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CULTURAL HERITAGE RISK ANALYSIS MODELS: AN OVERVIEW

Ana Rita RAMALHINHO[1], Maria Filomena MACEDO[1,2*]

[1] Universidade NOVA de Lisboa, Faculdade de Ciências e Tecnologia, Departamento de Conservação e Restauro, Campus de Caparica, 2829 – 516, Caparica, Portugal
[2] Universidade NOVA de Lisboa, Faculdade de Ciências e Tecnologia, VICARTE, Campus Caparica, 2829-516 Caparica, Portugal

Abstract

The risk assessment is a critical step in achieving, defining and supporting the decision-making process. In this context, in the past two decades, an increase in the number of models for assessing/analysis of risks applied to collections and/or immobile cultural heritage was observed. The present work consists of the first review of the literature, from 1999 to 2016, on risk assessment applied to movable and immovable cultural heritage. A total of twenty-seven risk assessment models have been compiled that can be applied to different types of cultural heritage such as: immovable property (26%) and movable property (74%). It was possible to conclude that approximately 48% of the risk analysis models are quantitative, 19% are semi-quantitative and 33% of the models are qualitative. Two different tables were created in order to help the reader: one for movable and another to immovable cultural heritage. These tables compile information to characterize the models (name, type, applicability, examples, date and references). The advantages and disadvantages of using each model was discuss in a separated table.

Keywords*: Risk assessment; Model; Immovable; Movable; Cultural heritage; Overview*

Introduction

Throughout the present study only risk assessment models will be approached. Given the wide range of contexts in which the word "risk" can be inserted, it is envisaged that the term "risk assessment" may acquire different meanings. In this way it was found pertinent to contextualize the terms to which it is usually associated and to specify the difference between "risk assessment" models, “risk analysis” models and "risk management" models. For this, some definitions were compiled. First, “risk” can be defined as a potential for realization of unwanted, adverse consequences to cultural property; “risk models” are expressions that includes formulae, constants and variables together with unambiguous definitions of the constants and variables. The term "risk assessment" consists of a formal and structured identification of the generic, specific risks and consequent calculation of the magnitude values associated with the different risks. The "risk analysis" consists of the analysis of the results, whether qualitative or quantitative, obtained by the risk assessment and the proposal of different ways of mitigating these risks. And lastly, "risk management" uses the results of risk analysis to guide the application of available resources to mitigate risks associated with cultural heritage [1].

*Corresponding author: mfmd@fct.unl.pt

Risk assessment is a critical step in achieving and defining the methods which try to estimate the risk of our immovable and movable cultural heritage cultural heritage most urgent needs. Under these conditions, the concerns for developing the best methods in this field are varied. There are several qualitative, semi-quantitative and quantitative assets available.

Heritage managers and curators often need to prioritize and make choices about how to best to use the available resources to protect collections, buildings, monuments and sites. This means that questions such as: *What to do first? What are the priorities of the heritage asset in its specific context? How to optimize the use of available resources to maximize the benefits of the cultural heritage over time?* must be answered. To do this, the identification of the risks of the cultural property in study is necessary, using the ten agents of deterioration defined by the *Canadian Conservation Institute* [2]. Each agent of deterioration can manifest in 1 or more within 3 types of risk characterized by frequency of occurrence and severity of their effect on collections (Type 1 - *Rare and Catastrophic*; Type 2 - *Sporadic and Severe*; Type 3 - *Continual and Gradual*) [1].

In this work we will refer to risk assessment models as *qualitative, semi-quantitative* and *quantitative risk assessment*. So, the authors found it useful to clarify this terminology before starting to discuss the risk models.

Qualitative risk assessment

In a qualitative risk model, risk is defined by a non-numerical estimation used to identify assets to be detailed and bear a simple and rapid assessment. This assessment is used often when numerical data are inadequate or unavailable, resources are limited (budget or expertise) and time allowed is reduced [3]. Even though qualitative analyses still involve analytical and evidence-based characterizations of the risk and establish descriptive or categorical treatments of information instead of numerical estimates. Qualitative analyses are useful in situations where theory, data, time or expertise are limited. Also, they provide adequate results when decision makers only need a qualitative assessment of the risk. Furthermore, qualitative models can also be useful for problems where quantitative risk analysis is impractical. For instance, qualitative analysis is useful in cases where a large number of immobile cultural heritage assets needs to be evaluated in the fastest and suitable way, allowing the identification of the situations where a more detailed assessment (that can made with a quantitative or semi/quantitative model) will be later needed [4, 5].

Semi-Quantitative risk assessment

In semi-quantitative methods the result value does not need to be an exact number, since these methods are used to describe the relative risk scale. In a semi-quantitative approach, different scales are used to characterize the likelihood of adverse events and their consequences. Analyzed probabilities and their consequences do not require accurate mathematical data. The objective is to develop a hierarchy of risks against a quantification, which reflects the order in which the risks and the relationship between them should be taken under consideration [3].

Semi-quantitative assessment is particularly useful when the quantification of the risk is very difficult and, to a considerable extent, ambiguous**.** At the same time, qualitative interpretation is too subjective. The combination of the two models can be a solution in some cases, combining the specific advantages of each and decreasing their disadvantages [3].

Quantitative risk assessment

Quantitative analysis means looking at the actual numbers. Quantitative risk assessment models use measurable, objective data to determine asset value, probability of loss and associated risks. In order to conduct a quantitative risk analysis, the users will need high-quality data, a well-developed project model and prioritized lists of project risks (usually obtained after performing a qualitative risk analysis).

Material and Methods

In this work a review of the literature between 1999 and 2017 was made using digital platforms of articles specialized in the field, such as ResearchGate, ScienceDirect, Jstor, Web of Science, The Getty, ICROM, etc. This review was carried out with the objective of gathering together all the models of risk assessment and analysis, applied to cultural heritage, already published. A compilation and a critical review regarding these models were accomplished.

Results and Discussions

The models identified during this work were divided into two groups: the risk analysis models applied to movable cultural heritage and the risk analysis models applied to immovable cultural heritage.

Each of these groups is presented in three parts: the first part consists of a table with information who characterizes the different models by name, type, applicability, examples, date and references. The second part compares the advantages and disadvantages associated with each model and finally, in the third part a summary is presented with the context and the procedure of each of the models.

