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THE CONCEPT MODEL OF SUSTAINABLE BUILDINGS REFURBISHMENT

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ABSTRACT. Sustainable development principles reaching many spheres of human activities, public buildings refurbishment is not an exemption in this case. Buildings refurbishment supports excellent opportunities to reduce energy consumption in buildings as well as encourages other sustainable refurbishment principles implementation – citizens' healthcare, environment protection, rational resources use, information about sustainable refurbishment dissemination and stakeholders groups' awareness. During the pilot refurbishment FP-6 project Brita in PuBs, authors of this article have developed conceptual sustainable public buildings refurbishment model. Model was created basing on sustainable development principles, their consideration in decision making process and model efficiency influencing factors. In order to demonstrate models' application possibilities following the healthcare principle, practical case study of Vilnius Gediminas Technical University main building pollution mapping is given at the end of this article.

KEYWORDS: Sustainable development; Building refurbishment; Healthcare; FP-6 Project Brita in PuBs

1. INTRODUCTION

The building sector accounts for 40% of the final energy consumption in Lithuania and EU countries (Statistics Lithuania, 2006; Eurostat, 2007). Housing, working and leisure places lightening, heating, cooling and water heating energy consumption is higher than in transport or even industrial sectors. Furthermore, this consumption continues to grow as well as buildings energy proportion in final consumption and CO_2 emission to environment increase.

Recently the issues considering climate change often discussed in Europe, much attention is paid on energy consumption questions. These problems inspired new strategic documents as Buildings Energy Efficiency Directive, Green Book considering energy use efficiency, Energy Efficiency Action Plans and European Energetic Tools establishment.

The aforementioned documents emphasize

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the importance of understanding that buildings refurbishment not only decreases energy consumption but also improves whole condition of the building: its exploitation, noise insulation conditions, exterior, and comfort; prolongs buildings life cycle, increases value of the buildings, reduces negative impact to environment and guarantees healthy living and working conditions. Satisfaction of these requirements is obligatory in sustainable refurbishment provision.

Sustainable refurbishment initiatives are supported by European Commission. Vilnius Gediminas Technical University participates in the pilot FP-6 buildings retrofit project Brita in PuBs (Bringing Retrofit Innovation to Application in Public Buildings). The Brita in PuBs project on Eco-buildings aims at increasing the market penetration of innovative and effective retrofit solutions to improve energy efficiency and implement renewables, with moderate additional costs (Brita in PuBs project, http://www.brita-in-pubs.eu/). The sustainable refurbishment model developed under participation in this project is introduced in this article. In order to demonstrate models' application possibilities following the healthcare principle, practical case study of Vilnius Gediminas Technical University main building pollution mapping is given at the end of this article.

2. SUSTAINABLE DEVELOPMENT PRINCIPLES AND MODELS OF BUILDINGS REFURBISHMENT

The energy requirements of present civilizations are a key issue for sustainable development. Regarding the limited supply of nonrenewable energy resources and the emission of greenhouse gases affecting global climate, it had been postulated that a sustainable energy system cannot be reached merely by substituting less sustainable resources by more sustainable ones, but also requires an overall reduction of present energy consumption levels, primarily in industrialized countries (Imboden and Jaeger, 1999; Imboden, 2000).

The issues of sustainable refurbishment have been intensively tackled for years in the Central Europe and other countries: Austria, Switzerland, Germany and the Netherlands. Scandinavian countries, though, have already developed different strategies of integral refurbishment in Denmark, Sweden, etc. The field of housing structures refurbishment is taking a central place in the efforts for integral refurbishment and revitalization of larger areas, especially in larger housing estates (Ruano, 2002).

According to Sobotka and Wyatt (1998), the rules of sustainable development must refer to the building sector as a building object in its life cycle (regarded as product life chains), starting with obtaining raw materials for the production of the building itself and their evaluation, through to demolition of the building.

Sunikka (2003) concludes that the real potential for sustainable building and CO_2 reduction lies in management of the existing stock of residential buildings. According to Papadopoulos et al. (2002), Gorgolewski (1995), Hong et al. (2006) the energy efficient refurbishment of existing buildings is an important tool for the reduction of energy consumption in the building sector, the improvement of prevailing indoor thermal comfort conditions and also for the improvement of environmental conditions in urban areas. At the same time, it is technical, economic and social problem posed by the manner in which many cities have been built and the restrictions imposed by economic constrains that tantalize most countries in South-Eastern Europe.

