BHER, functions of its models and other elements the solution of practical case study, demonstrated in chapter 3 is performed.

The main page of the system is presented in Figure 4.2.

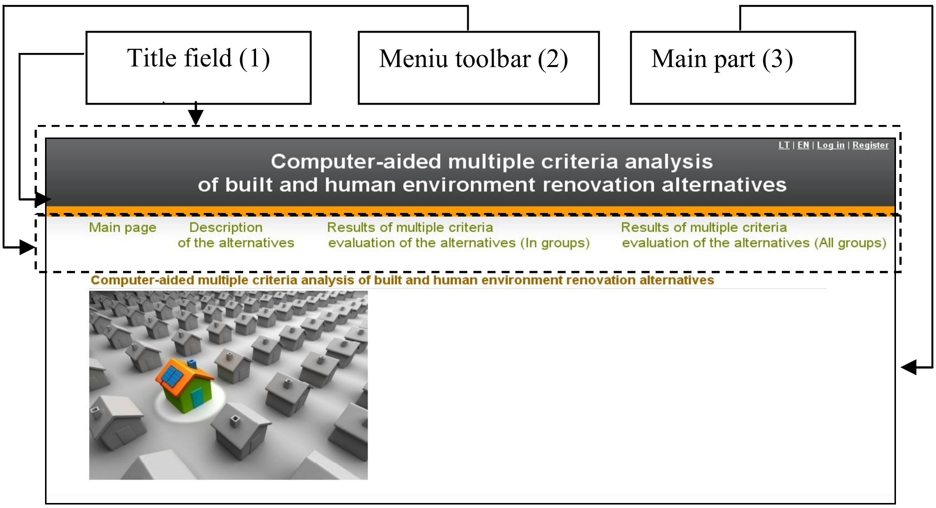


Fig. 4.2. Main page of DSS-BHER system

The main page of the system consists of three main components:

- title field (1);
- menu toolbar (2);
- the main part (3).

In the *title field* the title is presented (*Computer-Aided Multiple Criteria Analysis of Built and Human Environment Renovation*), the user can choose Lithuanian or English language, Log in to the system (if has the administration rights) or Register to the system (if wants to perform the multiple criteria analysis basing on the data provided by administrator).

The *toolbar menu* consists of several options:

- main page;
- description of alternatives;
- results of multiple criteria evaluation (in groups);
- results of multiple criteria evaluation (all groups).

In the *main part* the information is provided to user. The content of the main part changes according to the option selected by user.

Further a work with the system is described in more detail.

4.2.1. Providing the Data for Analysis

In order to perform the multiple criteria assessment of renovation projects‘ alternatives, firstly the initial data must be provided and stored in corresponding databases: data about project alternatives, attributes, criteria groups, sub-criteria, criteria and sub-criteria weights, etc.

In order to provide initial data for analysis the user must have administrator rights. He must login by entering the user name and password.

Once the user has logged in, he can enter all the necessary data for analysis into relevant databases, consisting of (Fig. 4.3):

- objects groups;
- objects;
- objects criteria;
- objects criteria parameters;
- criteria groups;
- images;
- measuring units.

All the information describing the analyzed alternatives as well as criteria can be provided in conceptual and quantitative forms. For instance, in the provided case study user enters initial data about objects (the analyzed renovation projects alternatives) in text form as well as provides the photo (Fig. 4.4).