Risk Assessment Models applicable to Movable Cultural Heritage

Table 1, show the twenty risk assessment models found in the literature, applied to mobile cultural heritage, presented from the oldest model to the most recent:

Table 1. Characterization of Risk Assessment Models applicable to Movable Cultural Heritage between 1999 and 2016 presented by type of model, model operation, practical application, date and respective references

Model name (acronym)	Type of Model	Model Aim	Applicability	Practical Applications	Date	Ref.
Risk Assessment for Object Conservation (RAOC)	Quantitative - Mathematical Equations	Allows to calculate several aspects associated to the risks as: probability; progression of risk and loss of value.	High: To apply this model it is necessary to work with a complex set of mathematical equations.	NA	1999	[6]
Cultural Property Risk Analysis Model (CPRAM)	Semi- Quantitative - Mathematical Equations	Allows to calculate the Magnitude of Risk (MR) to 100 years and hierarchize the specific risks, aiding in the decision making and management of the collection.	Medium: The assignment of values to different variables can become complicated. Sometimes it is necessary to rethink/reorganize the data and above all, know the collection deeply.	- Canadian Museum of Nature, (Canada); -Museum Amstelkring; (Netherlands) Arquivo Histórico Ultramarino (Portugal)	2003	[1, 7, 8]
Risk Mapping Galleries (RMG)	Semi-Quantitative - Divided into classes	Evaluation of the environmental conditions to design object-friendly spaces, from which is possible to identify generic environmental risks and general mitigations strategies.	Medium/Easy – The general concept is easy to understand and applying. However, it demands the monitoring of environment factors like temperature, relative humidity, pollutants, particulates, radiation, vibration and insect pests. This requires time and/or expensive equipment.	The Kings Library in British Museum, (London)	2005	[9]
Time-Weighted Preservation Index (TWPI)	Quantitative - Mathematical Equations	Measures the effect of environment on spontaneous chemical changes or natural aging.	Medium/Hard - Based on complex mathematical equations and algorithms, its application will require knowledge about more specific areas (mathematics, materials, etc.), which makes it difficult to apply in smaller institutions without great resources.	NA	2007	[10–12]
Mold Risk Factor (MRF)		Measures the risk for growth on objects of xerophilic mold species on objects.		NA		
Maximum Equilibrium Moisture Content (MaxEMC)		Measures the effect of the environment on metal corrosion.		NA		
Minimum and Maximum Equilibrium Moisture Content (MinEMC and MaxEMC)		Measure potential for physical damage in organic materials caused by high or low absorption of water.		NA		
Maximum Percent Dimensional Change (Max%DC)		Measures the effect of the environment on (primarily) EMC -driven dimensional change.		NA		
Fire Risk Assessment for Collection in	Quantitative – Mathematical	Obtains quantitative data related to museum fires. Analyzes the data in the	Medium: It has a simple methodology to apply, requiring	NA	2008	[13]

Museums (FACM)	Equations	light of risk management; allowing its use as a reference material for other models; Can be used to help prevent and reduce the impact of fire incidents and to predict the risk of fire for an institution.	interpretation of information and applying it in a simple equation.			
Scientific Collections Risk Evaluation (SCoRE) database	Qualitative - Software	Provides a platform for organization and analysis of extremely large sets of risk data in a number of different ways.	Medium/Easy: The SCoRE database is built in both Microsoft Access and MySQL. Is under progressive revision to be even more user-friendly and efficient to both scientific and operations staff.	American Museum of Natural History, New York New York, (USA)	2008	[14]
CCI – ICCROM - RCE Method	Semi-Quantitative - Divided into classes	The main objective of this model is to establish risks priorities based on the values of the MR.	Easy: the methodology is based on a list of questions and an attribution of a pre-defined color-code to the answers.	-Glenmore National Historic Site, (Canada) -Eldon House, (London).	2010	[15–17]
Preservation Risk Information System Model (PRISM)	Quantitative - Software	Assists in the identification of hazards, determination of levels of risk, comparison of the effectiveness and cost effectiveness, and comparison of methods to mitigate recognized risks.	Medium/Easy: This is a user-friendly software that uses a Microsoft Excel workbook with customized screens to guide users through input of data to characterize the elements of risk to their collections and the controls used to manage those risks.	UC Berkeley Library's collection, California (USA).	2011	[18]
Collection Risk Management (CRM)	Quantitative - Software	Assists collection managers to independently analyze and manage risks, helping them in decision-making for collection preservation.	Easy: The existing CRM methodology was simplified to be an easy tool for its users, allowing them to independently perform risk analyses and make decisions on the mitigation of the relevant risks	"A Monument for the Television Revolution" (1990) installation by Jeffrey Shaw and Tjebbe van Tijen.	2012	[19, 20]
Pollution Pathway Method (PPM)	Quantitative – Mathematical Equations	Compares the efficiency and costs of different measures applied in paper-based institutions to reduce the effects of indoor pollution.	Hard: It is a complex mathematical model.	Swiss National Library and Library of Geneva. (Switzerland).	2012	[21]
Risk Awareness Profiling Tool (RAPT)	Qualitative - Color Code (Software)	The main objective of this model is assessing the level of risk awareness in the organization; It provides a profile that indicates areas where awareness in the organization is good, and areas where improvement is needed.	Easy: the methodology consists in an identification of all risks (generic and specific) to attribute a numeric value between 0 and 5 (based in a questionnaire). The risks are organized by the value of the MR obtained.	Birmingham Museum and Art Gallery	2012	[22]
ANALITICA™	Qualitative - Mathematical Equations (Software)	It calculates the probability of fracture formation during complex climate fluctuations.	Very easy: It is only necessary to fulfill information from the institution and complete the assessment by answering.	Viking ship (The Oseberg)	2012	[23]
A, B, C Method	Semi -Quantitative - Mathematical Equations	The goal of this model is to assess the risks to the heritage, and to act in order to reduce them as effectively as possible, given the available resources.	Medium: this model can be applied in a day or a month depending on the number of people associated with the team. The methodology is explicit in the manual, which facilitates its application. However, the assignment of values to the variables requires knowledge of the collection and conservation because it is necessary to discover the threats and the possible consequences for each situation.	To revise the method, CCI as applied the model to Canadian institutions and ICCROM in projects carried out in Latin America, Asia, and Europe.	2012	[24]
Pest Risks in Collections (PRC)	Qualitative - Color Code	This methodology aims to provide a tool that sketches possible scenarios for insect pests in collections.	Easy: This method requires knowledge to assess the level of control of insects in the institution.	Civic Museusm, (Canada)	2013	[25, 26]
New Risk Assessment Methodology for Cultural Heritage (NICHE)	Quantitative - Mathematical Equations	Environmental risk assessment methodology, specifically addressed to the protection of paper based materials housed in libraries, archives or historical buildings, in relationship with their indoor microclimatic conditions.	Easy: this model was designed for people with no software training to be able to work with it.	Classense Library of Ravenna (Italy)	2014	[27]
QuiskScan	Qualitative - Color Code	Allows to quickly relate the vulnerabilities of collection items to generic risks based in the 10 agents of deterioration.	High: to apply this model is necessary to work with a complex set of mathematical equations.	NA	2016	[28]

Table 2, shows the advantages and disadvantages associated with each of the twenty models complied in Table 1.

Table 2. Advantages and disadvantages of Risk Assessment Models applicable to Movable Cultural Heritage between 1999 and 2016.