Recently, more attention is paid to sustainable, complex refurbishment satisfying integrated social, technical, economic, ecological needs of various stakeholders groups. Sobotka and Wyatt (1998) apply the principles of the "sustainable development" to refurbishment of panel buildings. Keeping and Shiers (1996) are considering environment friendly "green refurbishment" of commercial buildings, Kincaid (2000) reviews adaptability potential for buildings and infrastructure in sustainable cities.

Baldwin (1996) presents the following main goals of sustainable building on the basis of a document written in the UK containing indicators of sustainable development:

1. Minimization of climatic changes and risks to human health and biodegradation in consequence of economic activities, that is:

- to reduce climatic changes through the reduction of CO_2 emissions to the atmosphere due to energy consumption in buildings;
- to reduce emission of chemical compounds which cause thinning of the ozone layer;
- to minimize waste through:
  - recycling or re-use of materials,
  - collecting and segregating office and domestic recyclable waste such as paper and plastic;
  - elimination or reduction of waste on construction sites;
- to take care of wildlife habitats through preventing building on ecologically valuable sites and to protect and enhance local ecology; to build in areas of little ecological value; to re-use existing buildings, perhaps changing their function;
- to take care of the indoor environment in buildings, eliminating the risk of health loss by better air ventilation of space, minimizing sickness rate with respiratory system diseases, avoiding potentially harmful building materials, minimizing noise, etc.;
- to protect against radioactivity (radon).

2. Optimal use of non-renewable (finite) resources, i.e. energy, land, minerals and other natural resources.

3. Employing renewable resources such as solar energy for heating of houses, wind and water for energy accumulation. Use wood as the main building material.

4. Building such objects which will enable future generations to meet their needs in the domain of quality, durability, flexibility, adaptability and town planning.

According to Keeping and Shiers (1996) the benefits of "green refurbishment" include:

- lower energy costs through the use of simpler, low-tech heating and power installations;
- lower maintenance costs due to simple building services, which are easily accessible, and low-tech equipment, which is cheaper to repair or replace; and
- "healthier" buildings have been demonstrated to reduce absenteeism.

Sitar et al. (2006) emphasize the following integrated sustainable refurbishment 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 refurbishment is mostly related to technical-ecological aspects of building life cycle. Definitely it also involves satisfaction of social (healthy housing, etc.) and economic (energy saving, low maintenance costs, etc.) needs. Integration of these needs makes the concept of sustainable development implemented.

There are much more factors influencing refurbishment sustainability than was mentioned here. The concept of sustainable refurbishment should cover and integrate all the possible economic, social and environmental needs. It makes sustainable refurbishment very sophisticated. Therefore, recent papers adopt decisions on economically efficient refurbishment to new technology methods: Adeli (1998) 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 refurbishment, Rosenfiels and Shohet (1999), Lavy and Shohet (2007) – decision support model for semi-automated selection of renovation alternatives, Alanne (2004) proposes a multi-criteria "knapsack" model to help designers select the most feasible refurbishment actions in the conceptual phase of a refurbishment project, Dascalaki and Balaras (2004) – new XENIOS methodology for assessing refurbishment scenarios and the potential of application of renewable energy sources and rational use of energy in the hotel sector. Kaklauskas and Gulbinas (2005), Kaklauskas et al. (2005, 2006), Zavadskas and Kaklauskas (2000), Zavadskas et al. (1997, 2001a, 2004, 2008), Antuchevičienė et al. (2006), Šaparauskas and Turskis (2006), Banaitienė et al. (2008) integrate various IT supported knowledge management, decision support, expert models for buildings' life cycle management as well as refurbishment projects' assessment and optimization.

Recently more attention is paid on negative pollution effects decreasing measures. Kaklauskas and Zavadskas (2007) presented decision support system for innovation with special emphasis on pollution, Zavadskas et al. (2007a) – research on modelling and forecasting of a rational and sustainable development of Vilnius with emphasis on pollution, Zavadskas et al. (2007b) performed Vilnius urban sustainability assessment with an emphasis on pollution.

Numerous sustainable buildings refurbishment models are proposed in the literature. Among the most typical approaches there are 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. Siller et al. (2007) presents the model describing the temporal development of the Swiss building stock and its energy demand due to heating and hot water generation. The building stock is characterized by the energy reference area (ERA), which is a measure for the effective heated area. In the renovation sub-model every building (represented by the corresponding ERA) is subject to a sequence of renovations, which are determined by the renovation period and the fraction of realized renovations f_r.

Sitar et al. (2006) considered the model of sustainable renovation of a multi-apartment building. The sustainable renovation of a building is presented in two scenarios, in which an energy efficient renovation examines the connection between possibilities of architectural design, renovation technology, and energy efficiency for the heating of the building.

