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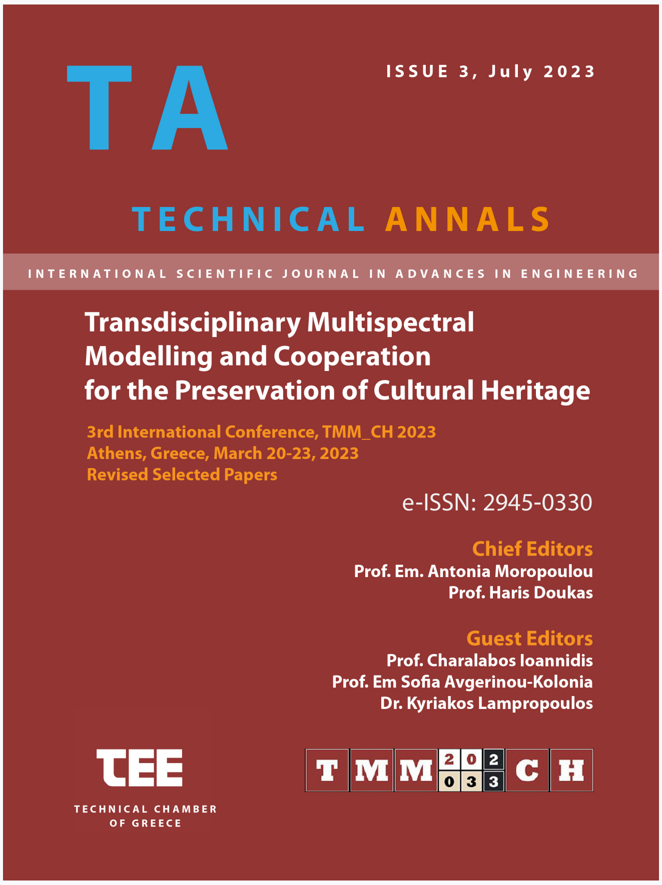

The concept of risk and its measurement in the field of built heritage conservation: critical aspects and potential improvements

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The concept of risk and its measurement in the field of built heritage conservation: critical aspects and potential improvements

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Abstract. The term risk has been defined in different ways in various scientific areas. As a result, there is a certain confusion over the meaning and the use of the term. In order to understand better the variety of approaches to the concept of risk and consequently its measurement, representative studies, carried out by researchers and professionals, are considered. Which are the most important aspects that built heritage conservation adopted and developed and how these aspects have led to the use of different methods of assessment and evaluation of risks? Secondly, different methods of risk assessment and evaluation, adopted in various activities of the built heritage conservation process, are selected and analyzed. With the aim to highlight their strengths and limitations, a comparison is drawn, permitting us to have an overall picture of the available methods and at the same time to identify the eventual gaps and the critical aspects of the research/practice. Lastly, based on the acknowledgment of the limits and the problems of the various methods, suggestions for improvement are made.

Keywords: Risk Concept, Risk Analysis, Risk Assessment, Risk Management, Preventive Conservation, Built Heritage Conservation, Built Heritage Management.

1 Introduction

Over the last thirty years, preventive and planned conservation approaches to the built heritage management have been gaining ground in the European context. Research and policy have marked a shift from isolated and episodic restoration interventions to long term processes of constant care and local development. Management tools and practices such as periodic maintenance based on regular inspection surveys and systematic monitoring, information management, risk preparedness, as well as systemic projects, valorisation strategies, and people involvement practices, have emerged and have gradually been developed [1-3].

A paradigmatic approach is the Monumentenwacht model, based on the concept of supporting preventive conservation through a service of regular inspection surveys and the carrying out of minor, "first-aid", on-the-spot repairs. The organisation model, founded in the Netherlands in 1973 and subsequently in Belgium in 1991, has been studied and adapted to suit different statutory and cultural contexts by various European countries from the 90s onwards [4-9]. Undoubtedly, the European standard *Conservation of cultural property – Condition survey of immovable heritage* [10] follows the Monumentenwacht rationale and represents an attempt to implement preventive strategies.