Model name (acronym)	Advantages	Disadvantages	Ref.
Risk Assessment for Object Conservation (RAOC)	- Allows to calculate the value of MR; -The results are organized according to the value of MR.	- Requires advanced knowledge in mathematics; -All the variables are calculated by complex mathematical equations.	[6]
Cultural Property Risk Analysis Model (CPRAM)	-This model can be applied with a calculator or by using spreadsheet software such as Microsoft Excel® or OpenOffice; -Detailed analyses; -Allows the identification of specific risks; -Allows a hierarchy of specific risks and performance priorities; -Allows a MR estimate of 100 years.	-Requires time and resources; -To compare different kinds of risks it is necessary to develop or adopt a common scale to predict evenly the loss of value; -To this kind of assessment, based on common sense, it is always necessary a review which sees beyond the results.	[1]
Risk Mapping Galleries (RMG)	-Allows to accomplish a complete monitorization of the environmental conditions of the space;	-- Does not consider all the risks associated to the space, leaving the missing risks to other departments. -Need specific equipment to monitoring all the values needed. -Need people who knows read and interpreting the values obtained.	[9]
Time-Weighted Preservation Index (TWPI)	- Documents unfavorable conditions; - Analyzes the causes of the unfavorable conditions; - Prioritizes the efforts based on their relative threat; -Allows to determine how well each storage area is performing for collection preservation; - Allows to determine how well one environment is performing compared to another; - Allows to determine how the different material behaves in specific locations; - By means of the predefined values it is possible to establish a comparison with the values obtained by the evaluator.	- Needs specific equipment to monitor all the values needed; -Needs people who know how to read and interpret the values obtained. -Needs people who knows read and interpreting the values obtained.	[10–12]
Mold Risk Factor (MRF)		-Needs specific equipment to monitor all the values needed; -Needs people who have minimum knowledge in microbiology; -Needs people who know how to read and interpret the values obtained.	
Maximum Equilibrium Moisture Content (MaxEMC)		-Is only able to give an approximation of values due to the complexity of the evaluated material; -Needs specific equipment to monitoring all the values needed; -Needs people who knows how to read and interpret the values obtained.	
Minimum and Maximum Equilibrium Moisture Content (MinEMC and MaxEMC)		-Needs specific equipment to monitoring all the values needed; -Needs people who know how to read and interpret the values obtained.	
Maximum Percent Dimensional Change (Max%DC)			
Fire Risk Assessment for Collection in Museums (FRACM)	- Helps institutions review and improve the fire protection strategy; - Helps to estimate the water damage; - Evaluates all types of buildings.	- A large sample of systematically reported fire incidents is needed.	[13]
CCI – ICCROM – RCE Method	-Considers the generic and specific risks; -Organizes risks by the value of magnitude of risk; -Helps to establish priorities in mitigation strategies;	-To this kind of assessment based on common sense is always necessary a review which sees beyond the results.	[15-17]
Scientific Collections Risk Evaluation (SCoRE) database	- Analyzes data according to location, risk type, or collection unit and it is also able to document current procedures, practices, and events; - Allows to analyze data for large and diverse collections; - Enables focus on issues of highest priority; - Allows view data by collection unit, building, floor, specific risk, etc., making data organization more efficient and searchable; - Generates reports to prioritize collection needs and determine how to most effectively allocate museum funds.	-It requires the previously application of another risk assessment model.	[14]
Preservation Risk Information System Model (PRISM)	- Uses values of MR to map a scale of 1-100 creating a relative rating; - Breaks up risk into a range of common collection hazards; - Points up the consequences of bad management decisions.	- Developed for a specific type of cultural heritage (libraries) -This model is entirely dependent on the accuracy of the data entered;	[18]
Collection Risk Management (CRM)	-Has an On-line digital handbook associated; - Can be applied in smaller institutions with limited time, resources and knowledge so they can also gain insight into their own situation; - Applicable to all kinds of collections.	-This model is dependent on the accuracy of the data entered.	[19, 20]
Pollution Pathway Method (PPM)	- Compares the efficiency and costs of different measures paper-based to reduce the effects of indoor pollution; - Allows planning the best strategy form risk mitigation.	- The mathematical description is very complex; - Restrict collections and specific materials; - Is difficult to select which parts in the diagram mostly influence the loss of value of the collection.	[21]

Risk Awareness Profiling Tool (RAPT)	- Provides guidance to help develop better awareness of risks in the organization and a database where the staff can consult the results when they want.	-Just accesses the awareness of the risk, it does not identify the generic or specific risks.	[22]
ANALITICA™	- Compares specific pattern of pathologies between objects with similar pathologies; -Can be performed by non-technical users using free reader software; - Allows a satisfactory prediction of results with the analysis of one specific object; -Allows detailed distributions for any variables considered significant.	-Works only with a prediction on physical damages cause by temperature and relative humidity; -Data is missing for the viscoelastic parameters of aged materials – modulus, strength, elongation at break, all of which are known to change with age.	[23]
A, B, C Method	-Can be applied with a calculator or by using spreadsheet software such as Microsoft Excel® or OpenOffice; -Allows to calculate the MR of generic and specific risks to different types of collections, buildings or sites; -Helps defining priorities based on values of MR and types of risks.	-To compare different kinds of risks is necessary to develop or adopt a common scale to predict evenly the loss of value; -To this kind of assessment based on common sense is always necessary a review which sees beyond the results.	[30]
Pest Risks in Collections (PRC)	-Can generate a qualitative data for the probability of damage to a certain extent in 100 years related to the level of control.	- Has a lack of data on "probability of entry" and "extent of damage" for different species or types of pest; - Absence of data to predict the impact of risk scenarios; - Few information available on prevention and control methods.	[25, 26]
New Risk Assessment Methodology for Cultural Heritage (NICHE)	-It is very versatile and suitable to be extended to the level of an absolute risk assessment methodology; -Defines the conditional and unconditional probabilities; -Takes explicitly into account the effects of microclimatic conditions on the works of art, based on up- to-date scientific knowledge.	-Works with a complex set of mathematical equations; -Needs trained specialists for its application.	[27]
QuiskScan	-Capable of identifying the generic risks to the collection; -Short-time application.	-Incapable of identifying the specific risks; -Cannot define different levels of priority in the same category of risk.	[28]

The following chapters present a summarised context and procedure of the twenty risk assessment models applied to movable cultural heritage.

Risk Assessment for Object Conservation (RAOC)

This semi-quantitative model was published by *J. Ashley-Smith* in 1999 [6]. The risk assessment consists of four conceptually distinct steps:

1. *Release assessment* - Consists in the identification and quantification of the sources of risk agents into the environment of objects.
2. *Exposure assessment* - A description and quantification of intensity, frequency and duration of exposure, including an estimate of the number and nature of the objects exposed.
3. *Consequence assessment* - Characterization of damage in objects due to specified exposure conditions.
4. Risk estimation: Application of quantitative measure to a specific group of objects given an exposure experience. This measure should include an estimate of distribution and severity of effects and an indication of the uncertainties in the estimate.