Van der Flier and Thomsen (2005) presented analytical model which starts from the 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).

Caccavelli and Gugerli (2002) presented refurbishment decision making model for office buildings refurbishment under TOBUS project. Model includes building type, various data analysis, refurbishment and modernization alternatives selection, decision making process, actions plan and refurbishment strategy development, implementation phases.

European Commission (2003) initiated FP-5 Sustainable refurbishment project SUREURO. SUREURO has developed models and systems that provide housing organisations, interested parties; local authorities, town planners, construction companies etc, opportunities to perform refurbishment processes within a normal time schedule and budget. The SUREURO models and systems offer users considerable environmental improvement and energy savings. The effort of SUREURO is to combine an overview of usable and available SUREURO models and systems and the context on which housing people can use these tools and, furthermore, what kind of management and participation skills are required in order to be successful. 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.

Other sustainable refurbishment models are based on Building Life Cycle Analysis and costs management. For example, project SAVE "Refurbishment of Buildings at High Quality and with controlled costs" (2005) considers an integrated planning of the refurbishment-process, on the other hand, enables an economic optimisation in terms of the whole lifecycle-costs (LCC) of the building. Integrated planning is defined as a concept with LCC assessment as the core element, which is; however, open for additional quality related criteria depending on the preference and the framework conditions of the investor.

It can be summarized that sustainable refurbishment is significant problem in current buildings stock taking much scientists attention as well as European Commission initiatives. Sustainable refurbishment is widely discussed in the literature and various models and decision making tools proposed. Indeed in this article conceptual sustainable refurbishment model presented by authors synthesizes various sustainable refurbishment elements and new refurbishment aspects to be considered in sustainable refurbishment development.

3. THE CONCEPTUAL MODEL OF SUSTAINABLE BUILDINGS REFURBISHMENT

The main results expected from public buildings refurbishment are:

- Energy savings;
- Increase of comfort;
- Healthy working environment assurance;
- Extension of building life cycle;
- Economized exploitation;
- Environmental protection.

Basing on aforementioned expected results and the general sustainable refurbishment principles authors propose sustainable refurbishment model where main factors influencing models efficiency – macro and micro environment, buildings refurbishment decisions making groups – are additionally considered. Model also involves decision making process and sustainable refurbishment information dissemination in all decision making stages (see Figure 1).

Elements of proposed model are further discussed.

Sustainable refurbishment principles. Sustainable refurbishment must reconcile further dimensions:

- social (collaboration, public awareness and education, social safety, etc.);
- ecological (ecological construction materials, energy, waste, noise, land use, heath, air quality, etc.);

