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Evaluation of climate adaptive building shells: multi-criteria analysis

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Abstract

The paper defines the most suitable climate adaptive building shell technology for Latvian climate conditions by application of multi-criteria analysis. During the analysis seven alternative technologies are considered and seven criteria are defined in order to make a well-grounded decision.
The results indicate that the optimal would be a climate adaptive building shell technology that has integrated phase change materials.

Keywords: multi-criteria analysis; climate adaptive building shells; energy efficiency

1. Introduction

Energy efficiency in buildings is a major field for final energy consumption reduction, especially this factor relates to old buildings [1, 2]. Majority of modern building constructions are made of static systems that are not able to adjust to optimal energy consumption or indoor climate. Insulation thickness, thermal mass, the surface of windows are fixed, stationary values. Unable to change during whole year. Seldom used shutters for windows in order to control heat loads [3–6].

Meanwhile the demand for satisfying working environment and economic performance has increased. The use of climate adaptive building shells (CABS) is considered to be one of the key factors in meeting the ever growing requirements [7]. Although most possible measures of energy consumption decrease are considered to be encouraged [8],

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R. Loonen [9] claims that the concept is rather immature and needing more research as there are not many successful applications of CABS in practice.

Designing projects in which climate adaptive facades or roofs are planned to be integrated are often linked with risks – long periods of payback time and high operation costs. If the developer choses to take the risks, the outcomes are claimed to be beneficiary. But the decision must be justified during the designing stage [10].

2. Problems during operation

Switching from static to adaptive buildings is not only a complicated process from building engineering system complexion point of view, but also in terms of operation. J. Monoley alleges that design is not anymore the creation of a monumental building, but it has become the assembly of a complex model. In order to achieve a successful, energy efficient result it is not enough to simply add adaptive features to the existing system. CABS must satisfy different demands that compete or even conflict with each other. Therefore coherent actions must be taken. Separate façade sub systems must coordinate between each other and building systems or elements. For instance, climate adaptive building shells must find the compromise among daylight and glare, fresh air and draft, shutters and luminaires, heat gains and overheating [11].

3. Climate adaptive building shell typology

Literature research of CABS reveals that there have not been many attempts at summary of different types or detailed investigations of specifics of each type. To acquire a frame on which typology can be based, the work of R. Loonen is applied [12]. Focusing on distinct adaptive behavior of smart building shells it is possible to distinguish several sections [11]: climate, humans, time frame, mechanisms.

This split is also taken as a template for choosing the possible technologies for implementation in Latvian climate conditions. The climate section includes CABS that react to the environment – regulating heat loads with shutters for instance. Human section however splits the CABS in several subsections that each represents a different type of building shells that change their properties based on human behavior. Technologies that fit the time frame section have the ability to adapt seasonally or in shorter periods of time. Lastly, the mechanisms that are used in CABS can be split in two subsections – micro and macro. If a material changes its internal energy changing its structure and thermos-physical or optic properties, it is considered micro mechanism, phase change materials for instance. Whereas macro mechanisms include energy change without affecting the properties of a material – PV panels for example.

4. Multi-criteria analysis

Decision making is a branch of science about the definition of possible alternatives and choosing the most fitting scenario that is founded on several factors and is in harmony with the decision maker's expectations. Each decision is made in a specific environment that is formed by the available information and its quality, number of alternatives and priorities in the time of decision. When the decision is not obvious and alternatives conflict with each other, multi-criteria analysis may be applied in order to make a quality decision. Another advantage of multi-criteria analysis is the transparency of the process. Multi-criteria analysis is a valuable tool for dealing with complex problems when dealing with a great number of alternatives [13–15].

The decision making is formed in five following stages.

4.1. Definition of the problem, generation of alternatives and definition of criteria

In the wide range of climate adaptive building shell technologies that is found in the scientific literature, magazines and real-life examples a decision of the best fitting technology for Latvian weather climate must be made. Subtracting the technologies that are specific for warm climate zones that would just simply not be possible to adapt to Latvian climate a number of reasonable technologies is left – seven different CABS are generated as possible alternatives: