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Model for a Complex Analysis of Intelligent Built Environment

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ABSTRACT

The purpose of intelligent built environment is to improve inhabitant's quality of life and to satisfy inhabitants by replacing routine work with smart devices and robots. Smart devices and robots can interpret changes in the built environment and respond appropriately. The problem is how to define a rational intelligent built environment when many various stakeholders are involved, projects have thousands of alternative versions and the quality of life and economical efficiency changes with alterations in micro and macro environmental conditions and the constituent parts of the process in question. Moreover, the realization of some objectives seems more rational from the economic perspective though their significance is varied from other perspectives. The formalized Model for Complex Analysis of Intelligent Built Environment and the Multiple Criteria Decision Support System of Intelligent Built Environment developed by the authors of this paper show how changes in project alternatives and the extent to which the goals of various stakeholders are satisfied cause respective changes in the value and utility degree of a project. To achieve the above-mentioned aims new multiple criteria analysis methods were developed.

1. Introduction

Research shows that various scientists have achieved deep insights into different and very important areas of intelligent built environments: structures and materials [1], smart streets [2], smart locks [3], dust [4], lighting [5] and heating [6], intelligent tutoring system [7], clothing [8], health [9], multimedia service systems [10], materials [11], antenna [12], energy [13], evaluation of the intelligent building systems [14], modelling temperatures [15], multiple criteria lifespan energy efficiency assessments [16], intelligent mechanical systems [17], total sustainability in built environments [18], renewable building energy systems [19], comparative impact of passive design strategies and active features in hot climates [20], evaluation of intelligent buildings based on the level of service system integrations [21], standard communication infrastructures [22], voice recognition technology, sensors, and user interface improvements.

There is a growing demand for various above-mentioned solutions of intelligent built environments and studies are being performed in this area. For example, Chen at al. [16] present a multiple criteria decision-making model for lifespan energy efficiency assessments of intelligent buildings. Nishioka et al. [17] describe the measurements and evaluation of indoor thermal environments in a large domed stadium. Omer [19] analyses renewable building energy systems and passive human comfort solutions. Ochoa and Capeluto [20] describe the comparative impact of passive design strategies and their active features in a hot climate. Kua and Lee [18] propose a methodology for the promotion of total sustainability in a built environment. According to Kua and Lee [18], barriers to the promotion and acceptance of intelligent buildings, and even practices, can generally be grouped as being caused by the lack of: financial resources and confidence to use new and 'untested' technologies; professional capacity to incorporate and manage intelligent technologies; knowledge of developers and owners about the environmental impact of inefficient buildings; and information on opportunities granted by intelligent technologies. Kua and Lee [18] believe that in order to overcome these barriers, different forms of information should be created and shared among the concerned parties, i.e. architects, building scientists, engineers, conservators, material and equipment suppliers, manufacturers, service and maintenance professionals, marketing professionals, advertising agencies, project developers, owners, and policy-makers.

Several scientists are involved in the modelling of different elements of an intelligent built environment. Ríos-Moreno et al. [15] are modelling temperature in intelligent buildings by means of autoregressive models. Outside air temperature, global solar radiation flux, outside air relative humidity and air velocity were used as the input variables.

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Only a few researchers are trying to perform an integrated analysis of an intelligent built environment. For example, Wong et al. [14] promote and enhance the understanding of key intelligent indicators, and set the foundation for a systematic framework which can be used for appraising the system intelligence of various intelligent building systems. The key intelligent indicators provide developers and building stakeholders with a consolidated inclusive tool for the system intelligence evaluation of the proposed components in design configurations.

An overview of literature (completed by Wong et al. [23]) related to intelligent building research and indicates that previous research efforts dealt mainly with three research streams, including advanced/innovative technology, performance evaluation methodologies and investment evaluation analysis. According to Wong et al. [23] there is a growing demand for tools to support intelligent decision-making for building investments. Wong et al. [23] believe that despite the above-mentioned three research streams there is still a lack of a generally accepted tool for supporting intelligent decision-making for building investments.

It must be noted that researchers from various countries engaged in the analysis of intelligent built environment do not consider the research objects (an intelligent built environment, the parties involved in its design and implementation, as well as the micro and macro environments that make a particular impact on the intelligent built environment) selected by the authors of the present investigation. A complex analysis of the above-mentioned research objects was made with the help of new methods for completing a multiple criteria project analysis and was specially developed by the authors for this purpose.