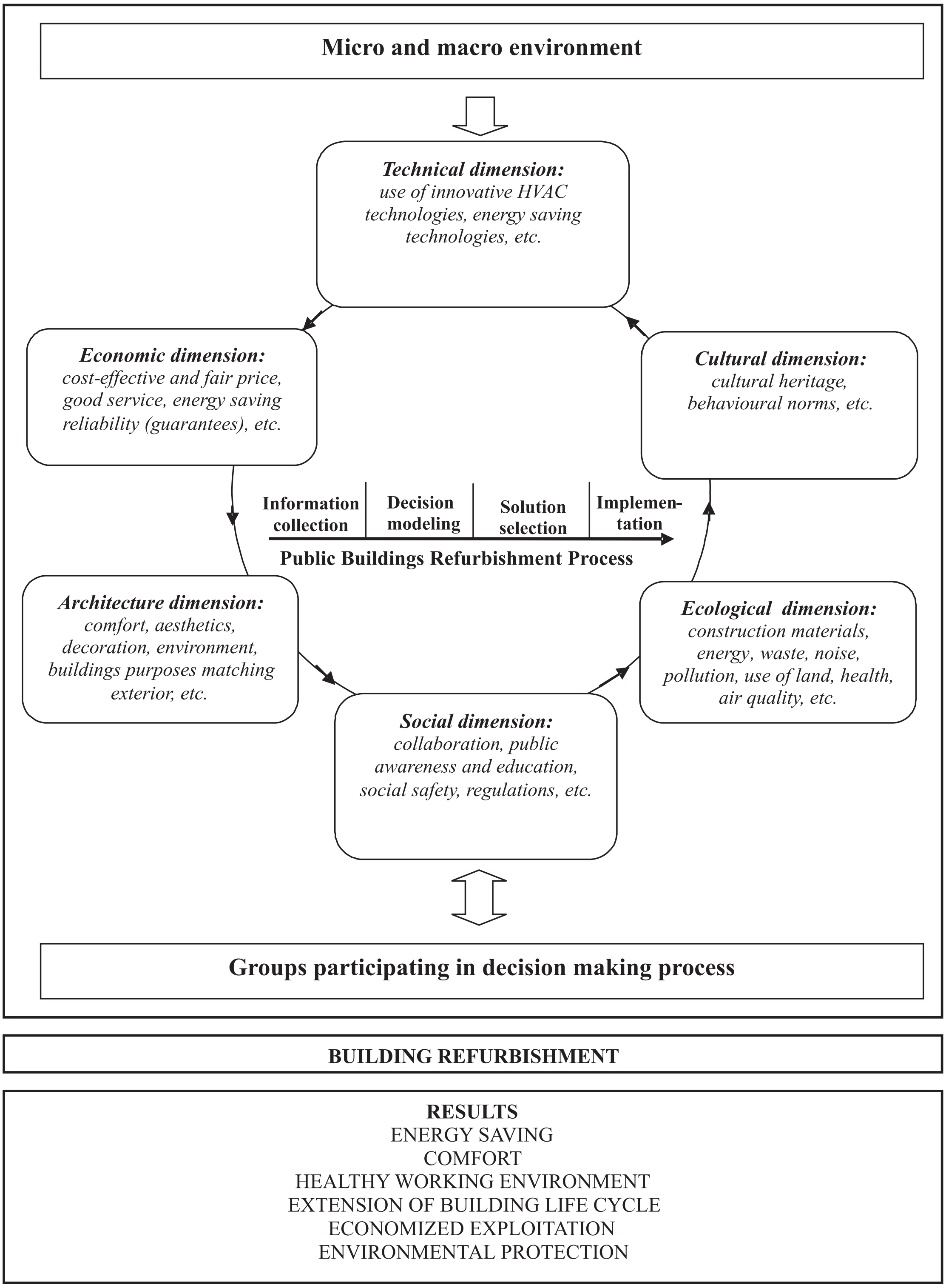

Figure 1. The conceptual model of sustainable buildings refurbishment

- economic (cost-efficient price, fair price and good service, energy saving reliability, etc.);
- cultural (cultural heritage, behavioural norms, etc.);
- architectural (comfort, aesthetics, decoration, environment, buildings purposes matching exterior, etc.);
- technical (innovative HVAC technologies, energy saving technologies, etc.).

All the above mentioned dimensions are closely related, complementing each other and influence general refurbishment efficiency. Sustainability dimensions are inseparably connected, i.e. usage of innovative technologies in building refurbishment can satisfy ecological and economic needs, or cultural and architectural dimensions encourage social needs satisfaction.

Sustainable building refurbishment should be implemented basing on the aforementioned principles.

Citizen's healthcare principle. Safe buildings environment must be ensured. It means taking care about air quality in premises, lightening, control of noise levels and water pollution by chemical substances, etc. Good air quality in premises can noticeably improve living quality, especially for people with allergic diseases. In order to ensure healthy living and working conditions it is necessary to take care both of indoor microclimate and external environment. General parameters determining indoor microclimate to be controlled before and after refurbishment are: air velocity, humidity, dew point, lightening, air circulation velocity, acoustics, and temperature. In order to ensure healthy external environment, substances quantity in the air must be controlled: sulphur dioxide, nitrogen dioxide, particular matters, ozone. Exceeding norms substances quantities in the air can encourage some kinds of illnesses.

Effective energy use principle. Particularly energy consumption encourages environmental problems i.e. global warming, acid rain. In order to ensure energy efficiency in buildings modernization and refurbishment main attention must be paid on buildings insulation, heating, cooling, conditioning, lightening systems design. The best results usually achieved when modern innovative energy saving measures in buildings refurbishment applied: buildings insulation by innovative materials (e.g. Erhorn-Kluttig and Erhorn, 2007), energy efficient windows (e.g. Engelund, 2007; James and Bahaj, 2005), hybrid ventilation (e.g. Jicha and Charvat, 2007), natural lightening (e.g. Athanassakos, 2007), buildings heating and conditioning by solar energy, solar headers, solar batteries (Voss, 2000; Ferrari and Adhikari, 2007), passive solar energy using buildings heating systems (Buvik and Hestnes, 2007), heating pumps.

Rational resources use principle. Sustainable refurbishment should encourage efficient construction materials and natural resources use as well as extension of building life cycle and environment reaching waste quantities decrease. Energy efficient technologies in construction can both decrease greenhouse effect encouraging environmental pollution and reduce total life cycle costs. Accordingly solar energy technologies help to decrease the pollution and resources use.

