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Original article

Expert system for predicting buildings service life under ISO 31000 standard. Application in architectural heritage

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ABSTRACT

The expert system for predicting the service life of buildings, fuzzy buildings service life (FBSL), is a computer application that contributes to the preventive conservation of architectural heritage. It establishes the process for evaluating and analysing the vulnerability and the main risks for heritage buildings, managing durability and service life according to their functionality. This paper demonstrates, after a detailed study and analysis of the two main reference standards in the field of risk management, namely the international standard ISO 31000:2009 and the European standard EN 31010:2011, that the FBSL expert system has been developed in compliance with the specifications established in these standards. This research justifies the use of this method, based on a new expert system that predicts the future service life of homogeneous heritage sites worldwide. This model manages the risk affecting these buildings and also complies with the aforementioned standards. Finally, the practical application of the FBSL expert prediction system was carried out through the study of a specific architectural heritage site.

1. Introduction

The *service life of* a building is established as its "*bearing capacity*, namely the capacity of a building to guarantee, with the necessary degree of reliability, the stability of the overall building and the necessary resilience, for a certain period of time, referred to as period of service" [1]. The analysis of this concept is included in international standard ISO 15686:2014 [2].

The assessment of the conservation status of a building and its durability over time is related to the components that make up the building, and are sensitive to events that generate one or various consequences, *vulnerabilities*. Extrinsic actions are considered to be effects of uncertainty in the building or *risks* [3,4].

Vulnerabilities and risks have been analysed in different ways [5]. In any case, the main aim of this study was to assess conservation status in architecture [6] including interactions with nature [7,8], static-structural and anthropic factors [9].

Haagenrud [10] shows that different agents cause deterioration, generating direct and indirect consequences in terms of building maintenance and repair costs. The service life of buildings is an important element in the socioeconomic stability of contemporary societies, representing fifty per cent of the wealth of most European countries at the beginning of this century.

The gradual degradation of architectural heritage buildings over time full concerns among users and influences their needs and expectations, prompting a significant increase in research into the buildings service life [11,12].

Until now, different predictive models [13–15] have been used to forecast the durability of architectonical elements [16,17], together with intelligent systems for regulating and controlling their installations. Modelled fuzzy in research to diagnose pathologies in architectural heritage [18] and in studies related with structural swings in the event of seismic tremors [19]. Neural network systems for controlling ventilation and wind chill among other applications [20,21].

The literature contains partial studies of building construction system; Vieira et al. [18] applies a fuzzy model to calculate the physical life of materials.

In contrast, the fuzzy building service life (FBSL) is a universal model developed by Macías-Bernal et al. [9] that classifies the functionality of a group of buildings with homogeneous characteristics based on inputs as the result of a system output. This expert system is, in fact, the first to combine the concept of building vulnerability with the external risks to which the building is subject. This model

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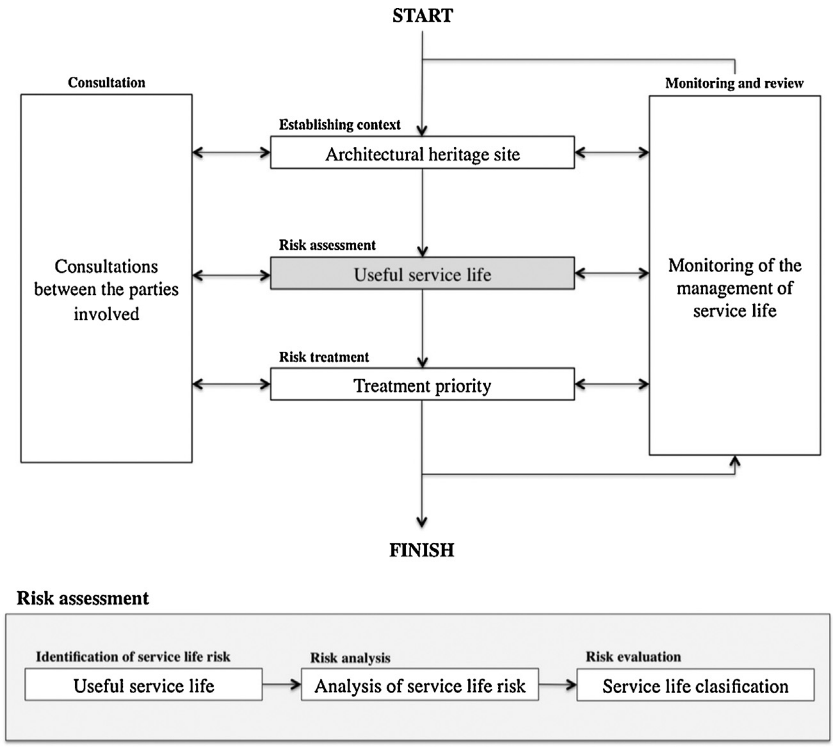

