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A framework for the simplified risk analysis of cultural heritage assets

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ABSTRACT

A simplified risk assessment framework specifically developed for built immovable cultural heritage assets is proposed. The framework addresses all the components in a risk analysis and can be used as a screening procedure for the preliminary assessment of a large number of assets with limited resources. Furthermore, the framework can also be used to identify cultural heritage assets that require a more refined and resource demanding risk evaluation. The proposed risk analysis framework falls into the category of qualitative methods and is based on an existing approach developed for the vulnerability assessment of critical infrastructures. The qualitative risk analysis of the proposed methodology is based on a set of structured assessment flowcharts that address the main components of a risk analysis: the likelihood of the hazard, the vulnerability of the asset to the hazard, the consequences of the hazard, the loss of value of the asset and the capacity to recover from the event. To illustrate the applicability of the proposed methodology, an application example is also presented for the case of seismic risk.

1. Introduction and research aim

Risk is a concept deeply embedded in the collective consciousness of modern society and there is currently a worldwide trend to enhance our understanding of risks in order to increase our ability to manage them. Although an objective and universal definition of risk is yet to be established [1], it can be seen as a measure of the combined likelihood of occurrence of a threatening event and of its potential consequences. Such threatening events are usually termed hazards and represent a potentially damaging physical event, natural or man-made, that can cause loss of life or injury, property damage, social and economic disruption or environmental degradation [2]. On the other hand, the potential consequences, globally termed as losses, can be seen as the result of existing vulnerabilities (e.g. physical, social, economic or environmental vulnerabilities) that represent the susceptibility to the damaging effects of the hazard [2] combined with a lack of ability to cope with those consequences, i.e. a lack of resilience [3].

Disasters can occur when the probable nature of the hazard becomes a real damaging event and when the potential consequences turn into actual losses. Over the years, several international initiatives have been promoted to address the issues of disaster risk reduction (DRR) and disaster risk management (DRM) in order to establish new approaches to reduce the impact of disasters in society. The wide-ranging concepts of DRR and DRM involve the development and application of policies, strategies and practices to minimise disaster risks throughout society. In 2005, the adoption of the Hyogo Framework for Action (HFA) 2005-2015 [4] was an important step towards these objectives. The HFA was the first internationally accepted framework where international agencies and national governments have set targets and commitments for DRR which were defined through five priorities for action. Of those five priorities, Priority Action 2 specifically addressed risk assessment and monitoring [4]. Therefore, the HFA clearly acknowledged that the sustainable implementation of disaster mitigation actions can only be achieved when based on adequate knowledge about the hazards threatening relevant assets and their vulnerability to those hazards.

Even though the HFA ended in 2015, efforts towards DRR continue since the HFA has now been replaced by the Sendai Framework for Disaster Risk Reduction 2015–2030 [5]. This new framework is expected to build on the achievements of the HFA to establish a set of improvements. Despite the worldwide progress achieved in DRR with the implementation of the HFA, several features were identified for its enhancement (e.g. see [6–9]). Among other aspects, the importance of cultural heritage and its irreplaceable value for society have been explicitly recognized, thus emphasising the need to assess the impact that potential hazards may have on cultural heritage [5,6]. Moreover, the significant role of cultural heritage in social cohesion and sustainable development

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has also been highlighted, making it a key resource to build resilient societies [10].

Despite these concerns, irreplaceable losses of cultural heritage continue to occur throughout the world as a result of natural or man-made disasters (e.g. [11–16]). Even though numerous cultural heritage assets require the implementation of risk mitigation measures (e.g. [17–21]), the development of such measures needs to be based on adequate knowledge about the risks these assets are facing. However, for most countries, carrying out a multi-hazard risk analysis for a large number of cultural heritage assets requires efforts and budgets that are frequently unavailable. Therefore, assessing the risks for a large number of assets with limited resources is only feasible when based on simple methodologies.

To address this need, a methodology developed to perform the qualitative risk assessment of a large number of assets with limited resources is presented herein. The proposed methodology involves all the components in a risk analysis and can be used as a screening procedure for the preliminary assessment and identification of built and immovable cultural heritage assets that require a more refined and resource demanding risk evaluation. Given the general format of the methodology, it is expected to be applicable to any type of cultural heritage asset threatened by any type of hazard. Specific aspects of the framework were further detailed for the particular case of seismic risk and an application to a single cultural heritage property is presented to illustrate these procedures. The results of this example are also correlated with those of a more detailed and complex analysis.