Construction waste transportation and utilization increases additional costs of construction companies and government. Contrarily, waste decrease during building life cycle ensures construction companies and government costs savings both in short and long time perspectives. Waste minimizing has more positive effects. Part of waste (i.e. concrete) can be reprocessed and reused. Bricks and metals can be used even without reprocessing. It can be summarized that waste decrease encourages contractors and countries resources savings and ensures ecological environment protection.

Environment conservation (responsibility) principle. Refurbished buildings negative impact to environment should be minimized as possible. Aforementioned refurbishment measures, such as harmful substances quantities control in external environment, innovative energy saving technologies, etc. ensure environment conservation. Very important measure in this case – renewable energy resources use.

Affordability principle. Accordingly to sustainable development principles, buildings refurbishment encouraging environment conservation and favourable living conditions must be affordable to people and not too expensive (Chwieduk, 2003). Dissemination about refurbishment is wide, labour – intensive and involving numerous functions activity. In information dissemination processes all the participants from municipalities, designers, contractors, politicians, building owners and users – all the stakeholders those are directly involved in problem solution – must be incorporated. Information dissemination measures and channels should be selected in accordance to information type and expected target group (Project BRITA in PuBs, 2006a). Possible dissemination channels: collaboration networks, information booklets sent by e-mail, web sites, internet tools, professional magazines, newspapers, media (radio, television, news), seminars, workshops for construction professionals, learning programmes, qualification courses, distance learning systems, etc.

Decision making process. In order to design and implement buildings refurbishment basing on sustainable development principles it is necessary to follow these principles from idea till implementation. Suitable decisions must be made starting from 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.

Public buildings refurbishment process, starting from the idea and ending with implementation, is quite long and can be divided into four main phases.

First phase – data and information collection, aims and tasks determination, problem formulation. At the initial phase refurbishment purposes, tasks, results, main project participants, their aims and their relations are determined, building's type defined, analysis of refurbishment necessity performed. The reasons for refurbishment can be various – building's physical depreciation, standards and requirements failure, building's moral depreciation, aims to reduce energy consumption, improve internal environment quality, buildings failure to satisfy users needs, etc.

When refurbishment reasons are clarified, further activities to achieve the main tasks are discussed. It must be decided if the total refurbishment of the building is needed or just partly modernization available. 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 about sustainable refurbishment principles is crucial. In this phase the general information about energy saving, technical information about innovative technologies and information about refurbishment is costs the most needed (Project BRITA in PuBs, 2006b).

Decision modelling phase. After refurbishment aims and the need for refurbishment defined, the next and very important phase is decision modeling. 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. Buildings' refurbishment analysis 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 refurbishment strategy all refurbishment stakeholders groups needs must be considered. Accordingly, refurbishment alternatives must be analyzed basing on many criteria (Zavadskas et al., 2001b; Banaitienė et al., 2008). In this phase the information about already implemented refurbishment projects, best practice examples, projects strengths and weaknesses 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 can 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.

Model efficiency influencing factors. Three main structural elements influencing models' effectiveness and implementation efficiency are distinguished:

- macro environment;
- micro environment;
- participating in decision making process stakeholders' groups.

Macro environmental influence on sustainable buildings refurbishment. The highest level influencing public buildings, their construction and refurbishment efficiency is macro level. In this level buildings refurbishment is influenced by social, political, economic, cultural, scientific, technical and other factors. In some circuimstances each group of mentioned factors can be crutial and refurbishment project can fail. In order to avoid negative impacts, it is important not to separate buildings refurbishment consideration processes from environmental conditions and their changes.

Social factors (living conditions and standards, educational background, labour force regulating legal acts, health protection, public organizations, media, citizens attitudes to renovation, innovations in refurbishment process etc.) are influencing stakehoders aims and their capabilities. Buildings refurbishment implementation is closely related with countries and public interests (economic, supplementary activities, social, environment protection and other requirements implementation in country, regional and municipality levels).

Culture (literacy, cultural traditions, religion, cultural needs, quality and working conditions requirements etc.) is influencing stakehoders requirements and their aims.

Science and technologies (fundamental and utilitarian researches development level, information technologies and computarization level, industrial and manufacturing technologies level, communication, etc.) influence buildings refurbishment process' efficiency, state requirements to its participators.

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

Political decisions (regional cohesion programmes, preferential credits, governmental orders, dotations, subsidies, construction activities reglamenting documents, law changes, etc.) have big influence on buildings refurbishment efficiency. Public buildings managers have opportunities to increase energy use efficiency, get refurbishment projects financing encouraging energy resources and energy savings. In turn it can influence refurbishment projects quantities in all the country.