In the Italian context, the definition of conservation as a long term process "ensured through consistent, coordinated and planned activities of study, prevention, maintenance, and restoration", offered by the Italian Cultural Heritage and Landscape Code since 2004 [11], represents a change of direction. The Italian approach to conservation is based on an integrated study of the cultural heritage and its environment, not only physical but also social-economic. The Pilot Project for the Planned Conservation of the Cultural Heritage in the Umbria region elaborated by Giovanni Urbani in 1975 [12], the setting up of the Risk Map project by the Central Restoration Institution in 1992 [13-16], the Guidelines for the Conservation Plan issued by the Lombardy region in 2003 [17], as well as the ten-year Cultural Districts project in Lombardy [18-20] represent the gradual steps and the considerable results achieved by implementing a preventive and planned approach to the built heritage conservation in Italy during the last decades [2, pp. 73-75].

What gains in importance in these examples is how to make rational decisions about cultural heritage conservation, or else how to make an efficient use of limited resources. The use of risk analysis, decision analysis, and risk management methods has been introduced in order to prioritise the activities, to reduce the costs and the losses and to increase the benefits and the quality of conservation results. Under this perspective, these approaches have focused on the relationships between cultural heritage and its environment, as well as their changes over time.

2 Risk concepts: definitions and general aspects

The term risk has been defined in different ways in the various fields and as a result, a certain confusion characterises the meaning and the use of the term. In order to understand better the variety of approaches to the concept of risk and consequently its measurement, different representative studies carried out by researchers and professionals have been considered. Firstly, the overview of different risk perspectives made by Ortwin Renn [21] and his proposal for their integration, secondly the overview provided by Douglas Hubbard [22] and his insistence on the importance of a scientific approach to risk management. Within this reference framework, the aim is to better frame the concept of risk and to understand the approach developed and the practices adopted in the field of the built cultural heritage.

2.1 Amplification of risk

The first study, carried out by Ortwin Renn, distinguishes seven approaches to the conception and assessment of risk evolved in the various academic fields: the actuarial approach; the toxicological and epidemiological approach; the engineering approach;

the economic approach; the psychological approach; social theories of risk; and cultural theory of risk [21, p. 56].

As Renn underlines the diversity of these concepts depends on "the selection of the underlying base unit (i.e. operational definition), the choice of methodologies, the complexity of measures against risk, and the instrumental and social function of the risk perspective" [21, p. 56].

According to the analysis carried out by the author, the first three approaches can be grouped together as technical risk analyses. In short, "they anticipate potential physical harm to human beings or ecosystems, average these events over time and space, and use relative frequencies (observed or modelled) as a means to specify probabilities. The normative implication is obvious: since physical harm is perceived as an undesirable effect, technical risk analyses can be used to reveal, avoid, or modify the causes that lead to these unwanted effects. They can also be used to mitigate consequences, if causes are yet unknown, remote from human intervention or too complex to modify. Their instrumental functions in society are, therefore, oriented to risk sharing and risk reduction, through mitigation of consequences, standard setting, and improvements in the reliability and safety of technological systems" [21, p. 59].

Criticism about technical analyses comes from the social sciences and centres on the two following statements: the perception and evaluation of risks is a complex and multi-faceted process that is determined by values and preferences – although it is not always acknowledged [21, p. 59; 23 pp. 3, 10]; the inclusion of complementary objectives within the goal of risk reduction requires participation by interest groups and the affected public [21, pp. 60, 77; 23, p. 10].

As stated by Renn [21, p. 77], the other perspectives on risk broaden the concept of risk, by including the interpretations of undesirable events and "socially constructed" realities, and by focusing on the evaluation of the risk context and the associations between the risk and social or cultural artifacts. Several contributions offered by influential researchers, such as Daniel Kahneman, Amos Tversky, Paul Slovic, Baruch Fischhoff, Sarah Lichtenstein, Roger Kasperson, and Mary Douglas, among others, bring out the limits of experts' knowledge and can help to enrich risk management [21, 23]. Thus, Renn [21, p.79] suggests the integration of the different perspectives and not their replacement, that is to say cultural and social considerations cannot supersede technical and economic considerations but should incorporate them in order to offer a frame "that assigns each perspective an appropriate place and function".

2.2 A scientific approach to risk management

Another author to have mapped out the current state of different perspectives on risks is Douglas W. Hubbard [22, pp. 55-93]. He proposed a division into four general groups: actuaries, war quants, economists, and management consultants. The taxonomy takes into consideration the types of problems they focus on and the methods they use. The author's scope is to analyse the problems faced by these diverse schools of thought and to propose methods to fix them. Criticism has focused on the one hand on the most popular, newer methods that "don't necessarily build on the foundation of earlier methods that have stood up to scientific and historical scrutiny. It's more like the rapid construction of mining towns in the American West during the Gold Rush, where nice facades are quickly erected with minimal attention to structural quality in the rest of the building. And anybody can put up a shingle saying he is a risk management expert" [22, p. 23]. On the other hand, the author denounces the fact that while the limits of the experts' knowledge have been studied to a large degree, and relatively simple techniques have been developed to overcome the difficulties, risk managers employ hardly any of these methods [22, pp. 96-97].

The last aspect faced by the author regards the challenges for risk management: "confusion regarding the concept of risk"; "completely avoidable human errors in subjective judgments of risk"; "entirely ineffectual but popular subjective scoring methods"; "misconceptions that block the use of better, existing methods"; "recurring errors in even the most sophisticated models"; "institutional factors"; and "unproductive incentive structures" [22, pp. 76-77].

In regard to the concept and the definition of risk the author distinguishes between risk and its related concept of uncertainty as well as the measurements of each [22, pp. 79-80]. As the author claims, this distinction not only represents the actual use of the terms in the insurance field and other areas of professions and research, but it corresponds also to the general use of the terms by the public [22, pp. 79-80].

The review offered by Hubbard [22, pp. 80-93] calls attention to several other definitions of risk (such as the Frank Knight's definition, risk as volatility, risk as a good thing, etc.) that "were mutually exclusive, contradicted common sense uses of the language, and defied even the academic literature available at the time" [22, p. 91]. Finally, the author argues that risk terminology has to be considered part of a broader field of decision analysis, and thus adds the required terms concerning "strict uncertainty", "risk/reward analysis" and "ignorance" [22, pp. 92-93].

2.3 Defining risk in the field of built heritage conservation

The definition of risk, that is the degree to which loss is likely to occur, as a combination of two principal, dominate components "hazard", and "vulnerability", is widely acceptable in the field of built heritage, at an international level [24, 25]. The former term regards the probability that a threat of a given intensity will occur in a particular place. Whereas the latter concerns the degree of loss associated with the particular hazard and related to the exposed system and its propensity to be damaged.

In regard to the two frameworks of risk perspectives discussed before, the following aspects emerge. Firstly, the approach to risk developed in the field of built heritage shares the same point of view with engineers, who model systems of components and their interactions. The vulnerability studies concerning historic buildings and constructive techniques draw attention on the complex interaction of different elements, materials and boundary conditions. For this reason, the assessment is based on a gradual knowledge process acquired through the combination of information gained from a variety of analyses.

The second aspect regards the intrinsically twofold character of the built heritage conservation. On the one hand, the safeguarding of the cultural values associated to the building materials and techniques and on the other hand, the guaranteeing of the necessary level of its technical performance. The buildings are not objects to contemplate but they have to stand up. They have to be safe, accessible, comfortable, energy efficient, secure, easy to look after, etc. [26-28]. In order to balance these two aspects and to determine compatible solutions (often alternatives that meet the performance level "equivalently"), it is required to define the possible alternatives, to identify and analyse their consequences, both risks and benefits, and then to select the most acceptable option. Under this perspective, the acceptable risk is the risk associated with the most acceptable alternative in a decision problem. Fischhoff et al. [29] state that this can have two implications: first, the most acceptable alternative may not be the one with the least risk, and second, the acceptable risk is situation specific, depending on the set of alternatives, consequences, values, and facts in the decision process.

3 Assessing and evaluating the risks to the built heritage

The implementation of the Disaster Risk Reduction DRR phase framework in the cultural heritage sector provided by the STORM – Safeguarding Cultural Heritage through Technical and Organisational Resources Management project makes clear the interconnection between the conservation activities and the risk assessment/management actions. Specifically, the different built heritage conservation procedures and actions have been analysed in terms of scale of application, main objectives, DRR phases, direct/indirect actions, and involved actors, both institutions and professionals [30, pp. 24-43].

Among the various approaches to the measurement of risk stand the common methods of expert's audit, stratification methods, weighted scores, calculus of preferences and probabilistic models [22, pp. 24-26]. Representative examples of the above categories of risk assessment methods are examined. The selection of the examples, as the table 1 illustrates, is based on two criteria: firstly, assessments that include different risk factors, and secondly, assessments carried out during different conservation activities, e.g. inspection survey, maintenance planning, documentation, intervention compatibility evaluation, and environmental monitoring/management.

Table 1. Examples selected for the analysis of risk assessment methods

Examples selected	Conservation activities	Risk factors considered	Risk assessment methods
Monumentenwacht model organisations	Inspection survey	Continuous/slow acting risk factors	Expert's audit
Pompeii maintenance planning project	Maintenance planning	Natural and human risk factors	Expert's audit
Risk map project	Documentation	Natural and human risk factors	Stratification method
EN 16883:2017	Project/intervention compatibility evaluation	Inappropriate project/intervention	Calculus of preferences
NICHE project	Environmental monitoring/ management	Indoor climate risk factors	Probabilistic model

3.1 Monumentenwacht organisations model: preventive conservation based on regular inspections

Despite the differences between the various European initiatives, the Monumentenwacht model, based on regular inspection and immediate repairs in order to avoid consequential damage, supports preventive conservation.

The inspections are usually carried out by a tandem of experts in the conservation sector and consist in examining the building both from the outside and inside, starting from the roofs, and arriving through the masonry structure to the foundations. As Lipovec and Van Balen [5, p. 196] describe "particular attention is given to critical points such as chimney pots, gutter eaves, openings. The examination is not limited to finding the parts most exposed to potential damage but also checking all the details, such as windows, doors, and metal or wooden decorations both inside and out. Paying equal attention to all parts of the building, functional and decorative, the Monumentenwacht service contributes to the preventive conservation process, established by the cultural values, and not just to the maintenance. In this way, the goal of providing the owner with a true "state of health" of the buildings, which is presented in the form of a report, is achieved. The final document, accompanied by photographs and recommendations for priority interventions, is useful both for the company that will carry out the works, and as a reference for the owner regarding problematic points and expenses".

Concerning the evaluation of the damages and the indication of risks and priorities, the Monumentenwacht inspection approach "relies on the existence of visible damage phenomena and qualitative analysis rather than a quantitative analytical and experimental approach. This analysis entails an inductive process based on the experience gained by analysing and comparing the behaviour of different structures with similar materials and construction techniques in similar environments" [31].

Considering the three types of risks proposed by Waller [32-33], the visible damage phenomena can be compared to the first type of mild/constant risks. In particular, the continuous monitoring of long-term structural damage accumulations is able to provide an early warning system for structural and safety assessments [31].

3.2 Preventive and planned conservation in Pompeii: constant planning based on monitoring and progressive experience/knowledge

The planned conservation project in Pompeii implements the Italian shift in conservation field, matured mainly in research studies and in the national heritage law, "from exclusively operational interventions to processes of study and control, to be implemented before, during, and after the strictly executive phases" [34].

