MULTIPLE CRITERIA ANALYSIS OF THE LIFE CYCLE OF THE BUILT ENVIRONMENT

MONOGRAPH

EDITORS
A. Kaklauskas, E. K. Zavadskas
To design and achieve effective the life cycle of the built environment a complex analysis of its stages as well as stakeholders, their aims and potentialities is needed. The effect of micro, meso and macro environmental factors should also be taken into account. A thorough built environment’s life cycle (brief; design; raw material extraction, transport and processing; construction materials production and distribution; construction; use, repair and maintenance; demolition; disposal, reuse, or recycling) analysis is quite difficult to undertake, because a buildings and its environment are a complex system (technical, technological, economical, social, cultural, ecological, etc.), where all sub-systems influence the total efficiency performance and where the interdependence between sub-systems play a significant role. Various stakeholders (clients, users, architects, designers, utilities engineers, economists, contractors, maintenance engineers, built environment material manufacturers, suppliers, contractors, financing institutions, local government, state and state institutions) are involved in the life cycle of the built environment, trying to satisfy their needs and affecting its efficiency. The level of the efficiency of the life cycle of the built environment depends on a number of variables, at three levels: micro, meso and macro level. The problem is how to define an efficient built environment life cycle when a lot of various parties are involved, the alternative project versions come to hundreds thousand and the efficiency changes with the alterations in the environment conditions and the constituent parts of the process in question. Moreover, the realization of some objectives seems more rational from the economic perspective thought from the other perspectives they have various significance. Therefore, it is considered that the efficiency of a built environment life cycle depends on the rationality of its stages as well as on the ability to satisfy the needs of the stakeholders and the rational character of environment conditions. Formalized presentation of the research shows how changes in the environment and the extent to which the goals pursued by various stakeholders are satisfied cause corresponding changes in the value and utility degree of a built environment life cycle. With this in mind, it is possible to solve the problem of optimization concerning satisfaction of the needs at reasonable expenditures. This requires the analysis of the built environment life cycle versions allowing to find an optimal combination of goals pursued and finances available.

References to the most modern world scientific literature sources are presented in the monograph. The monograph is prepared for the researchers, MSc and PhD students of civil engineering, construction management and real estate development. The book may be useful for other researchers, MSc and PhD students of economics, management and other specialities. The edition was recommended by the Committe of Studies of VGTU Faculty of Civil Engineering.

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prof. dr. A. Banaitis, Faculty of Civil Engineering,
Vilnius Gediminas Technical University

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The monograph analyses the life cycle of the built environment. This, however, is only one of many periodic life cycles characteristic to various systems across the universe (time and calendar cycles, planetary cycles (astronomical cycles, climate and weather cycles, geological cycles), organic cycles (agricultural cycles, biological and medical cycles, brain waves and cycles), physics cycles (mathematics of waves and cycles, electromagnetic spectrum, sound waves), miscellaneous cycles (economic and business cycles), music and rhythm cycles, religious, mythological, and spiritual cycles, social and cultural cycles, military and war).

The building life cycle assessment (LCA) methodology dates back to 1960s, when concerns over the limited availability of raw materials and energy resources led to new ways to account for energy use and the consequences of these uses (SAIC 2006). First developed in the 1960s, Life Cycle Assessment (LCA) is the most widely used and highly regarded tool for quantifying the environmental impacts of products and services (SteelConstruction). The oil price increases of the 1970s spurred significant research and activity to improve energy efficiency and find renewable energy sources. This, combined with the environmental movement of the 1960s and 1970s, led to the earliest experiments with contemporary green building (Barrows and Iannucci 2009).

In the 1980s, the product life cycle was used by Weber (1976), Doyle (1976) and Wasson (1978) for external purposes, such as marketing. Its application broadened in the present decade into building materials, construction, chemicals, automobiles, and electronics. This was primarily because of the formalization of LCA standards in the ISO 14000 series (1997 through 2002) and the launch of the Life Cycle Initiative, a combined effort by United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC), in 2002 (SAIC 2006). In the 1990s and later, the building life cycle analysis was used by Preiser (1983), Fereig and Younis (1985), Gustafsson and Karlsson (1989), Zavadskas, Kaklauskas and Bejder (1992a, 1992b), Zavadskas, Peldschus and Kaklauskas (1994), and other researchers. Later, Kaklauskas (1996, 1999) applied the concept of the building life cycle analysis in the construction industry life cycle analysis.