To calculate the variables needed to the estimation of the "risk" (R) defined as a combination of probability and change in value, is necessary to use several mathematical equations. Its complexity requires people who understand these fields of knowledge, which imposes a limitation to most of the institutions.

The results of the assessment are entered in an array which allows to attribute to each of the agents of deterioration a ranking. It can also be presented in a graphical form that enables differences in susceptibilities of the collections to be recognized quickly.

Cultural Property Risk Analysis Model (CPRAM)

This is a semi-quantitative model, developed in 2003 by *R.R. Waller* [1]. In this model numerical values between 0 and 1 are assigned to four variables. The product of these variables permits to obtain a magnitude of the specific risks for a collection, carrying numeric values by the expression ($MR = FS \times LV \times P \times E$) allowing to hierarchize the specific risks, thus aiding in the decision making and management of the collection.

This model is very used in institutions all around the world. Although time and other resources are required, the result is very useful to understand the institution needs. The main disadvantages of this model are the calculation of the loss of values, which can be tricky and requires a pre-stablishing of values. Also in this kind of methodologies the assessor can fall into a under or overestimation of risks, leading to a need of a multidisciplinary team or different points of view.

Risk Mapping Galleries (RMG)

This model was developed based in other approaches of *R.R. Waller* [1], *J. Ashley-Smith* [6] and *G. Accardo et al* [30].

It allows a qualitative approach applied to organic and inorganic materials based in the fact of an individual agent of deterioration and degradation represents different levels of risk to different parts of the collection. Its prime objective is the evaluation of the environmental conditions to design object-friendly spaces, from which is possible to identify generic environmental risks and general mitigations strategies.

The focus point are the environment risks like temperature, relative humidity, ambient pollutants, indoor pollutants, particulates, visible light, ultraviolet light, vibration and insect pests. To do this is necessary to establish a monitoring campaign to identify ambient conditions and identify the environment risks.

This methodology works by a risks map built from the assessment using matrices where the environmental risks are classified by type (Type 1, Type 2 or Type 3) depending on the damages they may cause on objects. The final matrix adds all the information allowing comparing the impact and the likelihood between the level of risk (high, moderate and low) to the organic and inorganic objects as well the entire collection.

IPI's Preservation Metrics®

Developed by the Image Permanence Institute, Rochester Institute of Technology

These are sets of algorithms that process gathered temperature and RH data and produce numerical estimates of the risks of environmentally induced decay. A quantitative approach that allows it to assess the conditions of the preservation storage environments from a material impact perspective through an identification of environmentally induced chemical change in organic materials, dimensional change or mechanical damage, biological decay or mold risk potential, and moisture-induced corrosion.

The metrics include: the preservation index and time-weighted preservation index (chemical decay), mold risk factor; maximum equilibrium moisture content (metal corrosion) and maximum and minimum percent equilibrium moisture content and percent dimensional change (mechanical damage).

Time-Weighted Preservation Index (TWPI)

TWPI is based on the science of chemical kinetics (based isoperm concept invented by Donald Sebera) which results in a life expectancy values expressed in years. Allows measure the effects of environment on spontaneous chemical change or natural aging in all organic materials (paper, textiles, plastics, dyes, leather, fur etc.). The main advantage of TWPI is its ability to condense a whole period of changing temperature and relative humidity (RH) conditions into one value by properly averaging or "weighting" how much each interval of time contributes to the decay rate overall.

The calculations are made by a reading of the temperature and RH pairs, where the temperature is lagged by using a 24 hour running average and RH using a 30 day running average. The lagged values are checked in a look-up table that provides the PI value at that condition. The PI values for all the temperature/RH readings are then properly averaged to produce the TWPI value.

Mold Risk Factor (MRF)

The MRF measures a risk for growth on objects of xerophilic mold species in all organic materials or inorganic materials with organic films. A growth model equation was created by a microbiologist, who tested the general model by tracking dry weight gain and aflatoxin production in various mold colonies and in different temperature and humidity conditions.

The fact that storage environments often don't have constant temperature and humidity conditions, the mold risk factor (MRF) includes integration of the approximate growth progress during each reading period.

This model works by the monitoring and put in a look-up table the temperature and RH conditions recording the growth rates expressed in days to germination. If conditions are favorable for growth, then is read from the table and the reciprocal growth rate is calculated and expressed as fractions of the way to germination per day consequently multiplied by the reading period expressed in days. The result is the fraction of the way to germination that has occurred during the reading period. These fractions are added as a running sum, contrariwise if conditions are not favorable for growth, then nothing is added.

Maximum Equilibrium Moisture Content (MaxEMC)

The MaxEMC evaluates the risk of metal corrosion in a storage environment. Since a model for this metric would be extremely complex to create and temperature and RH will affect not only the rate of reaction, but also if the reaction will not occur at all. Therefore, MaxEMC is used as an approximation to include time and, primarily, RH. The temperature and HR values used in the calculation are lagged in the usual way using a 24 hour running average for temperature and a 30 day running average for humidity.

Minimum and Maximum Equilibrium Moisture Content (MinEMC and MaxEMC)

This metric deals strictly with physical deterioration and not with potential for mold growth or rate of chemical decay, evaluating the potential for physical damage in organic materials caused by too much or too little adsorbed water. The USFPL provides equations that combine temperature and RH to produce EMC values for an "average" piece of wood. Temperature and RH values are lagged by using a 24 hour running average for temperature and a 30 day running average for relative humidity. These lagged values are plugged into the USFPL equations to produce a EMC value. These EMC values are sorted to find the highest and lowest in magnitude, and each value is evaluated separately.

Maximum Percent Dimensional Change (Max %DC)

The model Max% DC concerns about physical damage caused by changes in dimension in all organic materials based in an equation that use temperature and RH to determine EMC and additional equations to determine dimensional change from a 10% EMC level by USFPL. These relative dimension values can be used to calculate a metric based on the magnitude of the change from the minimum to the maximum dimension.

The larger thermal effect is a result of thermodynamic law that says that the EMC of adsorbent materials, such as wood, paper, plastics, and gelatin, decreases at constant RH as temperature increases.

To calculate the values, temperature and RH values are lagged using a 24 hour running average for temperature and a 30 day running average for RH. These lagged values are used to look up dimensional change values from 10% EMC for an average piece of tangentially cut wood measured parallel to the fibers. For the results the minimum value can simply be subtracted from the maximum value to find the maximum dimensional change.

This analysis based on metrics can be used to argue for funding or other resources needed to make improvements in storage conditions, providing arguments to a strategic management storage environment for collection preservation. In conclusion the use of this tool is a powerful method for risk analysis in preventive conservation that can facilitate decision making to the institutions.

Fire Risk Assessment for Collection in Museums (FRACM)

This quantitative assessment proposed by *Jean Tétreault* in 2008 [13], aims to provide a tool to different institution to assess the fire risk and obtain quantitative data in the light of risk.