The methodological approach, as described by Osanna and Rinaldi [34], is based on a process of three distinct, but related phases, i.e. inspection activity, execution phase, and critical synthesis, that is to say a critical evaluation of the interventions. The inspection activities, carried out by interdisciplinary teams of archaeologists, architects, restorers, and structural engineers, and the recording of the detected processes of degradation aim at identifying the critical aspects, without ignoring the complexity of the diagnostic phase, and to plan the short- and medium-term interventions. The assessment, based on visual and empirical observations, concerns the evaluation of the damage severity and its evolution process determining three urgency degrees.

Notwithstanding the difficulties in evaluating the decay progression and its speed – because of the interactions of the various decay processes, as well as the lack of information/documentation with regard to the history of the past interventions – the continuous monitoring of the archaeological park conditions and the daily practice of the operators have enabled on the one hand, the management of emergencies, and on the other, have improved the acquisition of knowledge and experience, necessary for the effectiveness of the maintenance planning.

What is more, the recording and the evaluation of the efficiency of the interventions over time can lead to the development of true expertise, or better as Shanteau argues [as cited in 35] "experience only leads to learning if a clear cause and effect link exists between action and consequences and it is possible to identify critical success factors", or rather "it is not having experiences that matters – it is what you learn from them".

3.3 Risk Map project: an advanced technological documentation tool for cultural heritage management

The Risk Map, initiated in 1992-96, is an ongoing project that regards the development of a geographic information system (GIS) concerning the cultural heritage management. From the nineties to the present, over 95.000 monuments on the national territory have been geo-referenced on vector maps and aerial orthophotos, as well as all the listed building restrictions issued from the year 1902 to 2005 have been collected in the system [36].

This database, accessible to various public technical and administrative bodies (research institutes, public agencies, and ministries), stores, organizes and manages data related to both the cultural heritage conditions and its environment. In this way, it contributes to the knowledge sharing and the examination of the various data relations necessary for the management of the emergencies, of the infrastructures and the territory, and for the protection of the cultural heritage [36-37].

In regard to the risk assessment, simple stratification methods such as risk maps (called also heat maps or risk matrices) use normally two or three ordinal scales which are multiplied together in order to get an aggregate score, e.g. likelihood and consequence or hazard, vulnerability and exposure. The Italian Risk Map in particular uses three different combinations of four indicators, hazard and exposure for the territorial risk, hazard and vulnerability for the individual risk, and local hazard and vulnerability for the local risk.

Moreover, the vulnerability assessment, in this case linked to the evaluation of the conservation state, is carried out through the evaluation of three criteria, gravity, extent and urgency for each type of damage and for each type of element. The overall vulnerability of the building is an average score of all its components and their damages [38]. As a result, the criticalities of single elements or limited areas are levelled down and consequently the priorities cannot be identified.

Scoring methods, both weighted scores and multiplicative matrices have been criticized as "worse than useless" [39]. Among the main problems they manifest, the fact that they have been developed separately from scientific methods in risk and decision analysis, and that they are “sources of error on their own as a result of unintended consequences of their structure” stand out [22].

Apart from the ineffective use of scoring methods, the vulnerability assessment linked directly to the evaluation of the state of conservation could be inadequate for two principal reasons. Firstly, because the presence of damage is not always equivalent to the expectation of damage, or better as Della Torre [40] underlines, for the prevention is more important the changeable relationship between object and its context and the analysis of scenarios that could give rise to processes that are not yet perceptible in their concrete effects. Secondly, as Michalski [41] argues “the danger is that one is endlessly fixing only urgent problems. Option C is a decision to fix the urgent situation in the short term (option A) at the same time as committing to a plan to fix the slower situation in the long-term (option B), no matter what. We may talk about the rights of future generations, but we may not have faced the implications of a moral arithmetic based on it. Option C is not simply saying do A plus B, it is saying that we may have to abandon some A type issues in order to ever get B started. Here, I believe the modelling of realistic outcomes, and not simply a response to urgency, will be crucial”.

