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Original article

Supporting the selection of a variant of the adaptation of a historical building with the use of fuzzy modelling and structural analysis

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ABSTRACT

Changing the function of a historical building through adapting it to new use is one of the more effective ways of extending the life-cycle of degraded historical structures. The process of selecting a new method of use of a historical building requires the involvement of conscious decision-makers, whose view of the benefits associated with the adaptation reaches beyond economic gain, but also includes the importance of the protection of cultural heritage, as well as other benefits associated with the concept of sustainable development. The will to include interdisciplinary benefits, as well as the distinct nature of the decision-making problem that is the imprecise nature of information and the conflicts between the parties invested in the decision-making process adds to the complexity of the problem. The proper approach to these kinds of decision-making problems is making an attempt at deconstructing the problem and expressing it in a synthetic manner in the form of a model, followed by performing its analysis. The literature on the subjects provides a number of multi-criteria methods that can be used to support making decisions of this type. However, most of these methods do not take into account the relationships between the selection criteria, while none of them is suited to processing the imprecise and uncertain character of the initial data, which is a typical feature of decision-making problem at hand. Wishing to address these issues, the authors of this article propose a complex, multi-criteria approach that incorporates the above elements. Finally, the authors provide a practical example of the practical implementation of the aforementioned approach as a tool supporting the selection of a new form of use for the Great Armoury historical building, located in Gdańsk, Poland.

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1. Introduction

One of the missions of modern civilization is the protection of its cultural heritage by preventing the degradation of its constituent elements and the proper conservation, development and propagation of its values. Historical buildings are one of the elements of this heritage, and their only chance of being preserved is either having their importance recognised by society, or being adapted to fulfil a more useful role. The usefulness of a historical building is established by the development of civilisation, which in many cases means that the original function of certain structures are no longer viable and should be altered. Adapting a historical building to a new form of use is therefore a chance to lengthen its life cycle, a chance to preserve its historical substance for future generations [1].

The choice of a new form of a building's use requires the verification of both its material and intangible value, as well as assessing the mutual interrelations between the qualities of the building and the possible variants of its adaptation. Legal regulations such as architectural conservation guidelines or those contained within local spatial development plans are not without meaning in the formulation of the set of possible forms of use for a building. In addition, over the course of analysing the selection of a new form of use for a historical building, we should also pay attention to the fact, that these buildings, which – as a part of our cultural heritage – are a resource which should be protected not only in terms of its cultural value, but also constitutes a potential for the creation of socio-economic values, and the forms of redeveloping these structures should be friendly to the natural environment, in accordance with the concept of sustainable development [2,3].

The selection of a new form of use of a historical building is a problem that requires the assessment of numerous factors (criteria) of an interdisciplinary character. An effective means of tackling these types of decision-making processes is attempting to synthetically describe their core issue through the use of a decision model.

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The making of objective decisions is a difficult problem in the construction industry. The decision-making process is very complicated and time consuming due to the complex character of construction projects. This is why it needs to be supported by numerous knowledgeable experts from various fields within the construction industry. Difficulties are also associated with the development of an appropriate set of criteria that can be a part of the decision-making model. Taking into account the differences in the opinions of experts that result from the uncertain character of the data in the analysis of the decision-making process requires support in the form of using methods based on fuzzy logic [4,5].

A multi-criteria analysis of such a model of reality, in addition to utilising the appropriate tools, can allow the person making the decisions to make the proper choices in light of previously established criteria [6–12].

We can find numerous decision models in subject literature [13–15], the analysis of which provides the ability to choose the form of use that an abandoned structure can be adapted to, using various criteria, some of which are partially tied to sustainable development. However, the aforementioned approaches are not reliable when dealing with historical structures, as their specific character and the conditions they impose force the decision-maker to take into account additional factors and interrelations tied to cultural heritage. Numerous multi-criteria decision-making models have been developed for use in the field of protecting historical structures, with most of them being tied with: evaluating these buildings [16], with supporting the planning decisions that take these buildings into account [17–19], as well as establishing priorities in their revalorisation [20–24].