Micro environmental influence to sustainable buildings refurbishment. The second level factors making influence on buildings construction as well as refurbishment efficiency are micro environmental factors. These factors are influenced by macro level factors. For example, taxation system in macro level directly influencing construction materials and services prices in micro level. Government attitude to construction activities (various legal acts, taxes exemptions, dotations, subsidies etc.) influence construction as well as refurbishments processes efficiency.

Public buildings refurbishment decisions, sustainable development principles implementation are effected by various micro level factors:

- buildings depreciation level;
- buildings obsolescence;
- quality of premises;
- facilities management;
- innovative technologies use;
- innovative technologies supply;
- dissemination about innovative technologies;
- refurbishment process financing;
- information systems, etc.

Stakeholders groups participating in public buildings refurbishment and their relations. There are many stakeholders participating in public buildings refurbishment decision making process:

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

Aforementioned groups are making refurbishment decisions; hereby their dissemination about sustainable refurbishment principles is very important. Also it is crucial to ensure this information to reach them. Different knowledge is needed to different stakeholders groups participating in the refurbishment process.

The part of above proposed model is illustrated by pollution maps case study.

4. CASE STUDY

In Brita in Pubs Project the pilot retrofit of 9 demonstration public buildings in the four participating European regions (North, Central, South, East) was implemented. In Lithuania the main building of Vilnius Gediminas Technical University was renovated.

In order to analyze environment pollution in refurbished buildings environment and to measure pollution influence on users' health, examples of pollution maps were created. The USA Environment Protection Agency (EPA) methodology was used for this purpose (US EPA, 2006). Air Quality Index (AQI) was calculated and basing on it the map of pollution impact on human health was developed.

The higher the AQI value, the greater the level of air pollution and the greater the health concern. For example, an AQI value of 50 represents good air quality with little potential to affect public health, while an AQI value over 300 represents hazardous air quality.

An AQI value of 100 generally corresponds to the national air quality standard for the pollutant, which is the level EPA has set to protect public health. AQI values below 100 are generally thought of as satisfactory. When AQI values are above 100, air quality is considered to be unhealthy-at first for certain sensitive groups of people, then for everyone as AQI values get higher.

The purpose of the AQI is to help you understand what local air quality means to your health. To make it easier to understand, the AQI is divided into six categories (see Appendix 1).

The map of pollution impact on human health and mentioned methodology enable to decide what associated health effect might be due to concentration of pollutants and what kind of diseases it might cause. Analysing the map the most attention is paid to such diseases groups as heart and lung diseases. The pollution impact on human heath is different for individual groups of people. In the methodology there are mentioned four main groups, i.e. sensitive groups (people with respiratory, cardiopulmonary and cardiovascular diseases), adults, active children, older adults.

AQI index is calculated for particular pollutant in VGTU area (ozone, particular mates, carbon monoxide, sulphur dioxide, nitrogen dioxide). Values are illustrated in maps (see Figure 2 and 3).

Basing on the given maps there it is possible to state that the air quality in the zone of concern is good or moderate. Near the streets the pollution is bigger and carbon monoxide and sulphur dioxide levels are reaching unsatisfactory levels. That means that people living and working in this territory are always on exposure of pollutants. So in this zone sensitive individuals might experience discomfort and respiratory symptoms. Also there is possible aggravation of heart or lung diseases in people with cardiopulmonary diseases and older people.

Basing on the above proposed pollution maps it is possible to plan refurbishment measures efficiently in order to implement sustainable development principles in public buildings refurbishment.

5. CONCLUSIONS

Sustainable refurbishment is significant problem in current buildings stock, taking much scientists attention as well as European Commission initiatives. Sustainable refurbishment is widely discussed in the literature and