Provides information to characterize the buildings and the levels of control (1 to 6 being the level 1 the least efficient protection and level 6 the ultimate reasonable protection); the likelihood of the occurrence of fire (average in years between fires, per museum); causes of museums fires; Extent of fire damage; Estimated factions of loss of material by heat and combustion based on the control level in the building and a classification of materials based on sensitivity to heat and combustion.

This methodology uses five parameters to assess the Consequence of a fire incident:

1. Fire-spread distribution based on the control level;
2. Maximum fraction of material (collection and non-collection) that can be damaged by different sizes of fire;
3. Expected fractional loss of the maximum fraction of material that could be damaged;
4. Possibility that when the fire starts, there is a collection in the room, on that floor, or in the building (e.g. the building is a museum containing objects, the fraction is 1);
5. Fraction of loss of value for burned objects;

In the end the risk, as the product of the Likelihood and the Consequence, is: e.g., a museum with 3 floors, 4 rooms per floor, which contains a mixed collection in storage and exhibit spaces spread throughout the building. Risk = (1 fire/140yrs) x (14% value loss/fire):

= 14%/140 yrs

= 0.10% loss of value per year.

Knowing that all of institution is susceptible to the fire occurrence this is a very useful and simple assessment, which allows understanding the weaknesses and the strengths of the building providing the tools to the improvement of the levels of control and consequently reducing the risk of fire occurrence.

CCI-ICCROM-RCE Method

This model integrated a risk management project developed by the CCI [17]. The projects were completed in association with CCI Collection Risk Assessment Database that were developed by the CCI in collaboration with the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) and the Rijksdienst voor het Cultureel Erfgoed (RCE) for the Preventive Conservation – Reducing Risks to Collections courses offered through ICCROM from 2005 to 2011 [16].

This method allows evaluating sites, buildings interiors and collections. The part of risk assessment approach is based on three steeps:

1. Identification of all risks for each of the ten agents of deterioration (specific risks), expected to cause significant loss in collection were described in summary sentences that stated the hazard [2];
2. The attribution of a numerical score between 0 and 5 (5 represents the highest risk). It was derived from the answer to each question by the CCI Collection Risk Assessment Database. The three scores were added to determine the magnitude of risk score (MR), which has a maximum of 15;
3. Evaluation to establish priorities. The specific risks were classified on a scale from low to extreme based on the calculated MR. Risks scoring 10 and higher – high to extreme risks – were considered priority risks for reduction. The risk scale used is a logarithmic scale, which expresses values in 'order of magnitude', were also grouped by agent of deterioration, and the total MR score calculated for each group.

Scientific Collections Risk Evaluation (SCoRE)

Developed by the American Museum of Natural History (AMNH) in 2008 this is a quantitative approach, developed to minimize the risk of data entry error due to the big amount of data built in both Microsoft Access and MySQL.

The software was created to store and utilize data in an efficient manner, allowing data organization more efficient and searchable trough view data by collection unit, building, floor, specific risk, etc., generating reports to prioritize collection needs and can determine how to distribute the museum funds more effectively. The data report can be presented in various formats including, risk matrices and bar charts, which may include:

- Collection unit descriptions;
- Collections distribution;
- Collections size;
- Location specific reports;
- Risk estimation Logic;
- Risk profiles and matrices;
- Before and after reports;
- Catering to the audience.

This kind of data can be interpreted in very different ways through different individuals. That is why SCoRE allows for organization and analysis of risk data in many ways and provides the flexibility needed to generate reports according to various audiences and requirements. This method allows identifying challenges at a higher level, quickly and easily in specific areas to determine most effective mitigation strategies.

Although this model can be an improvement for a data interpretation of other models, this for other institutions that have than the AMNH (big amounts of objects and lot of data to analyze). With an easy methodology and many options of results, it allows identifying the mitigation strategies.

Preservation Risk Information System Model (PRISM)

The University of California, Office of Risk Management, Bickmore Risk Services, Sacramento, CA, and the UC Berkeley Library joined to develop a risk calculator, PRISM (Preservation Risk Information System Model), who is a tool on the University of California's Enterprise Risk Management Information System (ERMIS).

The risk assessment is done by a combination of hazard and occurrence of a potential "risk event". It has four "factors" that contribute to its relative risk rating: frequency, severity, recovery time and financial impact, expressed in stepped orders of magnitude. The values are combined by PRISM and mapped to a scale of 1-100 to create a relative rating.

PRISM is a tool for analysis and decision-making, developed to identify hazards, determine levels of risk, and compare the effectiveness, as well as cost effectiveness, of options for methods to mitigate recognized risks.

The PRISM methodology introduces three stages of risk evaluation:

1. Requests data about the following risk factors in the absence of controls:
   - Frequency of the risk event;
   - Recovery time from the risk event;
   - Recovery cost from the risk event.
2. Evaluates controls already in place to help manage risks to collection loss, e.g., fire suppression systems.
3. Evaluates costs and benefits from controls proposed to further reduce risk.

PRISM can be useful for institutions thet have similar characteristics and objects to libraries and archives. This is a model that allows assessing different kinds of hazards (e.g. earthquake, fire, flood, water leak, deterioration, missing, defacement, mold, infestation, damage, machine failure, and operator failure) resulting in different types of data (media: print, film, analog audiovisual, offline/online digital). These characteristics make this software user friendly who can be adaptable to various situations.

Collection Risk Management (CRM)

The CRM program concluded in 2012 with the meeting Reducing Risks to Heritage in collaboration with ICCROM and CCI. This model deal with all threats to which objects and collections are being exposed. The method consists of identifying possible risks, analyzing, quantifying, ranking them, and setting priorities to select strategies for mitigation. The field of security risks and calamities was covered in collaboration with the Safe Heritage Program.

The CRM was tested in different scenarios then further developed and simplified so that smaller institutions with limited time, resources and knowledge can also gain insight into their own situation. This methodology allows generating, qualifying or quantifying the various risks and ultimately made available in a usable form.

The data to assess risk scenario can be: quantitative information collect for events that could lead to loss of value and degradation processes. In the big advantage of this model is the handbook (Digital Collection Risk Management Manual) who describes the methodology step-by-step, provides guidance to conduct a risk analysis and sets out the available information on the ten agents of deterioration. Available on RCE-website [31] is easy to get so the user can apply in their own institution and carry out a risk analysis with their team.

Pollution Pathway Method (PPM)

This is a quantitative mathematical model developed by a partnership between tree institutions Swiss National Library Marianne, Library of Geneva and artemis-control AG in 2012.

This model counts with the Pollution Pathway Diagram who allows visual representation of the method is a mathematical core of the model describing the mechanisms of transport of pollutants in air, chemical reactions in the paper and use of objects. To apply this methodology the challenge is to select which parts in the diagram mostly influence the loss of value of the collection.

The model focus on the question: "*How the rate of degradation of paper is influenced by the absorption of air pollutants and how the uptake of pollutants by the collection is influenced by indoor sources such as books which emit volatile organic compounds (VOCs)"*.