3.4 Guidelines for improving the energy performance of historic buildings: evaluation of decisions according to their risks

During the last years, the Multi-Criteria Decision Analysis (MCDA) has been applied in the field of cultural heritage. The presence of a large number of aspects and of diversified nature, often in conflict, and many of them difficult to be quantified has led to the application of multi-criteria techniques to the evaluation of the various alternative projects [42]. For example, for the selection of equivalent safety measures [43], accessibility measures [44], reuse alternatives and enhancement strategies [45-46], and more generally of possible compatible solutions with the building values.

What stands at the base of these methods is the idea to put in relation the characteristics of a project with the objectives and the preferences (i.e. the attributes or criteria) of the decision-maker. The procedure of selecting appropriate measures to improve the energy performance of a historic building proposed by the European standard EN 16883:2017 [47] is a practical application of multi-criteria decision analysis. The recommended criteria include the following categories: technical compatibility, heritage significance, economic viability, energy performance, indoor environmental quality, outdoor environmental impact, and use aspects. The different solutions are evaluated according to their performance scores, which indicate how well they meet the criteria. In this case, a five level scale of assessment has been proposed, in order to evaluate the effects of the measures and to identify the measures that best meet the needs of a building.

3.5 Environmental risk assessment for cultural heritage protection: a method based on the concepts of systems theory and probability

The new environmental risk assessment methodology for cultural heritage protection (NICHE) elaborated da Andretta et al. [48] regards the cultural heritage housed in museums, galleries, and archives. As stated by the authors, although the method concerns the works of art and focuses on the risks related to the microclimatic environment, its application to other types of risks (e.g. structural, related to usage, arising from natural disasters, infesting agents, technical malfunctions, etc.) can be easily developed. In detail, "all situations where the effects of the sources of risk on the targets of interest can be described with an S shaped function (for example, a Dose-Response Curve, a Probit or a Logit models) can be treated with the NICHE approach, grounded in the comparison with threshold reference values reported in the technical/scientific literature and norms" [48].

The elaborated methodology is grounded in the following definition of risk: "The risk (R) for the Targets of Interest (Ti), due to an Anomalous State (STa) of the System (S) which produces a Source of Risk (SoR) of Magnitude (Md), is given by the probability of an Adverse Effect (Ea) on (Ti) caused by the (SoR), i.e. R = Pr (Ea, Md)" [48, p.23]. As the author describes [48-49], this definition is based on the concepts of the systems theory and of the probability.

The implementation of the methodology concerned the Classense Library of Ravenna and in particular the results of environmental monitoring carried out in 2014 over two periods that were considered extreme. In particular, a certain number of halls of the Classense Library corresponds to the system. The paper-based materials represent the targets of interest, the chemical-physical changes and the degradation mechanisms effects are the possible adverse effects. The indoor microclimatic conditions are equivalent to the anomalous states. Finally, the magnitude is expressed by the difference between monitored data and threshold values reported by the reference norms [48].

Concerning the assessment methods of risk, the authors distinguish between "absolute" and "relative" methodologies, according to the approach to the determination of the unconditional and conditional probabilities. The former requires their exact determination whereas the latter elaborates a ranking of risks by applying the same method to different scenarios.

4 Comparison and evaluation of the risk assessment methods

The analysis of different examples has focused on the description of the risk assessment methods that are used, and the examination of their principal aspects. With the aim to highlight their strengths and limitations, a comparison is drawn based on their reliability, effectiveness, and openness to evaluation.

Henderson and Waller, in their paper about effective preservation decision strategies [35], discuss two different decision-making processes, the heuristic and the analytic-deliberative. The first one is based on intuitive processes, which are rapid and can be reliable. The second requires time to complete and can be described by an analytic deliberative model (e.g. the cultural property risk analysis model by Waller). The authors argue that each of these processes has its strengths and weaknesses, and their use depends on the available resources, especially time, the quality and the type of the data available, and the context in which decisions must be made. This kind of distinction can also be made here, between the first two case studies, the assessment method of which is based on experts' judgements, and the other three that build a model for the analysis and the assessment of risks.