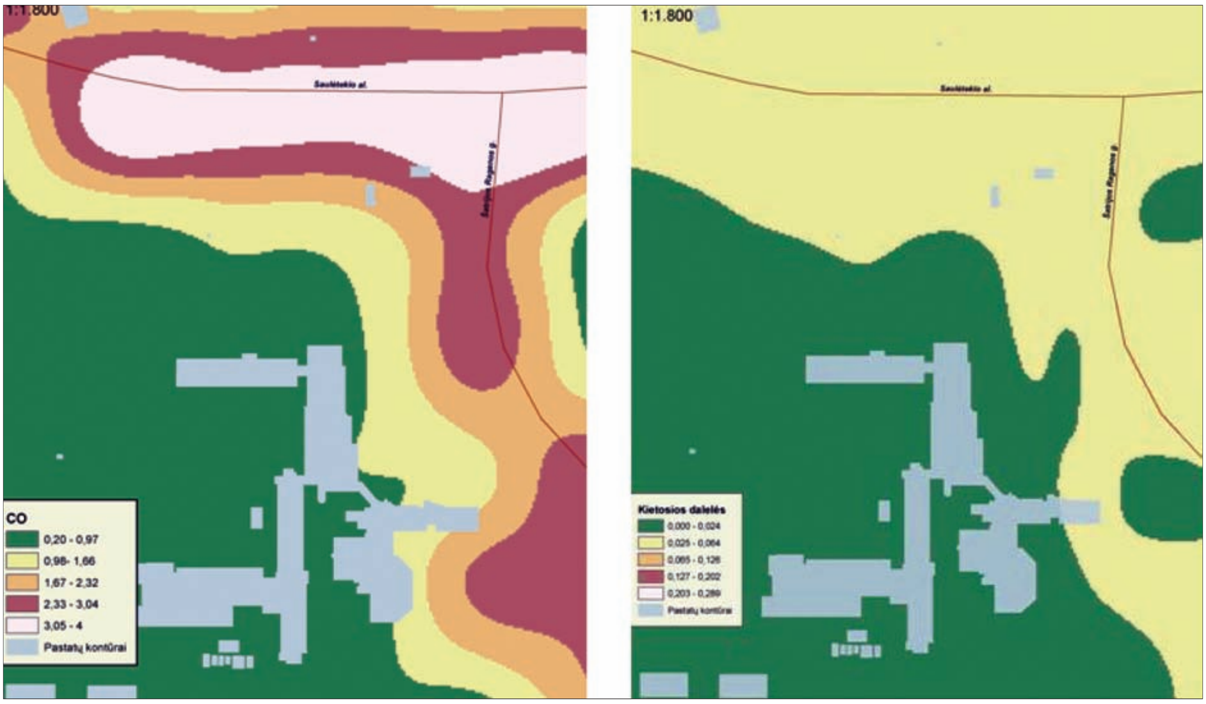

Figure 2. Carbon monoxide and particular mates pollution maps in VGTU area

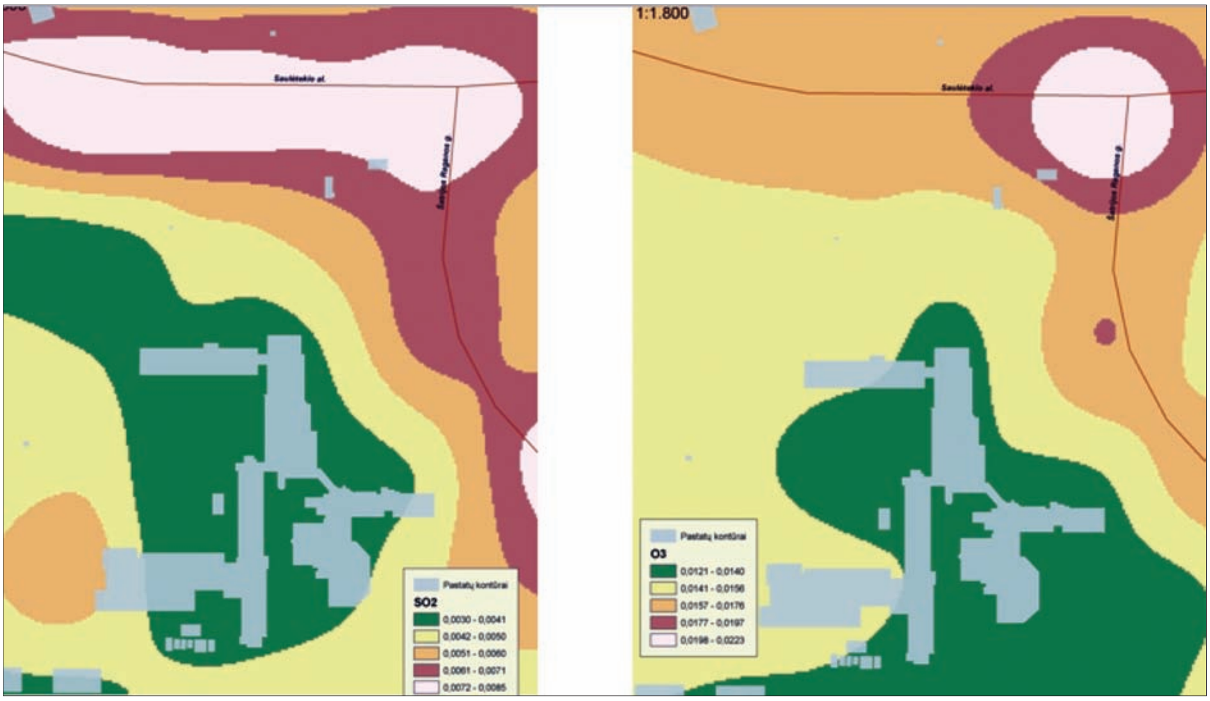

Figure 3. Sulphur dioxide and ozone pollution maps in VGTU area

various models and decision making tools proposed. In this article authors integrate sustainable development principles, decision making process and influencing factors into one unique conceptual sustainable refurbishment model.