2. Outlook of existing risk analysis methodologies

The ideal theoretical setting for conducting a risk analysis requires the probabilistic quantification of hazard, vulnerability and resilience. To establish probabilistic representations of those components, both sufficient/reliable data and adequate analytical/numerical procedures are necessary. However, in many situations, namely in the risk analysis of cultural heritage assets, defining these components in a reliable probabilistic context can be far too complex or resource demanding.

In terms of the hazard, its probabilistic representation can usually be achieved based on data from past events. Typically, for natural events such as earthquakes, floods, landslides or volcanic eruptions, a probabilistic hazard can be defined, e.g. see [22–25]. However, there are fields for which establishing a probabilistic hazard is still complex mostly due to a lack of adequate data [26–28]. For the case of vulnerability, its definition relies on the availability of procedures capable of forecasting the damaging/negative effects that a particular hazard may have on a certain asset under analysis. Although detailed vulnerability representations can be established in several contexts, e.g. [29,30], for the particular case of cultural heritage assets, their complexity and the lack of knowledge regarding their behaviour in certain situations are often important obstacles to the detailed definition of their vulnerability [31,32]. Furthermore, when the risk analysis addresses a large amount of assets, those difficulties are amplified due to resource-related restrictions that might also come into play. In such cases, vulnerability analyses often involve methodologies where simplified assumptions are made, e.g. see [33–37].

With respect to the resilience component, even though frameworks and quantitative approaches have been developed in some fields, e.g. [38–44] and references therein, methodologies addressing specific aspects related to the preservation of cultural heritage assets are still largely unavailable. In this particular case, disaster prevention with the purpose of coping with the consequences of disasters is commonly addressed by pre-event measures such as implementing education and training programmes in emergency/recovery procedures. Additional predictors of resilience measuring the expected time and resources needed to restore the functionality/quality of the asset [38] could potentially also be established. However, when dealing with cultural heritage assets, the multidimensional nature of the value of the asset and the complexity of its evaluation [45–48] are a major conceptual obstacle. Therefore, in such cases, predicting the time and resources that might be required to restore functionality and quality is much more difficult.

Based on these descriptions, the applicability of a framework that involves a comprehensive risk assessment procedure and the regular update of its results over time needs to integrate the following key issues:

(1) reliable and sufficient data to establish suitable hazard models;
(2) sufficient and reliable data on the assets under risk;
(3) suitable procedures to model the vulnerability;
(4) adequate models to predict the multidimensional consequences of the hazardous event;
(5) sufficient human, time and economic resources.

In the context of a risk assessment procedure for cultural heritage assets, 4 is the most difficult issue to address, regardless of the hazard involved. Furthermore, addressing 1, 2 and 3 successfully can be seen to depend on the availability of 5. In most cases, these resources will set the boundaries of the scope and comprehensiveness of a risk analysis and will be also fundamental for the successful regular update and monitoring of the risk assessment results over time. Therefore, when dealing with a large number of cultural heritage assets, it is important to have a simple methodology that can be used for the preliminary risk analysis of those assets to establish risk mitigation priorities or to identify assets requiring more detailed and resource-demanding analyses.

Based on these arguments, it can be seen that a qualitative risk analysis approach can fulfill the necessary requirements. In a qualitative risk method, risk is defined by a non-numerical estimate. Even though qualitative analyses still involve analytical and evidence-based characterizations of the risk, they establish descriptive or categorical treatments of information instead of numerical estimates. These methods simplify the risk analysis by reducing the required inputs and calculations to a set of judgments. The simple risk categories that are produced as outputs can then be communicated to policymakers and stakeholders in a simpler way [49]. Qualitative analyses are useful in situations where theory, data, time or expertise are limited but they also provide adequate results when decision makers only need a qualitative assessment of the risk. Furthermore, they can also be useful for problems where quantitative risk analysis is impractical. For example, the qualitative analysis of a large number of cultural heritage assets (e.g. nationwide) may be a suitable way to identify situations where a more detailed assessment is needed [50]. Qualitative methods may also be preferred when the more important sources of uncertainty will not change the end result or when quantitative analysis is likely to lead to inconclusive results [51]. In many situations, a qualitative risk analysis is able to provide risk managers or stakeholders with enough information for decision-making. For example, the gathered data may include sufficient evidence indicating that a given risk can, in fact, be disregarded. On the contrary, the gathered evidence may also point out to an unacceptably large risk, or to the fact that consequences of a given hazard are so unacceptable that mitigation measures are needed whatever the level of risk.