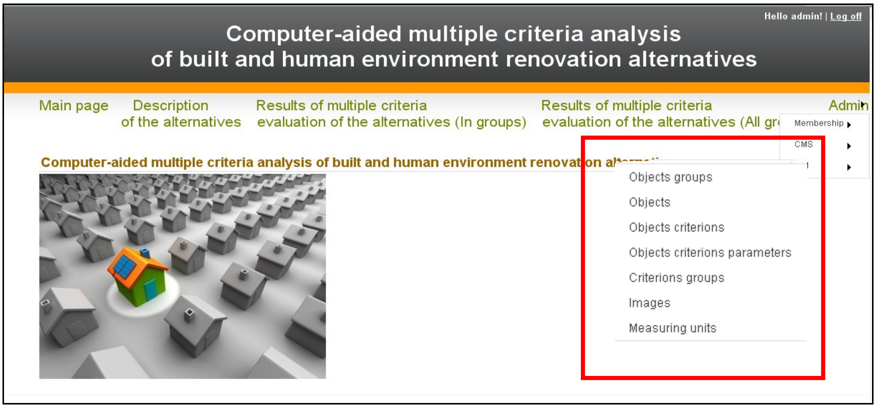


Fig. 4.3. Providing data for DSS-BHER system

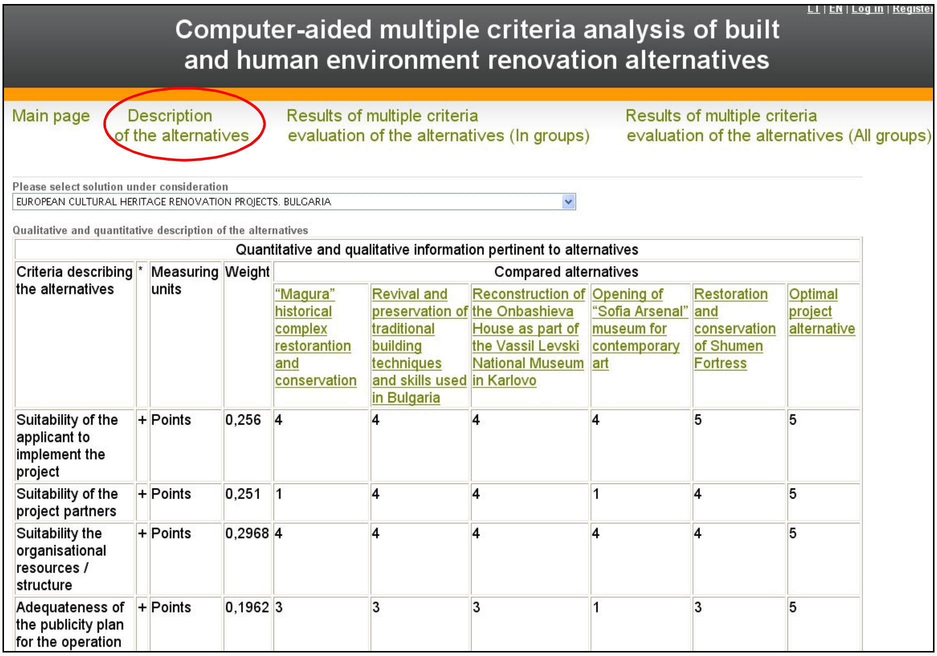
Fig. 4.4. Initial information about the analyzed project

The user who has administrator rights also provides the necessary data about the analyzed groups of criteria: group ID, name of the group, description, weights (determined by AHP method), graphical elements (if any), information if criterion is maximized, and measuring unit. Information can be provided in English or/and Lithuanian languages. All the provided data can be easily deleted or edited as well as the new groups of criteria added.

Data describing each criterion is also provided by user: criterion ID, name, description, weights (determined by AHP method), graphical elements (if any), information if criterion is maximized, and measuring unit. Very important issue is to assign each criterion to the relevant group of criteria. Codes are used for this purpose – the code of the according criteria group indicated, for example, code 7 determines the group of criteria *Applicant suitability*. All the provided data can be easily deleted or edited as well as the new groups of criteria added.

User who has the right of administration also enters all the values of attributes (parameters) describing each project alternative as well as the optimal alternative according to each criteria. Entering of the parameters is clear and parameters can be changed any time.

The data entered by user (administrator) is the initial data for multiple criteria analysis of renovation projects' alternatives. It is linked and presented in the table *Description of alternatives* which can be selected from the toolbar menu (Fig. 4.5).


LT | EN | Log in | Register

Computer-aided multiple criteria analysis of built and human environment renovation alternatives

Main page | Description of the alternatives | Results of multiple criteria evaluation of the alternatives (In groups) | Results of multiple criteria evaluation of the alternatives (All groups)

Please select solution under consideration

EUROPEAN CULTURAL HERITAGE RENOVATION PROJECTS, BULGARIA

Qualitative and quantitative description of the alternatives

Quantitative and qualitative information pertinent to alternatives									
Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives					
				"Magura" historical complex restoration and conservation	Revival and preservation of traditional building techniques and skills used in Bulgaria	Reconstruction of the Onbashieva House as part of the Vassil Levski National Museum in Karlovo	Opening of "Sofia Arsenal" museum for contemporary art	Restoration and conservation of Shumen Fortress	Optimal project alternative
Suitability of the applicant to implement the project	+	Points	0,256	4	4	4	4	5	5
Suitability of the project partners	+	Points	0,251	1	4	4	1	4	5
Suitability the organisational resources / structure	+	Points	0,2968	4	4	4	4	4	5
Adequateness of the publicity plan for the operation	+	Points	0,1962	3	3	3	1	3	5