The calculation of the loss of value of the collection is based in: the assessment of the efficiency of the measures located on the most relevant branches (determined through collection of data e.g. pollution levels, pH distribution etc.), and the determination of the relevant values for the collection. In the end the result is the analysis of the effect of the efficiency and costs of the mitigation measures located on collection loss of value will finally allow comparing e.g. the chemical filter option with the other options present in the institution.

This is a restricted model designed only for the analysis of one of the major deterioration agents (pollutants) and their effect on paper-based collections.

The methodology is not very simple to use which may impose some barriers to smaller institutions that may apply. For case studies in these characteristics is an added value when the objective is to rethink the applied mitigation measures.

Risk Awareness Profiling Tool (RAPT)

This qualitative model enables assessing the level of risk awareness in an organization (e.g.museum, library or other heritage institution) by computer software based in a survey developed by the Birmingham Museum in 2012. It indicates areas where awareness in the organization is good, and areas where improvement is needed, also provides guidance to help develop better awareness of risks.

The answers to some simple questions, about planning, policies and procedures, can lead you to furthermore detailed questions. The first-level questions are grouped into four areas covering the essential elements of the organization and its business:

• *Assets* - physical things, such as buildings and collections, and the less tangible things, such as information and intellectual resources;

• *Systems* - tangible and intangible connections and systems that allow use those assets to carry out your business;

• *Finance* - necessary balance between income and costs;

• *Audience* - people whose opinions and choices determine the business success.

It is recommended a team approach for participate in answering the questions to increase involvement in making necessary changes following the assessment.

The time for complete the assessment is estimated in between thirty minutes and two hours, depending on the number of people involved. When completed an assessment the results are showed as a color-coded risk awareness profile (red, amber and green), these results are automatically saved and can be printed at any time. Currently there is no database of similar information against which compare the results. When enough data is inserted into RAPT, it is intended that it will be able to generate a report comparing results with other organizations.

RAPT data is held by Birmingham Museum and Art Gallery. Non-personal data may be made accessible to other organizations such as the Museums, Libraries, and Archives Council (MLA) within the heritage sector to assist with strategic planning and research.

ANALITICA™

The software is Analytica™ by Lumina Systems™, is a qualitative mathematical model capable of calculate the probability of fracture formation during complex climate fluctuations in a collection of various museum objects due to stress over time, using viscoelastic behavior.

The model assumes a basic geometry of two attached layers, allowing the effect of flaws, notches, holes, delamination etc., to be incorporated as variable stress concentration factors. The micro part of the model was developed based in paintings to be capable of explain the behavior of the increasing in stiffness and decrease in extension before break of high pigment volume concentration (PVC) paints.

This software allows calculating: Equilibrium moisture content; Strain; Elasticity; Stress and Fracture on materials.

A, B, C Method

This semi-qualitative model "A, B, C Method" was conceived in a framework developed with the association of ICCROM, Canadian Conservation Institute (CCI) and Netherlands Cultural Heritage Agency (RCE) from 2006 until 2012. It establish the three main steps (*Identify risks, Analyze risks* and *Evaluate risks*) that should be applied to each risk. For the application of each risk assessment it is necessary to accomplish each of the three tasks: *Task 1*: Define the scope, goals and criteria; *Task 2*: Collect and understand the relevant information and *Task 3*: Build the value pie, e.g:

1. ***Identify risks*** (*Task 1*: Assemble the appropriate tools and strategies; *Task 2*: Survey the heritage asset and make a photographic record and *Task 3*: Identify specific risks, name them, and write their summary sentences);

2. ***Analyze risks*** (*Task 1*: Quantify each specific risk; *Task 2*: Split or combine specific risks, as needed and *Task 3*: Review and refine the analyses);

3. ***Evaluate risks*** (*Task 1*: Compare risks to each other, to criteria, to expectations; *Task 2:* Evaluate the sensitivity of prioritization to changes in the value pie and *Task 3*: Evaluate uncertainty, constraints and opportunities).

This model allows to calculate the MR of the specific risk on a 15 - point logarithmic scale by three components A (Frequency or rate), B (Loss of value to each affected item), and C (Items affected) combined to provide the measurement of the MR by simple addition (MR = A + B + C). Although it was thought for be a practical solution for the professionals of the institutions, it requires the work of a multidisciplinary team since it needs information of diverse fields as well as for the distribution of values it is necessary several opinions to be able to represent the relativity of a more faithful way.

Pest Risk in Collection (PRC)

This methodology allows to collected data on pest incidents for semi-quantitative estimates of many insect risk scenarios based on data on likelihood of entry (depending on species and entry routes), effectiveness of measures (prevention, detection, response) and extent of damage (depending on vulnerability of the object, population growth, consumption rate).

In the end is possible to sketch a table with eight levels of protection with the estimated time until noticeable damage for materials of different susceptibility associated to a color code. Based on acquire results it should be possible to assess and quantify risks and options for risk reduction so that they can be compared and ranked to determine priorities for collection care based on avoiding the largest or most urgent losses to the collection.

This methodology can be helpful in the understanding the current levels of control and points of weakness who can allow the entering of the pests. Requires the conservation, engineering and architectural knowledge to draw the mitigation strategies.

New Risk Assessment Methodology for Cultural Heritage Protection (NICHE)

This quantitative model was developed in close collaboration with conservation scientists and library collection managers. Is specifically addressed to the protection of cultural heritage housed in museums, galleries and archives, taking in account the effects of microclimatic reported in international norms and a new concept of risk by the follow expression:

$$R = Pr(E_a, M_d) = Pr(E_a|M_d)\cdot Pr(M_d),$$

where: $Pr(M_d)$ is the unconditional probability that the system produces a source of risk of magnitude M_d and $Pr(E_a|M_d)$ is the conditional probability of an adverse effect E_a on the targets of interest {Ti}, due to M_d.

Through this methodology it is possible to define the conditional and unconditional probabilities that contribute to the definition of risk, in various fields and takes into account the effects of microclimatic conditions on the works of art, based on up- to-date scientific knowledge, reported in international normative requirements.

Due to the mathematical knowledge required to apply this model (complex mathematical equations) its application may be compromised if the institution does not have the resources.

QuiskScan

The QuiskScan developed in 2016 by *A. Brokerhof and A. Bülow* [28] is a qualitative model based on a survey of predefined questions, whose answers can be: "high", "medium" or "low". At last, the combination of these results is related with a color-coded system of tables that allows to quickly relating the vulnerabilities of collection items to generic risks based in the 10 agents of deterioration. This model does not have examples of application because is a novelty.

In general, is very easy and quick to apply by a person who knows the collection.

This is an example model intended to be used as a first resource for an identification of the most damaging risks to a collection. It is suggested to apply the collected data into a more complex model.

Immovable Cultural Heritage Models

Table 3 presents by date (oldest model to the most recent), the seven risk assessment models found in the literature, applied to immovable cultural heritage. The advantages and disadvantages of the seven risk assessment models applied to immovable cultural heritage are described in Table 4.