In respect of reliability, or else the validity of the outcome of a method, in the case of the experts' judgement, lies mainly on the knowledge and the expertise of professionals and in particular their ability to identify indicators of risks [35]. In the case of Risk Map, the use of scoring methods, both weighted scores and multiplicative matrices, reduce the validity of the assessment results because of the irrational structure of their aggregation models. In the matter of the multi-criteria analysis, proposed by the Guidelines for improving the energy performance of historic buildings, the formulated objectives, i.e. the criteria and the weights selected for the assessment and the ranking of the various options, can affect adversely the reliability of the method in the context of built heritage if they are not coherent to the principles of conservation or they simplify complex questions. Finally, the validity of the probabilistic model of the environmental risk assessment, as Andretta et al. [48] argue, depends on the availability and the accuracy of the data.

Discussing the effectiveness of the different methods, or else their appropriateness for specific contexts, the following comments can be made. The need of making a rapid decision that is required in managing emergencies, or the need of a sensory judgement, essential for early detection of changes or signals of damage propagation call for regular inspections and continuous monitoring activities carried out by trained professionals. On the other hand, the restoring of data concerning the assessment of hazards, exposure and vulnerability – regardless the problematic risk aggregation methods, as well as the difficulties in keeping the information system updated owning to the required large amount of economic resources and time [50] – can be effective in the perspective of an enduring depository of the available knowledge. In regard to the multi-criteria analysis, the effective combination of technical data and cultural values seems to be appropriate in the context of the evaluation of the risk acceptability. As concerns the NICHE approach, the consideration of risks that can be described only by an S shaped function depends on the establishment of their acceptable limits.

The distinction between experts' judgements and analytical deliberative models, made at the beginning of this comparison [35], clarifies also the difference between tacit knowledge of experts that is not open to evaluation and the explicit scale of relating inputs to outcomes provided by the structure of the models that is available for critique. However, subjective inputs relied on experts' judgement are also required in the case of analytical models. In specific, the vulnerability assessment of the Risk map model, and the five-level scale of assessment proposed by the guidelines EN16883:2017 are based on experts' judgements. Moreover, the weights of the criteria in the latter are determined by the subjective preferences of the decision makers.

5 Proposals to improve risk assessment

The analysis and the comparison of the different methods highlighted the problems and advantages of each. With the aim to make better risk analysis, the various problems of the methods are discussed and suggestions for improvement are made.

With regard to the experts' judgements, in the context of regular inspections and continuous monitoring activities, the complex observation process made by the inspectors remains usually implicit, i.e. it is not explained, communicated or registered properly. As Della Torre [40] argues the condition survey is a typical secondary prevention practice, which entails tertiary prevention activities to avoid the propagation of damage, and primary prevention to improve behaviours and avoid problems caused by use, like loading, wear and tear, and indoor climate among others. Nevertheless, the shift in the conservation profession from restoration to preventive attitudes and practices is not immediate and still needs to be developed. For this reason, the distinction between condition assessment and risk assessment is of great importance. In fact, the identification of the most effective preventive measures cannot be linked directly to the condition of the building elements but requires a risk analysis based mainly on the complex interactions between the elements and within their environment. Hence, the description and the recording of the aspects associated with risks could clarify and explicate the reasoning behind the classification of the urgency of measures, allowing its review and evaluation.

As for the scoring methods and the ordinal scales in risk assessment, various researches [e.g. 22, 39, 51] highlight their limitations and argue that are not useful tools for risk assessment. While Cox [39] focuses on the mathematical properties of risk matrices and examines their limitations, Hubbard and Evans [51] identify and discuss the following four main problems. To begin with, scoring methods do not pay attention to the findings of psychological research on cognitive biases that are relevant to risk assessment and in particular to the assessment of likelihood (such as the effects of "overconfidence", "anchoring", "framing", and "inconsistency"). Another problem regards the variability in the interpretation of verbal labels that are used in ordinal scales either by different users or by the same user in different contexts. Moreover, the invalid inferences derived by treating ordinal scales as if they are ratio scales, such as distance or mass, are fallacious and harmful. The example of "star" ratings that are used by film critics is very characteristic, "two stars are simply better than one star, but not exactly twice as good. Four one-gallon containers of gasoline will pour exactly into one four-gallon gasoline tank, but Roger Ebert knows he would much rather watch one four-star movie than four one-star movies" [22, p. 119]. The last problem described by the two authors regards the exclusion of correlations among various risks and consequently their underestimation.