Fig. 1. Risk management process, ISO 31000.

is based on the fuzzy sets theory, developed in the 1960s–1970s by Zadeh [22] at Berkeley University and continued by Mamdani and Assilian [23] and Takagi and Sugeno [24]. The system is considered to be a new contribution in the field of expert systems based on fuzzy logic, capable of predicting the durability of buildings, thus contributing to the preventive conservation of architectural heritage. The aim of this study was to apply the FBSL under the international standard ISO 31000:2009 and the European standard EN 31010:2011, which regulate risk management and assessment, respectively. Field data on service life were gathered by assessing the preservation condition of 10 heritage buildings located in the Seville area, Spain.

2. Research objectives

The main aim of this article is to demonstrate that the new methodology for managing and assessing the risk affecting the service life of heritage sites with homogeneous characteristics – FBSL – conforms to international risk management standards. The new expert system for calculating the service life of buildings has been developed in compliance with the risk management regulations (EN 31010, ISO 31000) [25–27] and in the environment of inference systems based on the Xfuzzy3.0 fuzzy logic design tool [28]. This environment is formed by tools that cover the different stages of the fuzzy system design process, from its initial description to its final implementation, through the common specification language XFL3 (a flexible and powerful language that enables the expression of very complex relationships between fuzzy variables using hierarchical rules, membership functions, fuzzification and defuzzification methods).

This model according to the functionality of homogeneous groups of heritage buildings was developed by identifying a total of seventeen input parameters, (vulnerability, static-structural, atmospheric and anthropic risk factors), validated and ranked by a group of experts, and which are related to the output parameter of the expert system: the durability of buildings [9].

3. General aspects of the ISO 31000 and EN 31010 standards

The ISO 31000, designed by the private organization International Organization for Standardization (ISO), is a powerful tool applicable to any organization engaging in the implementation and improvement of the risk management process. This process facilitates the taking of decisions related to uncertainty or the possibility of future events and their effects on objectives, and also provides policies, procedures and provisions for the integration of risk management at all levels of the organization. The EN 31010 governing risk management [27] is a supporting standard for the ISO 31000 [25]. The methodology of principles and guidelines is established for both standards (Fig. 1).

The standard has been developed as a common understanding and effective agreement for generating the necessary steps to adequately identify, manage and evaluate *risk*, the latter being defined as a "combination of consequences between events associated with a probability of future occurrence" ISO 31000 and ISO Guide 73:2009 [25,26].

The general provisions of this standard provide the guidelines to be followed by numerous industries and different types of systems. Similarly, the vast geographical areas in which the ISO 31000 and EN 31010 are applied [27] have fuelled the academic debate regarding their results and some of the main concepts they develop [29–32]. For example, Aven [3] argues that the standard could provide more effective definitions of some of the concepts covered in order to improve their definition by developing them in greater depth.

4. The FBSL and ISO 31000

This model [9] is developed in compliance with the ISO 31000 and EN 31010 standards (Figs. 1 and 2) and therefore complies with the specifications established in international legislation governing risk management, assessment and analysis. The management process is developed below.