The selection of a new form of use for a historical building is an entirely different group of problems. In article [6] pointed to the use of a multi-criteria approach in the analysis of a new method of use intended for historical buildings as they analysed several variants in which a historical building in Vilnius, Lithuania, could be adapted. The authors proposed the TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) method as a tool of multi-criteria analysis of the selected adaptation variants. The weighted average method was used by Fuentes [25] while evaluating the possibility of returning four historical buildings to use in Spain. In article [26] analysed the adaptation variants of two historical buildings in the city of Taipei in Taiwan. In order to perform their multi-criteria analysis, they made use of the ANP (Analytic Network Process) method, which is one of the methods used in structural modelling. On the other hand, Giove et al. [27] used the Choquet integral in order to perform a multi-criteria analysis of the choice of a new method of use for the building of the Arsenal in Venice, Italy. An interesting approach to the solving of the decision problem at hand was recently proposed by Ferretti et al. [28] who analysed the possibility of using Multi-Attribute Value Theory (MAVT) in researching the preferred method of use of historical buildings in Turin, Italy.

As it has already been mentioned in Section 1 of this paper, the aforementioned approaches do not take into account the uncertain nature of the evaluations of experts, which occurs due to the imprecise nature of the information regarding the analysed problem of adapting a historical building. The hierarchic order of the relationships between the elements that are being analysed (decision-making criteria, variants of adaptation), which is used in the vast majority of the decision models that have been presented above, does not fully reflect the character of the structure of the problem of the selection of a new form of use for a historical building. By not taking into account the direct and indirect interrelationships between the interdisciplinary decision-making criteria, these methods overly simplify the reality that is being modelled.

The authors of the paper would thus like to propose a new multi-criteria approach, which takes into account the aforementioned

problems, which in turn is going to lead to an in-depth analysis of the decision-making problem in question.

First, the authors would like to define the multi-criteria problem of choosing a new form of use for historical buildings in light of the proposed criteria of choice. The authors are then going to use the multi-criteria WINGS method (Weighted Influence Non-linear Gauge System) developed by Michnik [29], which they are then going to expand over the course of their analysis so that it can be able to accommodate uncertainties and the aggregation of results of the evaluations conducted by experts – a necessary element due to the specific nature of the problem being discussed. The proposed expansion of the WINGS method is going to be implemented by the authors in order to analyse the problem of the selection of a new form of use for the historical Grand Armoury building in Gdańsk, Poland.

2. Research aims

The key limitation of the approaches to the analysis of the problem of the selection of a variant of the adaptation of a historical building that have so far been proposed is not taking into account the fuzzy character of the information that needs to be analysed by the experts in the initial phase of the decision-making process. The imprecise nature of the data that is tied to the historical building that is being analysed, as well as regarding the possible forms of its adaptation, is the effect of the uncertainty tied to the evaluations performed by the experts over the course of the analysis. In addition, the vast majority of the methods of carrying out multi-criteria analysis that have been proposed, the structure of the problem, and, as a result, the ties between its elements (the main goal, the criteria, the decision variants) take on a hierarchical order, instead of a network-type one, which is a far-reaching oversimplification of these types of decision-making problems, as the elements that need to be taken into account do not necessarily follow the provided order of going from the most to the least important.

The goal of this paper is to address these problems by proposing an approach which is going to take into account:

- criteria of choice that are both distinct and universal for this type of problem,
- the specifics of the relationships and connections (including so-called feedback loops) between the elements of the model,
- the uncertainty of evaluations caused by the imprecise nature of the data that is being operated on by the experts that take part in the analysis,
- the possibility of the aggregation of the fuzzy evaluations of the aforementioned experts.

The entirety of the discussion is supported by a practical example of the implementation of the proposed approach for the purposes of carrying out an analysis of the selection of a new form of use for the historical building of the Grand Armoury in Gdańsk, Poland.

3. The multiple-criteria decision-making problem

The aforementioned specifics and complexity of the problem of selecting a new form of use for a historical building, especially in the case of attempting to reconcile the interests of the parties involved in the problem, force the decision-making party to adopt a multiple-criteria approach to decision-making regarding the return of a historical structure to use.

On the basis of a literature review, the authors selected the most commonly arising criteria of choice associated with the protection of historical monuments. This selection was then consulted in a

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