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Achieving Nearly Zero-Energy Buildings by applying multi-attribute assessment

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ABSTRACT

According to the Directive (2010/31/EU), the main goal in the energy performance of buildings, especially for achieving longer-term objectives in the energy saving, is achieving Nearly Zero-Energy Buildings (NZEBs). Thus, this plan can be achieved by refurbishing of existing or by constructing new buildings to satisfy NZEB requirements. Nowadays, refurbishment of existing buildings to satisfy NZEB requirements becomes one of the major aim in construction. In solving this refurbishment problem, Multi-Attribute Decision Making (MADM) methods help here to evaluate existing state of buildings and to compare them with optimal alternative, which equals to NZEB. This comparison allows selecting optimal refurbishment methods to achieve NZEB requirements. However, existing MADM methods do not applied to compare existing alternatives (i.e. buildings) with the optimal alternative (i.e. NZEB), which is based on standards and laws. Usually existing researches present comparison of selected alternatives among each other or with the best alternative from compared, like in the TOPSIS or ARAS methods. Therefore, in this paper, we analyse the concept of a Passive house and NZEB and its applicability in Lithuanian standards and, respectively, define the optimal alternative (i.e. an optimal building). Second, we analyse possibility of extending existing MADM methods to be MADM optimal (MADM-opt). Moreover, we present several modifications how to transform WASPAS, ARAS and TOPSIS by adding optimal alternative. The modified methods were applied for evaluation of 13 apartments. The results show that MADM-opt is useful for the assessment of alternatives and their evaluation according to the optimal alternative. Moreover, it allows determining difference between the assessed alternatives and the optimal alternative.

1. Introduction

Based on the Energy Performance of Buildings Directive (Directive 2010/31/EU) [1] and the Energy Efficiency Directive (Directive 2012/27/EU) [2], the greatest energy saving potential lays in buildings. According to the Directive (2010/31/EU), the main goal in the energy performance of buildings (EPBD), especially for achieving longer-term objectives in the energy saving, is achieving Nearly Zero-Energy Buildings (NZEBs), where NZEB have very high energy performance and the required amount of energy comes mostly from renewable sources. According to the Energy Performance of Buildings Directive [1], all new buildings must be NZEB by the end of 2020 and all new public buildings must be NZEB by 2018.

Thus, this plan can be achieved by constructing new buildings to satisfy NZEB requirements or by refurbishing of existing buildings to satisfy NZEB requirements. However, nowadays refurbishment of existing buildings to satisfy NZEB requirements and users' needs becomes one of the major aims in construction. In general, in terms of sustainable development and sustainable construction, refurbishment of buildings is preferred to new construction. This helps to save energy and building materials in construction phase, also reduces generation of waste and other emissions. Seeing that in Europe over one third of buildings are older than fifty years [3], their refurbishment to satisfy today's needs and requirements becomes a topical question. However, buildings are of different physical and moral depreciation, have different location in a city that determines their value and perspectives of conversion and further use, and

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some of them may be protected as an architectural heritage, therefore different their redevelopment strategies have to be evaluated and the most ration strategy in terms of environmental, economic and social aspects should be selected.

In solving this multifaceted refurbishment problem, Multi-Attribute Decision Making (MADM) methods help here to evaluate existing state of buildings and to compare them with optimal alternative, which equals to NZEB. This comparison allows selecting optimal refurbishment methods and measures to achieve NZEB requirements.

The energy performance of buildings is defined by the particular class. In Lithuania, each building is assessed individually by a specialist, using certification system NRG3,[1] which is based on the Construction Technical Regulation (CTR) STR 2.05.01:2013 [4]. As stated in STR 2.05.01:2013 [4], a Passive House could correspond to class A, and a NZEB is a building that corresponds to class A++. Moreover, as stated in CTR STR 2.05.01:2013 [4], from November 1st, 2016 all constructed new buildings should satisfy the energy performance class A and higher. Accordingly, the targeted optimal alternative can be defined based on actual regulations.

Though, nowadays, there are a number of researches on applying MADM to select an optimal alternative in different fields, existing MADM methods have not been applied to compare existing alternatives (in our case – buildings) with the optimal alternative (in our case it is a Passive house or NZEB), which is based on standards and laws. Existing researches present comparison of selected alternatives (i.e. buildings) among each other or with the best alternative from compared, like in the Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS) or in the Additive Ratio Assessment (ARAS) methods [5]. However, this best alternative is defined on the basis of existing alternatives (i.e. as minimum or maximum of essential optimized criteria) or the best possible alternative in a space, which can be unsatisfactory comparing to the standards and laws. Moreover, in some cases it is necessary to evaluate a deviation of compared alternatives from existing standards, laws, norms and regulations.

Therefore, the main aim of the presented research is to extend existing MADM researches in construction in terms of NZEB and existing standards and regulations. Consequently, in this paper, we analyse the concept of Passive house and NZEB and its applicability in Lithuanian standards and, respectively, define the optimal alternative (i.e. an optimal building), based on Lithuanian standards, norms and regulations. Second, we analyse possibility of extending existing MADM methods to be MADM optimal (MADM-opt).

The balance of this paper is organized as follows. Section 2 presents the already published methods and used for the description of our proposition. Section 3 presents the developed theory of the assessment with optimal alternative, e.g. a description of the proposed MADM-opt, including adaptation of WASPAS, ARAS and TOPSIS to the usage of the optimal alternative. Section 4 describes calculations and results of the assessment of apartments by MADM-opt. Section 5 presents discussions and Section 6 presents final conclusions.

2. Methods and materials

2.1. Achieving Nearly Zero-Energy Buildings (NZEBs)

As was mentioned in Introduction, based on the Energy Efficiency Plan 2011 [6] prepared by the European Commission, the biggest amount of energy can be saved by achieving Nearly Zero-Energy Buildings (NZEBs). This plan can be achieved by refurbishing of existing buildings, since over 35 % of the EU's buildings were constructed more than fifty years ago [3], or constructing new buildings to be NZEB.

Nowadays, refurbishment of existing buildings to satisfy NZEB requirements becomes one of the major aim in construction. In solving this refurbishment problem, MADM methods help here to evaluate existing state of buildings and to compare them with optimal alternative, which equals to NZEB. This comparison allows selecting optimal refurbishment methods to achieve NZEB requirements and satisfy humans' needs. Moreover, according to STR 2.05.01:2013 [4], from November 1st, 2016 all constructed new buildings should satisfy the energy performance class A and higher.

A Passive House building standard is developed in Germany for the purpose of reducing heating needs by 90% [7]. A similar standard, *MINERGIE-P*, is developed in Switzerland.[2] According to the *Passive House Standard* [8], there are five methods to reach an appropriate indoor environment. All of them are mostly concentrated on the achievement of an appropriate *isolation* and *ventilation*. Yet, the Passive House concept means energy efficient building, the *Active House* concept is expanded to focus on increasing indoor air quality, fresh air quantity and natural sunlight quantity in a building also (Directive 2010/31/EU) [1]. However, a Passive House could be built (e.g. a new ones or a house could be renovated into Passive House) more economically and therefore, is more acceptable for homeowner, while an Active House can be reached using expensive technologies, which are not acceptable for most homeowners [7].

In Lithuania, the energy performance is defined by the particular class. Each building is assessed individually by a specialist, using certification system NRG3.[1] And, as stated in the CTR STR 2.05.01:2013 [4], buildings corresponding class A can be named NZEB.

According to the CTR STR 2.05.01:2013 [4], the particular class of the energy performance of a building should be evaluated according to the criteria presented in Table 1. Formulas for determining values of those criteria are presented in the CTR STR 2.05.01:2013 [4] and, therefore, not described in this paper.

However, to satisfy users' needs, an indoor air quality should be analysed also. As described in European Standard EN 15251 [8] indoor environment addresses six factors as follows: 1) thermal criteria for winter, 2) thermal criteria for summer, 3) air quality and ventilation criteria, 4) humidity criteria, 5) lighting criteria, and 6) acoustic criteria. In our research, we concentrate on indoor air quality (3, 4 and 6 criteria) and thermal environment (1 and 2 criteria). The lighting criteria is not analysed here, since in the existing buildings lightening could not be changed. E.g., orientation of the building remains the same and according to the renovation project, the existing architecture of the buildings should remain the same.

As was presented in the previous research [9], in different countries an indoor air quality is characterised according almost the same criteria. They are as follows: light, air quality, air ventilation and movement, thermal comfort, noise, and moisture and humidity. In this research, we are going to use the same air quality criteria as presented in Ref. [9].

There are a number of articles analysing and presenting recommendations for improving houses to meet the Passive House Standard [10] and assessing indoor climate in passive and conventional buildings. Some of them are as follows. Authors of Ref. [11] analyse thermal environment in a double office room and in a six-person meeting room and make recommendations on heat load distribution in rooms. In Ref. [12], authors as well analyse thermal comfort in office rooms and suggest different cooling cloth-

[1] http://www.spsc.lt/nrg/cms/index.php.

[2] http://www.minergie.ch/home_en.html.