The following chapters present a summarised context and procedure of the seven risk assessment models applied to immovable cultural heritage.

Store Assessment Form

The "Store Assessment Form" is a qualitative model proposed by *S. Keene, 2002* [32]. This methodology allows classifying storage rooms conditions in categories by the response to two forms:

The first, collect statistics about each store (e.g. size, the amount of storage it provides or the number of objects in it). Then is possible calculate what percentage of objects is in good storage, or bad storage.

The second form can be used to analyze the quality of the storage by choosing one box in each row, for each of the criteria. It allows to easily deciding on the quality of the store overall: Good, Adequate, Poor or Unacceptable.

Table 3. Characterization of Risk Assessment Models applicable to Immovable Cultural Heritage between 1999 and 2016 presented by type of model, model operation, practical application, date and respective references

Model name (acronym)	Type of Model	Model Aims	Applicability	Practical Applications	Date	Ref.
Store Assessment Form	Qualitative - Divided into classes	Assess the quality of storages.	Easy: Atribution of categories to the methods of storage in storage rooms by the anwsers to two forms.	Science Museum, National Museum of Photography, Film and Television, and National Railway Museum.	2002	[32]
The Risk Map of Italian Cultural Heritage	Quantitative - Software	It is a statistical approach, which depends both on the state of conservation of the cultural heritage and on the territorial danger conditions.	Medium / Hard - Needs specialized staff to work with the sofisticated equipment and sofware.	Historical town of Merida (Spain)	2003	[33, 34]
Vulnerability Matrix	Semi-Quantitative – Divided into classes	Allows to know the main risks and conservation conditions that can affect a monument in a site.	Medium / Hard - Needs specific fields of knowledge.	Torre del Oro, Seville	2006	[35, 36]
Condition Survey of Immovable Cultural Heritage (CEN/TC 346/WG1/TG 1)	Qualitative - Divided into classes	The main objective is to record, assess and document the condition of the object.	Easy: Based on a predefined table with the classifications which allows an easy assignment of categories.	NA	2010	[36]
The Delphi Method	Qualitative - Divided into classes	Allows a group of experts to reach consensus through the response to a questionnaire.	Medium/Hard: Requires a considerable amount of time in the preparation of the questionnaire as well as in the selection and processing of data.	Medina of Fez, Marocco	2013	[37]
Analytic Hierarchy Process	Quantitative – Mathematical Equations	Assess the risk of natural and anthropogenic hazards for cultural heritage.	Medium/Hard: Needs specialized people who knows how to work with the sofisticated equipment, sofware and mathematical equasions.	Paphos Distric, Cyprus	2016	[38]
Multi-hazard Risk Analysis	Qualitative - Divided into classes	-It is a simplified risk assessment framework; -Can be used as a screening procedure for the preliminary assessment of a large number of cultural heritage assets with limited resources.	The flowcharts are very easy to use. However, the seismic risk assessment is quite complex. The preliminary identification of assets that require a more refined and resource demanding risk evaluation.	The authors applied it to study the seismic risk of the Roman Temple of Évora (Portugal)	2016	[4]

Table 4. Advantages and disadvantages of Risk Assessment Models applicable to Immovable Cultural Heritage between 1999 and 2016

Model name (acronym)	Advantages	Disadvantages	Ref.
Store Assessment Form	- Improves knowledge of cultural heritage distribution in municipal districts; - Defines the extent of territorial danger through the formulation of corresponding indicators and indexes; - Relates the extent of territorial danger to different levels and combinations of information; -Estimates the magnitude of the risk involved for each cultural property.	- Needs specialized teams.	[33]
The Risk Map of Italian Cultural Heritage	-Easy to use	- It cannot identify the generic and specific risks.	[34, 35]
Vulnerability Matrix	-It is an easy and cheap methodology; -Provides a tool for helping in the decision of which factors should be considered more important in preservation efforts for a monument and the intervention planning.	-Requires knowledge in specific areas such as construction materials.	[37]
Condition Survey of Immovable Cultural Heritage (CEN/TC 346/WG1/TG 1)	-Allows to assess all types of buildings.	-Cannot indicate the specific risks; -Needs a big and multidisciplinary team;	[38]
The Delphi Method	-It is a cheap methodology; -Is a useful tool in the initial stages of developing an analysis plan or when a decision has to be made quickly on the basis of limited information; -This study might prevent the need for a larger more rigorous study;	-The results should be considered as preliminary estimations and be used with some caution; - The time and labor demanded, both for the persons responsible; -Participants must be able to articulate their thoughts when writing in the working language.	[37]
Analytic Hierarchy Process (AHP)	-This method is cost-effective and easily understandable to the users; -Can be implemented on diverse fields.	- Subjectivity in choosing the indicators; - Loss of potentially important information with the final aggregation of values;	[38]
Multi-hazard risk analysis	-Can be applied from a satellite; -Is able of analyze six different hazards; - Is successfully applied on different fields; - Helps decision-makers; -Capable of grouping together sites with similar characteristics facing similar threats.	-Comparative judgments are subjective because they rely on expert opinion; -Cannot be applied in all of types of monuments; -Lack the ability to adequately cope with any inherent uncertainty and imprecision in data. AHP is unable to handle incomplete information.	[4]

The Risk Map of Italian Cultural Heritage

This model was developed in a research project of the Instituto Centrale del Restauro (ICR), with the aim of developing a more rational and economical means of undertaking the maintenance, conservation, and restoration of the architectural and archaeological monuments of Italy in 2003.

The first step has been the creation of a geographical information system (GIS), which collects, processes, and manages both cartographic and alphanumerical data coming from peripheral units based in many Italian towns by the 'Soprintendenze'. The connection between environmental danger and risk to the monuments is highlighted through a mapping process, by overlapping computerized maps having a thematic content (such as air pollution, climate, and earthquakes) and the distribution of cultural assets. The second step has ensured that the above data were homogeneous through defining standardized schedules at different levels of detail that contain information both on the environment of the territory and the conservation status of the monuments.

The main steps of the project have been to:

1. Create an information technology center known, able to collect, process, and manage both cartographic and alphanumerical data at a national level.
2. Develop several regional information technology centers;
3. Organize all the information coming from the databases of the various research institutes, public agencies, and ministries into a single databank (specific data sheets and a common lexicon have been prepared and tested).
4. Process the collected data to calculate the various 'risk indexes'.

In the end the result is the combination of various maps, which provides a provisional estimate of the magnitude and extent of architectonic and archaeological heritage for each municipal district.

Vulnerability Matrix

"Vulnerability Matrix" is a semi-qualitative model applicable to immovable cultural heritage proposed by in 2006 by *E. Galán Huertos et al.* [34].

To apply this model is required specific knowledge in different fields of work (buildings engineering, hazard assessment and vulnerability analysis). The "Vulnerability Matrix" is prepared by inserting in the rows the hazards of the "environment parameters" and for the columns the "material modifications", "building structure" and "Visual Appearance". For each monument the Vulnerability Index is quantified by a visual study of the buildings, where the frequency and weathering degree of the deterioration patterns is considering, defining to the frequency of appearance between 1 and 3.

To calculate the vulnerability, the total value of the deterioration patterns are dividing for each monument by the sum of total value of deterioration patterns and finally is classified into vulnerability degrees using ordinal classes (low; moderate; high; very high and catastrophic).

This model requires a solid knowledge in different areas which can be a disadvantage to applying it because it needs specialized team. But otherwise this is a very helpful model because it provides a tool for helping to decide which factors should be considered more important in preservation efforts for a monument and the intervention planning.

Condition Survey of Immovable Cultural Heritage (CEN/TC 346/WG1/TG 1)

This assessment methodology integrates a Draft European Standard, prepared by Technical Committee CEN/TC 346 "Conservation of cultural property", the secretariat of which is held by UNI. This methodology works as an assessment for each heritage component (or collectively for multiple components exhibiting similar symptoms) that is performed, considering:

- Probable cause(s) of the recorded condition;
- Likely consequence due to the recorded condition;
- Likelihood that the consequence will occur;

- Likelihood that further investigation will reveal hidden damage and the consequence of this damage if found: any recorded deviations from the current regulatory requirements for the property; the need for measures and the necessity of additional investigations.

In the end the information gathered is analyzed and each heritage component a condition class shall be stated with a condition class. To ensure the information is reliable this assessment on immovable cultural heritage shall be performed by professionals (competences needed: preservation, architecture, building archaeology, history of technology, structural engineering, building physics and technical installations, as required. Knowledge of traditional materials and construction techniques is a prerequisite).

The Delphi Method

"The Delphi Method" is commonly held to have been developed at the RAND Corporation during the 1950s and 1960s.

This model allows a group of experts under anonymity to fill out a questionnaire, which will be answered in a sequence of two or more rounds until a consensus is reached. At the end of each round, to each member of the group is sent a summary of the answers given by the whole group, with the intention that individually re-evaluates their answers. This sequence promotes that each round the answers are increasingly coincident between the group and in this way, reach the consensus.

To apply this model is necessary considered the differences in the group selected to be able to elaborate questions. As an advantage it is possible to obtain several points of view on the same subject.

Analytic Hierarchy Process (AHP)

This qualitative model, proposed by Saaty in 1970's bind the multi-temporal GIS and the earth observation analysis, pretending goes a step forward targeting more reliable outcomes for cultural heritage management. The scope was to develop a more accurate methodology for risk assessment against natural and anthropogenic hazards. It is a multi-criteria decision-making method based on comparing concepts (alternatives) in pairs. AHP is an intuitively easy approach widely applied to help decision-makers who face several conflicting criteria and alternatives simultaneously.The results are in form of risk maps for each hazard affecting cultural heritage.

Multi-hazard Risk Analysis

In the "Multi-hazard Risk Analysis" a qualitative risk analysis methodology is based on a set of structured assessment flowcharts that address the main components of a risk analysis:

- Likelihood of the hazard;
- Vulnerability of the asset to the hazard;
- Consequences of the hazard;
- Capacity to recover from the event.

It is composed manly by two flowcharts that illustrate the full scope of the flowcharts and outcomes that can be obtained with the proposed framework. The first flowchart presents the part of the method that establishes the vulnerability of the cultural heritage unit resulting in five classes of increasing vulnerability of the immovable cultural heritage. The second flowchart presents the part where the vulnerability, obtain in the first flowchart, is combined with the hazard to determine the risk level. This will lead to five classes of increasing risk based on the vulnerability classes defined by the process and on the expected likelihood of the hazard. Both flowcharts have colors which aid the interpretation of the vulnerability and risk levels.

This model was developed to study the seismic risk assessment. The authors present the Roman Temple of Évora (Portugal), as a case study. In this part of the work they needed to go deeper in physics and mathematics in order to calculate geometric parameters (e.g. the slope angle of the foundation, slenderness and frequency parameters). This part of the model is difficult to be applied by people that are not from this field of knowledge.

Figure 1 and 2 presents the type of results and information obtained by the risk assessment models.

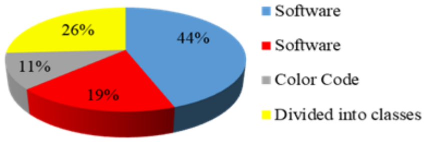

Fig. 1. Type of results obtained by risk assessment models

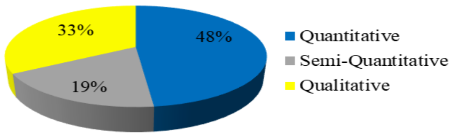

Fig. 2. Type of information obtained by risk assessment models

Conclusions

With this work it was possible to gather a total of 27 models of risk assessment.

Of the 27 models, it is clear that that the majority was designed to be applied to the mobile cultural heritage with 20 models corresponding to 74% of total, while 7 models correspond to models applicable to the cultural heritage with 26%.

It is also possible to conclude that, based in the Figure 1, in terms of the type of result in which the risk is expressed, we realize that they can be grouped in four different ways: Mathematical Equations, Software, Color Code and Divided into classes.

From these types of results, we can see that the most common type of result is expressed by mathematical equations with 12 models (44%), followed by the division by categories with 7 models (26%), software with 5 models (19%) and lastly in color code with 3 models (11%).

The type of information we can obtain with risk assessment models can be divided into three types of evaluation: Quantitative, Semi-quantitative and Qualitative.

From these typologies, based in the Figure 2 is possible conclude that most models produce quantitative information with 13 models (48%), qualitative type information with 9 models (33%), and finally models come up with semi-quantitative information with 5 models (19%).

With this work it was possible to build a small database to help conservators, curators and all responsible for any type of cultural heritage to select the risk assessment model that best suits their needs.

Abbreviations

AHP - Analytic Hierarchy Process
AMNH - American Museum of Natural History
CCI - Canadian Conservation Institute
CPRAM - Cultural Property Risk Analysis Model
CRM - Collection Risk Management
EMC - Equilibrium Moisture Content
ERMIS - Enterprise Risk Management Information System
FACM - Fire Risk Assessment for Collection in Museums
ICCROM - International Centre for the Study of the Preservation and Restoration of Cultural Property
MaxEMC - Maximum Equilibrium Moisture Content
Max%DC - Maximum Percent Dimensional Change
MinEMC - Minimum Equilibrium Moisture Content

MR - Magnitude of Risk
MRF - Mold Risk Factor
NICHE - New risk assessment methodology for Cultural HEritage SCoRE - Scientific Collections Risk Evaluation
PRISM - Preservation Risk Information System Model
PPM - Pollution Pathway Method
PRC - Pest Risks in Collections
RAOC - Risk Assessment for Object Conservation
RAPT - Risk Awareness Profiling Tool
RCE - Rijksdienst voor het Cultureel Erfgoed
RMG - Risk Mapping Galleries
TWPI - Time-Weighted Preservation Index

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