To design and achieve effective life cycle of the built environment a complex analysis of its stages as well as stakeholders, their aims and potentialities is needed. The effect of micro, meso and macro environmental factors should also be taken into account.

A built environment life cycle consists of closely interrelated stages: brief; design; raw material extraction, transport and processing; construction materials production and distribution; construction; use, repair and maintenance;
demolition; disposal, reuse, or recycling. A built environment life cycle may have a lot of alternative versions. These variants are based on the alternative brief, design, construction, facilities management, refurbishment, demolition, utilization and recycling processes and their constituent parts. Millions of the built environment life cycle alternative versions can be obtained. The diversity of solutions available contributes to more accurate evaluation of climatic and energetic conditions, risk exposure, maintenance services, as well as making the project cheaper and better satisfying a client’s architectural, comfortability, technological and other requirements. This also leads to better satisfaction of the needs of all parties involved in the project design and realization.

Various stakeholders (clients, users, facilities and property managers, architects, designers, utilities engineers, economists, contractors, maintenance engineers, built environment material manufacturers, suppliers, contractors, financing institutions, local government, state and state institutions) are involved in the life cycle of the built environment, trying to satisfy their needs and affecting its efficiency. The level of the efficiency of the life cycle of the built environment depends on a number of variables, at three levels: micro, meso and macro level.

The problem is how to define an efficient built environment life cycle when a lot of various parties are involved, the alternative project versions come to millions and the efficiency changes with the alterations in the environment conditions and the constituent parts of the process in question. Moreover, the realization of some objectives seems more rational from the economic perspective thought from the other perspectives they have various significance. Therefore, it is considered that the efficiency of a built environment life cycle depends on the rationality of its stages as well as on the ability to satisfy the needs of the stakeholders and the rational character of environment conditions.

Formalized presentation of the research shows how changes in the environment and the extent to which the goals pursued by various stakeholders are satisfied cause corresponding changes in the value and utility degree of a built environment life cycle. With this in mind, it is possible to solve the problem of optimization concerning satisfaction of the needs at reasonable expenditures. This requires the analysis of the built environment life cycle versions allowing to find an optimal combination of goals pursued and finances available.

This monograph consists of seven chapters.

In recent years, many theories, methods, models and systems for the analysis of the life cycle of the built environment have been developed worldwide and described in Chapter 1. For a broader application of the life cycle of the built environment in the practice of various countries, more attention needs to be paid not only on the selected most rational processes and solutions, the interest level of the stakeholders, but also on the micro, meso and macro level
factors. The authors of Chapter 1 developed the Life Cycle of the Built Environment Model over the course of two international projects (IDES-EDU and LEAN CC). Based on this Model, professionals involved in design and realization of the life cycle of the built environment can develop a lot of the alternatives as well as assessing them and making the final choice of the most efficient variant. Designing and realising an efficient life cycle of the built environment requires an exhaustive investigation of all solutions that form it. The efficiency of a specific built environment depends on a great number of factors such as energetic, technical, technological, economic, legal/regulatory, infrastructure, innovative and microclimatic, social, cultural, ethical, psychological, emotional, religious, ethnic, etc. Solutions based on alternatives allow a more rational and realistic assessment of traditions and of energy-related, economic, ecological, legislative, climatic, social and political conditions. They also help meet customer requirements better. Multi-variant design and multiple criteria analysis of the built environment came to mean processing and evaluation of loads of data. The number of feasible alternatives could be in the range of millions. With such enormous amounts of information, multi-variant design and multiple criteria analysis of alternative options has become problematic. To address these issues, the authors have developed the Life Cycle Model of the Built Environment. It can be noticed that researchers from various countries engaged in the analysis of the life cycle of the built environment and its stages did not consider the research's object as was analyzed by the authors of the present investigation. Authors of the Monograph analyse a life cycle of the built environment as follows: the built environment, the stakeholders involved in its life cycle as well as the micro, meso and macro environments, having a particular impact on it and making an integral whole.