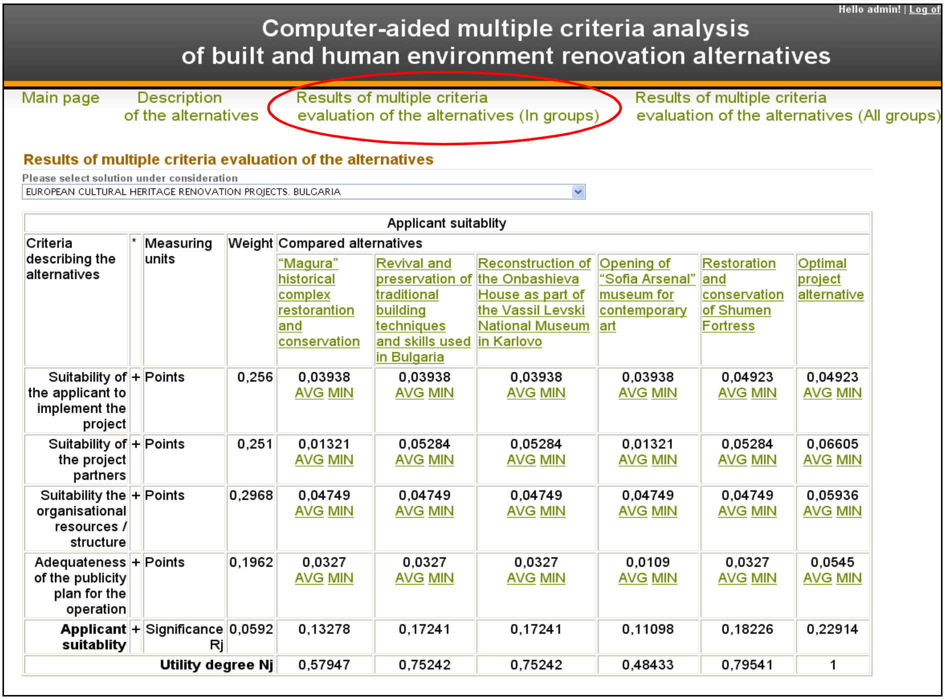
Fig. 4.5. Description of the alternatives

Once the main data is entered, the multiple criteria assessment of the renovation projects alternatives can be started.

4.2.2. Multiple Criteria Evaluation of Alternatives

At first the assessment of each alternative is performed in each group of criteria. For instance, the results of multiple criteria evaluation in the first group of criteria namely *Applicant suitability* are provided in Figure 4.6.

During the analysis the normalization of decision-making matrix is performed and weighted decision-making matrix is constructed (formulas (3.22), (3.23), (3.24)). Further, basing on the matrix data the multiple criteria assessment is performed basing on ARAS methodology and the significances R_j for each analyzed alternative is calculated (formula (3.25)). Than the utility degree is determined basing on formula (3.26). The utility degree is determined in comparison of each alternative performance with the optimal alternative.



Applicant suitablity									
Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives: "Magura" historical complex restorantion and conservation	Revival and preservation of traditional building techniques and skills used in Bulgaria	Reconstruction of the Onbashieva House as part of the Vassil Levski National Museum in Karlovo	Opening of "Sofia Arsenal" museum for contemporary art	Restoration and conservation of Shumen Fortress	Optimal project alternative
Suitability of the applicant to implement the project	+	Points	0,256	0,03938 AVG MIN	0,03938 AVG MIN	0,03938 AVG MIN	0,03938 AVG MIN	0,04923 AVG MIN	0,04923 AVG MIN
Suitability of the project partners	+	Points	0,251	0,01321 AVG MIN	0,05284 AVG MIN	0,05284 AVG MIN	0,01321 AVG MIN	0,05284 AVG MIN	0,06605 AVG MIN
Suitability the organisational resources / structure	+	Points	0,2968	0,04749 AVG MIN	0,04749 AVG MIN	0,04749 AVG MIN	0,04749 AVG MIN	0,04749 AVG MIN	0,05936 AVG MIN
Adequateness of the publicity plan for the operation	+	Points	0,1962	0,0327 AVG MIN	0,0327 AVG MIN	0,0327 AVG MIN	0,0109 AVG MIN	0,0327 AVG MIN	0,0545 AVG MIN
Applicant suitablity	+	Significance Rj	0,0592	0,13278	0,17241	0,17241	0,11098	0,18226	0,22914
		Utility degree Nj		0,57947	0,75242	0,75242	0,48433	0,79541	1

Fig. 4.6. Multiple criteria analysis results in criteria group describing *Applicant suitability*

From the provided example it can be stated that the best alternative considering *Applicant suitability* is alternative *Restoration and conservation of Shumen Fortress*. Its utility degree is 0.79 or 79% and it is closest to the optimal alternative, meaning that the project satisfies applicant suitability requirements by 79%. On the other hand, from the *Applicant suitability* aspect the least alternative is *Opening of Sofia Arsenal Museum for contemporary art*. Its utility degree is equal to 0.48 and it satisfies applicant suitability requirements only by 48%.