To avoid the problems assessed, Hubbard and Evans [51] emphasize mainly the need of quantitative methods that use explicit probabilities and magnitudes of losses, or else ratio scales, instead of using verbal or ordinal scales. Indicative and useful examples in this direction include the adoption of a common scale to convert the predicted deterioration into predicted loss of value proposed by Waller's Cultural Property Risk Analysis Model, or the aggregation of modelled risks proposed by the JCSS [52], as well as the model of Multi-Hazard Assessment of Vulnerability applied to historic buildings proposed by D'Ayala et al.[53].

Concerning methods such as multi-attribute utility theory (MAUT), or multi-criteria decision making (MCDM), as it was mentioned above, the evaluation and the ranking of the various decisions take into consideration their risks, in other words, risk analysis provides input to decision analysis [22, 54]. Moreover, these methods by taking into account tradeoffs become important for the risk management and the evaluation of the acceptable risk. Besides, the selection of the attributes and their weights brings greater transparency on the process of decision making. In order to increase the validity and the quality of the process and improve its outcomes two aspects should be considered, “what and whom to include on the one hand and what and how to select on the other hand” [M. Hajer, H. Wagernaar, A. Stirling, paraphrased by Renn, 55, p.49]. The “co-operative discourse” model proposed by Renn [55] for the involvement process of experts, stakeholders, and the public in risk governance integrates scientific expertise, rational decision-making, and public values. Specifically, the model combines selected formats of the three discourse types: epistemic discourse/group Delphi format, reflective discourse/value-tree analysis format, and participatory discourse/citizen panel format.

The last group of methods considered here are the probabilistic models of risks. Generally, the mathematical computation of losses and their magnitudes is regarded as the most scientific approach to quantitative risk assessment. Problems and errors related with subjective estimates, empirical testing of models, correlations, etc. have been raised by the research and improvements have been suggested and adopted [22].

6 Conclusions

Starting from the definition of risk in different scientific areas, the paper highlighted the two aspects of the concept of risk that built heritage conservation adopted and developed: the engineering approach based on the modelling of systems of components and their interactions within the environment, and the concept of compatibility based on the notion of the acceptable risk and its evaluation.

In regard to the different approaches to the assessment, the analysis notes that the methods vary from a qualitative to a quantitative approach to assessment, according to the scope of the analysis and the available resources. None of the approaches should be considered exhaustive. Each of these methods has its strengths and weaknesses and their effectiveness depends on the context, the conservation activity, or the management strategy. As Menoni [56] argues “risk assessment cannot be considered a monolithic tool, to be developed by experts and then delivered to decision makers who should make their decisions on its ground. Different types of policies and preventive strategies require different inputs, the ideal being experts working with and not for decision makers. The need to use a variety of tools, such as probabilistic risk assessment, scenario modelling, simulations differentiated not only according to the policy for which they are designed but also to the geographical scale and to the final users, require a rethinking of the entire matter, in order to better meet new and emerging demands”.

The limits and the critical aspects of the methods concern mainly the rooted restoration attitudes vs preventive practices, the difficulties in comparing and aggregating diverse risks, as well as the difficulties in integrating cultural and technical issues. Suggestions for the improvement of the various methods are made by taking into consideration the need for the review/evaluation of a method, for reflective analysis, diffusion of methods that work better, and teamwork that includes both different specialists and the public. However, additional analysis should be carried out in order to monitor the results of their implementation over time and gather evidence of their efficacy.

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