Chapter 2 “Facilities Management” presents following aspects: the origin and the analysis of the definition of the Facilities management; Facilities Management goals and tasks; Facilities Management process and other. Special attention paid on Facilities management services quality assurance. The quality criteria system for facilities management services in Lithuania is presented. The fulfilled survey in 2010 year on customer satisfaction with facilities management services in Lithuania is described. For decision making it is possible to apply different decision-making methods. The application of Nominal Group Technique for facilities management in Lithuania is analysed in the chapter. The two completed surveys are described. The complex Facilities Management Process analysis model is suggested. The Consulting Knowledge System for Facilities Management Sector in Lithuania is suggested and described. At the end the administration of housing in Lithuania, Estonia and USA is analysed. Conclusions presented as well.
Chapter 3 “Retrofit of buildings in urban neighborhoods” analyse modernisation and retrofit of buildings as one of the forms of urban development. Modernisation of apartment houses is a particularly relevant issue both in Lithuania and many other countries. To make it more efficient, the modernisation of apartment houses must be integrated an entire block or residential area must be renovated and the principles of sustainable development must be followed. It dwells on the issues related to retrofit planning in residential blocks/areas and analyses the condition of apartment houses and their environment and the strategies for retrofit of residential areas with apartment houses. The strategies aim to improve the living standards and the quality of environment, to cut energy consumption and CO\textsubscript{2} emissions, to maintain mixed social structure, to integrate new buildings into the existing environment in a sustainable manner, to develop an urban centre of a residential area as a functioning part of the city, to develop democratic planning and to seek close cooperation of modernisation partners. The scenarios based on relevant strategies must define the measures of retrofit, their priority and their potential effect. Some of the problems associated with assessing the retrofit effectiveness of apartment buildings in urban areas are considered. The retrofit of houses should be followed by the amelioration of their surroundings. The priority order of districts to be renovated depends on the condition of the buildings in a district and on strategic urban development programmes. In order to determine the profitability of investments in housing retrofit, a number of retrofit scenarios should be developed. The authors of this section offer a new approach to determining the retrofit effectiveness of houses based both on expected energy savings and the increase in market value of renovated buildings. In line with the proposed approach, retrofit scenarios for apartment buildings in Vilnius were developed, i.e. retrofit investment packages for various districts were prepared and arranged in the priority order for their application according to the method of geographical analysis suggested by the authors. Calculations of building retrofit effectiveness have shown that the replacement of original windows with new ones is not as effective in terms of heat energy saving as are the insulation of a roof, walls and other improvements because the investments are large and take a long time to be repaid. However, in addition to energy saving, window replacement improves the indoor climate of the building, its interior and architectural appearance as well as its market value. The sequence of building operations determines when the replacement of windows should be done. When financial resources are limited, managers of public buildings often begin the renovation of a building’s envelope with the replacement of windows. The client faces some problems in choosing among the great variety of windows to satisfy his/her needs, especially with respect to the cost-quality relationship. The method of multiple criteria complex proportional assessment (COPRAS)
developed by the authors aims at solving the above-mentioned problems. The solutions based on multicriteria analysis allow for a more rational and realistic assessment of customer’s needs as well as cutting down window renewal costs.