The adequate analysis is performed in all groups of criteria and the utility degrees are determined. These results are further supported as the initial data to multiple criteria assessment of alternatives in all groups of criteria module. The cycle of multiple criteria assessment according ARAS method is repeated: the normalization of matrix performed, weighted normalized decision-making matrix constructed and the significances of each alternative calculated. Once the significances determined, the utility degree is determined – performance of each alternative is compared to the performance of the optimal alternative (see Fig. 4.7 for results).

Hello admin! | Log o

Computer-aided multiple criteria analysis of built and human environment renovation alternatives

Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives: "Magura" historical complex restorantion and conservation	Revival and preservation of traditional building techniques and skills used in Bulgaria	Reconstruction of the Onbashieva House as part of the Vassil Levski National Museum in Karlovo	Opening of "Sofia Arsenal" museum for contemporary art	Restoration and conservation of Shumen Fortress	Optimal project alternative
Applicant suitablity	+	Significance Rj	0,0592	0,007861	0,010207	0,010207	0,00657	0,01079	0,013565
Relevance of the project	+	Significance Rj	0,1567	0,026089	0,025192	0,023677	0,023677	0,025455	0,032611
Methodological efficiency	+	Significance Rj	0,1672	0,022393	0,030447	0,020964	0,025267	0,024629	0,043517
Risk control	+	Significance Rj	0,1473	0,020086	0,020086	0,026782	0,020086	0,026782	0,033477
Economic feasibility	+	Significance Rj	0,1684	0,023367	0,027667	0,028485	0,024458	0,025493	0,038946
Contribution to cross-cutting targets (Sustainable development, etc.)	+	Significance Rj	0,042	0,006427	0,006444	0,006097	0,006528	0,006643	0,009861
Bilateral relations	+	Significance Rj	0,07	0,003931	0,011962	0,015723	0,003931	0,014799	0,019654
Main quantitative indicators of the projects	+	Significance Rj	0,1892	0,031464	0,021176	0,02428	0,022675	0,038789	0,050815
			Significance Rj	0,141618	0,153181	0,156215	0,133192	0,17338	0,242446
			Utility degree Nj	58,41%	63,18%	64,43%	54,94%	71,51%	100%
			Priority	5	4	3	6	2	1

Fig. 4.7. Multiple criteria analysis results in all groups of criteria

From the provided calculations results it can be stated that the best alternative which is closest to the optimal alternative is alternative number five –

Restoration and conservation of Shumen Fortress. Its utility degree is 71.51% and it is closest to the optimal alternative, meaning that the project satisfies the stakeholders' needs by 71.51%, the least alternative is number four – *Opening of Sofia Arsenal Museum for contemporary art*. Its utility degree is 54.94% and it satisfies only little more than half of stakeholders' needs.

Basing on the results the ranking of alternatives can be performed: $A_o \succ A_5 \succ A_3 \succ A_2 \succ A_1 \succ A_4$.

It must be noted that the analysis results provided by the system are adequate to the results of manually performed calculations by ARAS method (see Chapter 3). Accordingly it can be stated that the system is consistent, works properly and provides credible results. The system can be used in practice for built and human environment renovation projects assessment by all the participating stakeholders' groups.

The system differs fundamentally from previously developed systems of other authors in these respects:

- the newly developed method ARAS is used for multiple criteria assessment of renovation projects' alternatives;
- all the projects' alternatives are assessed as an integral part of built and human environment, according to stakeholders' needs and surrounding macro, meso and microenvironment;
- the hierarchically structured system of evaluation criteria is used;
- it is possible to evaluate the performance of each alternative in each group of criteria as well as in all groups of criteria;
- the priorities of the alternatives are determined in accordance to the optimal solution. If there are new alternatives added, the utility degree of current alternatives would not change;
- it is possible to determine the utility degree in percentage and to valuate in what extent the alternative satisfies the stakeholders' needs.

The developed system is universal and can be used for efficient decision-making on built and human environment renovation issues in both – national and international contexts, scientific projects as well as in an educational process of Vilnius Gediminas Technical University.