Model involves macro and micro environment factors analysis, integrates participating in refurbishment stakeholders' decisions and needs. Accordingly to sustainable refurbishment principles refurbishment not only decreases energy consumption but also improves whole condition of the building: its exploitation, noise insulation conditions, exterior, and comfort; extends buildings life cycle, increases value of the building, reduces negative impact to environment and guarantees healthy living and working conditions.

Much attention is paid on decision making process. In order to design and implement buildings refurbishment basing on sustainable development principles it is necessary to follow these principles from idea till implementation. 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.

In order to demonstrate models' application possibilities following the healthcare principle, practical case study of Vilnius Gediminas Technical University main building pollution mapping is given. The map of pollution impact on human health enables to decide what associated health effect might be due to concentration of pollutants and what kind of diseases it might cause. Basing on the above proposed pollution maps it is possible to plan refurbishment measures efficiently in order to implement sustainable development principles in public buildings refurbishment.

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SANTRAUKA

KONCEPCINIS DARNAUS VISUOMENINIŲ PASTATŲ ATNAUJINIMO MODELIS

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Darnios plėtros principai skverbiasi į daugelį veiklos krypčių, neaplenkdami ir visuomeninių pastatų atnaujinimo proceso. Pastatų atnaujinimas – tai puiki galimybė ne tik sumažinti suvartojamos pastate energijos apimtis, bet ir užtikrinti kitus darnios renovacijos principus – rūpinimąsi gyventojų sveikata, aplinkos tausojimą, racionalų išteklių naudojimą, taip pat ir informacijos apie darnią pastatų renovaciją prieinamumą. Vykdant demonstracinį FP-6 projektą *Brita in PuBs*, straipsnio autoriai sukūrė koncepcinį darnios visuomeninių pastatų renovacijos modelį, kuriame atsižvelgiama į darnios plėtros principus, jų taikymą priimant sprendimus ir modelio efektyvumą veikiančius veiksnius. Siekiant pademonstruoti modelio realizavimo galimybes, paskutiniame straipsnio skyriuje rūpinimosi sveikata principas iliustruojamas renovuojamo VGTU centrinio pastato užterštumo žemėlapio sudarymu.

APPENDIX 1. AQI values and impact on human health

Air Quality Index Value	Influence on human health	Colour	Meaning
0 to 50	Good	Green	Air quality is considered satisfactory, and air pollution poses little or no risk.
51 to 100	Moderate	Yellow	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution. Usually sensitive individuals might experience discomfort and respiratory symptoms. Possible aggravation of heart or lung diseases to people with cardiopulmonary diseases and older people.
101 to 150	Unhealthy (for sensitive groups)	Orange	Members of sensitive groups may experience health effects. Increasing likelihood of respiratory symptoms and breathing discomfort in active children, adults and people with lung diseases. Also aggravation of heart or lung diseases and premature mortality in people with cardiopulmonary diseases and older adults. People with heart diseases might experience chest pain and tightness. The general public is not likely to be affected.
151 to 200	Unhealthy	Red	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects. Greater likelihood of respiratory symptoms and breathing difficulties in active children and adults and people with lung diseases. Possible aggravation of the heart, cardiovascular symptoms and premature mortality in people with cardopulmonary disease.
201 to 300	Very Unhealthy	Purple	Increasingly severe symptoms and impaired breathing likely in active children and adults and people with lung diseases, increasing likelihood of respiratory effects in general population. Significant aggravation of heart or lung disease, cardiovascular symptoms and premature mortality in people with cardiopulmonary disease and older people.
301 to 500	Hazardous	Maroon	Health warnings of emergency conditions. The entire population is more likely to be affected. Hazardous Severe respiratory effects and impaired breathing likely in active children and adults and people with lung disease. Increasingly severe respiratory effects likely in general population. Serious aggravation of heart and cardiovascular symptoms and premature mortality in people with heart disease. Impairment of strenuous activities in general population.