Chapter 4 reviews academic research papers which discuss the role of values in the energy sector and then presents a set of criteria and automated decision support system for the assessment of the environment of energy generation technologies with emphasis on the dimension of social issues and values. Comprehension of the effect of energy generation technologies on the natural environment, human health and safety leads to a new and responsible approach to the choice and development of technologies. Although the issues predominant in the concept of sustainable energy development are economic and environmental ones, the changing environment necessitates a new approach towards the impact of social systems on the industry and demands for a more profound assessment of the role this aspect plays. Social development obeys the laws of sociology, thus energy policies must be established and solutions of technological development that meet societal needs must be found always making sure that the impact on social processes has been considered and public attitudes, values, sentiments towards development decisions, and the right of self-determination have been respected. Values—culture, cultural identity, ethics, beliefs, religion, education, weight of social institutes and other—can make an important impact on decisions related to the development of energy generation technologies, or even be the determining factor. Growing significance of public attitudes demands consideration of the dimension of values in environmental studies; when problems concern technologies they must also consider the values which are important and significant to the public or its separate groups. One way to make quantitative and qualitative assessment of the effect of technologies on the environment is through a thorough integrated analysis, which, in addition to economic and technical solutions, also considers other aspects of concern to the public. End parts of chapter examines how the dimension of values affects the analysis of the impact of environmental factors on the value of energy generation technologies. It presents a set of criteria for the assessment of energy generation technologies; the set, in addition to technological, economic and environmental criteria, includes criteria which reflect the values. The case study also introduces the automated decision support system EGTAV-SPS, which helped assess the effect of environment on energy production technologies.

Chapter 5 analyses definitions, resources and methods of information management; capital and information; expert and information systems; strengths and weaknesses of information systems and possibilities for their implementation in an organization and the best experience along with its information bases. The description of the life process of the built environment, the interest groups acting within it and the micro, meso and macro environment acting on
project effectiveness regards them as one entity. This description contains various aspects of explicit and implicit knowledge regarding the life process of the built environment. A major portion of knowledge on the built environment is implicit: abilities, competence, experience, an organization’s culture, informal and unrecorded procedures, skills, informal networks of organizational contacts, an intelligent organization’s capital, ideals, values, customs, traditions and emotions. The development of the complex data and information base on a built environment’s life cycle process and the informational model for the life cycle of the built environment’s renovation appear next. Also, Chapter 5 presents a write-up of the team and its team work employing Web-based technologies and discusses the computer-based work accomplished collectively.

In order to design and realize an efficient built environment life cycle with focus on climate change mitigation and adaptation, it is necessary to carry out exhaustive investigations of all the decision and processes that form it. The efficiency level of the considered built environment life cycle depends on a great many micro, meso and macro factors. The authors of Chapter 6 participated in the different EU projects related with built environment and climate change (LEAN CC (Linking European, Africa, and Asian Academic Networks on Climate Change), etc.). One of the LEAN CC project’s goals was to develop a Model and Intelligent System of the built environment Life Cycle Process for Climate Change Mitigation and Adaptation. The presented Model and Intelligent System enables one to form up to 100 million alternative versions. In order to demonstrate the micro, meso and macro factors that influence the efficiency of the built environment in climate change mitigation and adaptation processes, the Model will be considered as an example. In the past there has been no intelligent approach to learning from climate change mitigation and adaptation in built environment projects once they are completed. Now, however, the built environment is adapting concepts of tacit and explicit knowledge management to improve the situation. Top managers generally assume that professionals in enterprises already possess tacit and explicit knowledge and experience for specific types of projects. Such knowledge is extremely important to organizations because, once a project is completed, professionals tend to forget it and start something new. Therefore, knowledge multifold utilisation is a key factor in productively executing a climate change mitigation and adaptation in built environment project. The main purpose of the Chapter 6 is to present the Model of the built environment Life Cycle Process for Climate Change Mitigation and Adaptation which the authors of this Chapter have developed.

Chapter 7 “Distance Learning Experience in Construction and Real Estate at VGTU” contains the general information about distance learning development in the World, Lithuania and Vilnius Gediminas Technical University (VGTU). The main attention paid on infrastructure and new technologies used
in distance learning at VGTU. The Chapter analyses the possible ways of advertising and management of distance education. The possible ways of marketing and management at the Department of Construction Economics and Property Management are described. Joint second-cycle distance-learning programmes at the Department of Construction Economics and Property management are presented. In order to clarify a number of issues related to the study process (first and foremost the student motivation, efficiency of advertising, issues related to the quality of study materials, reaction of social environment, etc.) the 4 survey researches were conducted during the period of 2003–2013 years and the results are analysed and the conclusions presented in the Chapter 7.