4.3. Conclusions for Chapter 4

1. In order to increase the efficiency of built and human environment renovation decisions, basing on the model developed by author and the multiple criteria analysis method ARAS the Computer-Aided Decision Support System for Built and Human Environment Renovation (DSS-BHER) was developed.

2. DSS-BHER consists of a database, database management system, model-base, model-base management system and user interface.
3. The system allows evaluating the performance of each alternative in each group of criteria as well as in all groups of criteria and determines the priorities of the alternatives in accordance to the optimal solution.
4. The system determines the utility degree in percentage and helps to evaluate in what extent the alternative satisfies the stakeholders' needs.
5. From the provided calculations results it can be stated that the best alternative which is closest to the optimal alternative is alternative number five – *Restoration and conservation of Shumen Fortress*. Its utility degree is 71.51% and it is closest to the optimal alternative, meaning that the project satisfies the stakeholders' needs by 71.51%, the least alternative is number four – *Opening of Sofia Arsenal Museum for contemporary art*. Its utility degree is 54.94% and it satisfies only little more than half of the stakeholders' needs.
6. The analysis results provided by the system are adequate to the results of manually performed calculations by ARAS method. Accordingly it can be stated that the system is consistent, works properly and provides credible results.
7. The developed system differs fundamentally from previously developed systems of other authors: is based on the newly developed method ARAS; all the projects' alternatives are assessed as an integral part of built and human environment, according to stakeholders' needs and surrounding macro, meso and microenvironment; it is possible to evaluate the performance of each alternative in each group of criteria as well as in all groups of criteria; the priorities of the alternatives are determined in accordance to the optimal solution; it is possible to determine the utility degree in percentage and to valuate in what extent the alternative satisfies the stakeholders' needs.
8. The developed system is universal and can be used for efficient decision-making on built and human environment renovation issues in both – national and international contexts, scientific projects as well as in an educational process.

Conclusions

1. Basing on the analysis of research provided in scientific literature, the definition of renovation of built and human environment was specified. From the holistic perspective the renovation of built and human environment involves construction works aiming to renew and considerably improve physical, functional, economic, energetic, qualitative and other characteristics of the built environment followed by significant improvement of the quality of life. From this perspective the complex renovation of living areas should be performed including various types of buildings (i. e. housing, commercial, industrial, public), cultural heritage objects, infrastructure objects, the surroundings (i. e. parks, leisure zones), etc.
2. The Conceptual Model for the Integrated Analysis of Built and Human Environment Renovation developed by author fundamentally differs from the models developed by other authors as it facilitates holistic analysis of renovation process, participating stakeholders' groups and affecting macro, meso and micro environment, and helps to make efficient decisions in renovation.
3. The proposed multiple criteria assessment based methodology for built and human environment projects' assessment allows analyzing the pro-

jects' alternatives in a complex way, determining the priorities and selecting the best alternative. The methodology was practically applied in assessment of Bulgarian cultural heritage renovation projects for European Economic Area and Norway Grants.

4. In order to evaluate the cultural heritage renovation projects, a hierarchically structured system of criteria, consisting of 8 criteria groups and 48 sub-criteria, was developed. Basing on this system projects were evaluated with respect to whole possible effects on the built and human environment – the holistic approach was used, macro, meso and micro environment factors considered.

5. The weights of criteria were determined according to the AHP method basing on the algorithm proposed by author. The weights were determined as medians. The survey of experts was performed and the agreement of experts' opinions was checked.

6. The assessment of the renovation projects was performed by traditional multiple criteria evaluation methods SAW, TOPSIS, COPRAS as well as the newly developed method ARAS. Solution of the practical task conducted that the newly developed method ARAS is more advantageous than the other methods and is suitable for practical renovation tasks solutions.

7. On the basis of the model proposed by the author and the newly developed method ARAS the Computer-Aided Decision Support System for Built and Human Environment Renovation was developed and tested. It allows determining the utility degree of the renovation alternatives in comparison to the optimal alternative in automated way. Testing results proved that the system is consistent, works properly, provides credible results and can be used in practice.

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ANNEXES

The annexes are supplied in the enclosed compact disc.

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MULTIPLE CRITERIA ASSESSMENT OF THE BUILT AND HUMAN ENVIRONMENT RENOVATION PROJECTS

Doctoral Dissertation

Technological Sciences,
Civil Engineering (02T)

Laura TUPĖNAITĖ

GYVENAMOSIOS APLINKOS ATNAUJINIMO PROJEKTŲ DAUGIAKRITERINIS VERTINIMAS

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