An analysis of global experiences showed that the existing models do not allow multi-variant design and multiple criteria analysis of intelligent built environment alternatives, and thus the authors developed an Integrated Multiple Criteria Model of Intelligent Built Environment (MCAIBE). To some extent, MCAIBE also includes two of the above-mentioned research streams (performance evaluation methodologies and investment evaluation analysis) as described by Wong et al. [23].

The methods and models developed by other authors do not analyse the stakeholder groups (architects, building scientists, engineers, conservators, material and equipment suppliers, manufacturers, service, maintenance professionals, marketing professionals, advertising agencies, project developers, owners, policy-makers), the intelligent built environment and the influencing micro and macro factors (social, economic, technological, natural) as an integrated whole. All around the world, only separate elements of built environment were analysed and valuated in one form or another (structures and materials [1], smart streets [2], smart locks [3], lighting [5] and heating [6], intelligent tutoring system [7,24], clothing [8], health [9,25], multimedia service systems [10], energy [13,26], infrastructures [22], etc.) considering perspectives of different stakeholders. Besides, the global practice has not yet seen scientists making attempts on electronic development of possible alternatives of intelligent built environment, their assessment is based on numerous criteria and selection of the most rational variants for certain stakeholders. The formalized Model for Complex Analysis of Intelligent Built Environment and Multiple Criteria Decision Support System of Intelligent Built Environment developed by the authors of this paper show how changes in the project alternatives and the extent to which the goals of various stakeholders are satisfied cause respective changes in the value and utility degree of a project.

To achieve the above-mentioned aims new multiple criteria analysis methods were developed. The above three innovative aspects of multiple criteria analysis which deal with intelligent built environment form the basis of this article and are the main differences from the currently existing methods/models.

This paper is structured as follows: the Introduction; Section 2 describes the Model for a Complex Analysis of Intelligent Built Environment; Section 3 analyses the method of multiple criteria complex proportional evaluation of the projects; Section 4 describes the Multiple Criteria Decision Support System of Intelligent Built Environment; Section 5 presents a case study; and finally some concluding remarks on future research in Section 6.

2. Model for a Complex Analysis of Intelligent Built Environment

The research's aim was to produce a Model for Complex Analysis of Intelligent Built Environment by undertaking a complex analysis of micro, meso and macro environment factors affecting an intelligent built environment and to present recommendations on increasing its efficiency, competitive ability and improving inhabitant's quality of life. The research was performed by studying the expertise of advanced industrial economies (see [1–22]) and by adapting it to the Model under development.

Model for a Complex Analysis of Intelligent Built Environment (MCAIBE) was developed as follows:

- comprehensive quantitative and conceptual description of the research object;
- multi-variant design of an intelligent built environment;
- multiple criteria analysis of the intelligent built environment;
- selection of the most rational version of the intelligent built environment;
- development of rational micro and macro-level environment.

For a more comprehensive study of the research object and the methods and ways used for its assessment, the major constituent parts of the above-mentioned objects (an intelligent built environment, the stakeholders involved in the project's development and the micro and macro environment which makes a particular impact) will be briefly analysed. The Model will now be described in more detail.

The efficiency of the intelligent built environment (IBE) firstly depends on the combined effect of variable *macro-level factors*, such as the level of economic, political and cultural development, governmental policy (regional support programmes, control of competition, loans on easy terms, tax exemptions, commissioning of goods and services), legal and normative documents, the taxing system, the process of loan granting, interest rates, insurance systems, social policy, inflation, market, levels of unemployment, qualification of labour force, size of salaries, labour laws, environment protection, customs and traditions, availability of local resources, etc.

The national economic environment has a direct influence on IBE. It is determined by the policy of national authorities on taxes and money, capital movement, investment environment, loan granting and interest rates. The economic environment is also determined by such factors as demand, supply, competition, and pricing, etc. [27].

The social and cultural environment consists of institutions and other factors which help to shape and understand the main social values, opinions and norms of behaviour. Human personality matures in a certain society, which determines the main values and opinions. Each social group acts in a certain cultural environment, which consists of specific traditions and customs.

The political and legal environments have a direct influence on intelligent built environment. Political and legal environments consist of the political system, legislation and ownership rights. State and public establishments and organisations, as well as other stakeholder groups, influence political and legal environments.

The built environment functions in a certain natural environment, and affects and is affected by natural environment and energy saving.