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Multi-criteria decision-making system for sustainable building assessment/certification

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ABSTRACT

The paper presents a new multi-criteria decision-making technique to select criteria for building sustainability assessment. The methodology of building certification system is integrated with the multi-criteria decision-making (MCDM) methods. The criteria set for assessment is determined based on Swedish certification system Miljöbyggnad. Criteria weights are determined by applying Analytic Hierarchic Process (AHP) method. Weights of criteria are calculated based on Saaty's judgement scale and new original scale, presented by the authors. ARAS (Additive Ratio Assessment) method (MCDM method) is applied to solve problem under investigation. The developed assessment method involves LEED system's criteria.

1. Introduction

Modern society all over the world needs improving technologies of the construction processes, according to the sustainable development methodologies. The International Panel of Climate Change stated that there would be a steady increase in the ambient temperature during the end of the 21st century. This increase impacts the requirements of energy used for the buildings [1]. The construction sector has a big impact on the climate change, because of large energy consumption. More than 40% of energy, used in Europe, is used in the construction sector. Therefore, it is necessary to make the construction sector to be involved in the 'green', 'eco', 'sustainable' or another similar movement, which should improve the building quality, according to the stated criteria set. Sustainable development and building evaluation should be based on three different general groups of criteria: social, economic and environmental. Some of the building certification systems have prepared well organized methodologies, which includes these criteria, and more. A lot of building certification tools is created to improve the building quality. These tools evaluate the quality of the building, based on the different criteria. Most popular of them are LEED (North-American environmental certification, applicable to new

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Abbreviations: AHP, analytic hierarchy process; ARAS, additive ratio assessment (MCDM method); DGNB, Deutsche Gesellschaft für Nachhaltiges Bauen; DMM, decision-making matrix; MCDM, multi-criteria decision-making.

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constructions and improvements), LEED for Homes (Residential version of the LEED, applicable to initially new single-family residences; an adaptation for multifamily residential buildings is provided and also those undergoing improvement), BREEAM (English Environmental certification system), GBtool (Sustainability assessment methodology defined by an international consortium of researchers), Miljöbyggnad (Swedish certification system), ITACA Protocol (Italian certification).

Each certification system is unique and consists of different parts and criteria, which describe different sections of the building's life cycle. Furthermore, each system has its own methodology for the evaluation. Among protocols used for labelling there are some of them which utilize points, some others provide percentages and others utilize stars or alphabetic letters. Some of them (e.g. LEED and BREEAM) have high detailed and lengthy evaluation methodologies. Other (e.g. Miljöbyggnad) are simpler, with a clear-cut methodology. The main goal of the paper is to develop the multi-criteria assessment methodology for the building certification process integrating the multi-criteria decision methods with well-known Miljöbyggnad (Swedish certification system). The criteria set was proved through the years and experience, and was used to rise up the quality of buildings.

2. Theory

The real world is characterized by deep complexity. The very nature of multi-criteria decision-making problems is that there is much of a complex and conflicting nature. Assessment of buildings typically involves a wide range of criteria.

Multi-criteria decision theory is an adequate tool, since it allows us to take a wide range of assessment criteria into account (e.g. environmental impact, distributional equity, etc.). Mathematical algorithms have the important objective of guaranteeing consistency between the problem structuring and the ranking of feasible alternatives options.

The discussion on the methodology for assessing and certification green buildings require an improvement of the traditional criteria for environment quality, such as energy consumption [2]. Growing impact of buildings on the environment has created a greater need to take into account the environmental criteria. With regard to this, there are international environmental management systems standard, which is named as ISO 14001, and the slightly older approach of eco-labelling [3]. The ISO has been active in defining standardized requirements for the environmental assessment of buildings. ISO Technical Committee (TC) 59 ''Building construction'' and its Subcommittee (SC) 17 ''Sustainability in building construction'' have published two technical specifications [4]:

- ISO/TS 21929-1:2006 sustainability in building construction – sustainability indicators – Part 1: Framework for development of indicators for buildings [5].
- ISO/TS 21931-1:2006 sustainability in building construction – framework for methods of assessment for environmental performance of construction works – Part 1: Buildings [6].

Buildings are significant in terms of the economic and social development of cities, as well as their environmental impacts [7]. So the 'green building approach' should consider three dimensions – environmental, social, and economical [8].

2.1. *Worldwide certification systems*

In 2002 eight nations formed the World Green Building Council (GBC), a union of national councils whose mission is to accelerate the transformation of the built environment towards sustainability. Collectively, these nations represent 50% of the global construction activities, and their advices affect more than ten thousand companies and organizations. The World GBC provides an international forum, and provides proven tools that significantly accelerate market transformation from traditional, inefficient building practices to new generation high-performance buildings. It provides ''branding'', and transform the skills and knowledge of the industry as a whole. This is a critical response strategy for cities and countries worldwide to their national and international commitments to reduce carbon emissions and readdress other environmental impacts. GBCs are highly effective at engaging leaders across sectors to transform the built environment. These suggestions are proven, replicable and they generate momentum in building [9].

Green Building Councils have been developed the following rating systems (World GBC):

- Australia – Green Star [10];
- Canada – LEED Canada™ [11];
- Germany – DGNB Certification System [12];
- India – IGBC Rating System & LEED India™ Green Building Rating Systems [13];
- Japan – Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) [14];
- New Zealand – Green Star NZ [15];
- South Africa – Green Star SA [16];
- United Kingdom – BREEAM [17];
- United States – LEED Green Building Rating System™ [18];
- Sweden – Miljöbyggnad [19] (Table 1).

The presented case study presents an integrated multi-criteria assessment methodology for the building certification integrating the multi-criteria decision methods with Swedish certification system. The methodology of Unites States' LEED Green Building Rating System and Swedish certification system were basis to rise up the quality of buildings.

2.2. *Integrated MCDM and building certification methodology*

Decision-making is one of the most important and popular aspect of application of mathematical methods in various fields of human activities [20]. MCDM techniques have been used in many such performance measurements as MCDM are useful in identifying and evaluating compatible alternatives (or solutions) in decision support tools [21–27].

2.2.1. *Multi-criteria decision-making techniques*

Generally solution of MCDM problems involves five key steps [28]: