Preventive Conservation in Historic Houses and Palace Museums: Assessment Methodologies and Applications

SilvanaEditoriale

Preventive Conservation in Historic Houses and Palace Museums: Assessment Methodologies and Applications

Conference of the National Museum
of the Palace of Versailles (EPV),
the Association of European
Royal Residences (ARRE),
and the Research Centre
of the Palace of Versailles (CRCV)

In collaboration with the International Committee
for Historic House Museums (DEMHIST),
held at the National Museum
of the Palace of Versailles and Trianon

From 29th November to 1st December 2017

Conference Proceedings

Under the scientific direction of
Danilo Forleo
in charge of preventive conservation
and head of EPICO programme,
National Museum of the Palace
of Versailles and Trianon

Editorial coordination
Nadia Francaviglia
research assistant for EPICO programme,
Research Centre of the Palace of Versailles

Translations
Clarisse Le Mercier, Camila Mora

This book brings together the presentations of the speakers at the international symposium organised as part of the EPICO (European Protocol in Preventive Conservation) research programme, by the National Museum of the Palace of Versailles:
Catherine Pegard, *president*
Laurent Salomé, *director of the National Museum of the Palace of Versailles*
Tierry Gausseron, *deputy head*
Association of European Royal Residences (ARRE)
Research Centre of the Palace of Versailles (CRCV)

With the participation of
Ministère de la Culture,
ICOM – DEMHIST (International Committee for Historic House Museums)

Scientific committee
Lorenzo Appolonia, *president, Italian Group of the International Institute for Conservation – IGIIC*

Florence Bertin, *head of Collection Department at MAD – Musée des Arts décoratifs*

Michel Dubus, *ICOM-CC group coordinator for preventive conservation, Centre de recherche et de restauration des musées de France – C2RMF*

Danilo Forleo, *in charge of preventive conservation and head of EPICO programme, National Museum of the Palace of Versailles and Trianon*

Nadia Francaviglia, *research assistant for EPICO programme, Research Centre of the Palace of Versailles*

Agnieszska Laudy, *deputy head of Architecture Department, Museum of King Jan III's Palace at Wilanów (Warsaw)*

Bertrand Lavedrine, *director, Centre de recherche sur la conservation des collections – CNRS*

Sarah Staniforth, *former president, International Institute for Conservation – IIC*

Organizing committee
Elena Alliaudi, *coordinator, Association of European Royal Residences*

Hélène Legrand, *assistant coordinator, Association of European Royal Residences*

Matilde-Maria Cassandro-Malphettes, *secretary general, Research Centre of the Palace of Versailles Bernard Ancer, in charge of general affairs, Research Centre of the Palace of Versailles*

Olivia Lombardi, *executive assistant, Research Centre of the Palace of Versailles*

Serena Gavazzi, *head of the Patronage Department, National Museum of the Palace of Versailles and Trianon*

Noémie Wansart, *research assistant at Curatorial Department, National Museum of the Palace of Versailles and Trianon*

Thanks to
Lorenzo Appolonia, Lionel Arsac, Jean-Vincent Bacquart, Wojciech Bagiński, Jérémie Benoît, Marie-Alice Beziaud, Céline Boissiere, Anne Carasso, Élisabeth Caude, Gabrielle Chadie, Thibault Creste, Stefania De Blasi, Elisabetta Brignoli, Hélène Dalifard, Gaël de Guichen, Ariane de Lestrange, Festese Devarayar, Françoise Feige, Christophe Fouin, Éric Gall, Thomas Garnier, Roberta Genta, Denis Guillemard, Michelle-Agnoko Gunn, l'équipe du Grand Café d'Orléans, Pierre-Xavier Hans, Nicole Jamieson, Thierry Lamouroux, Marie Leimbacher, Nadège Marzanato, Béatrice Messaoudi, Stefan Michalski, Christian Milet, Marya Nawrocka-Teodorczyk, Marco Nervo, Lucie Nicolas-Vullierme, Clotilde Nouailhat, Agnieszka Pawlak, Amaury Percheron, Arnaud Prêtre, Gérard Robaut, Bertrand Rondot, Valériane Rozé, Béatrice Sarrazin, Béatrix Saule, Didier Saulnier, Emma Scheinmaenn, Violaine Solari, Emilie Sonck, Pauline Tronca, Rémi Watiez, Thierry Webley, Sébastien Zimmerman

CHÂTEAU DE VERSAILLES
EPICO European Protocol in Preventive Conservation
European Royal residences
Centre de Recherche Château de Versailles
DEMHIST
Liberté • Égalité • Fraternité République Française
Ministère Culture

With the patronage of
Arden-Plast, Boston University, Polygon, testo, Abiotec, ILTI Luce

Index

01

Preface

The main objective of the international conference that took place at the Château de Versailles from the 29th of November to the 1st of December 2017 was to take a new and global look on the conservation of collections exhibited in historic houses. It is only by observing at the same time the artworks, the décor, the architecture and the daily functioning of these monuments that we can understand the transformations that imperceptibly occur, so as to try to preserve this "eternal present" so dear to Cesare Brandi and thus "escape the passage of time."

In 2014, the Château de Versailles and its Research Centre initiated the EPICO (European Protocol in Preventive Conservation) research program, to consider in a more comprehensive way the preventive conservation of historic houses. So it is quite natural that the Château turned to the Association of European Royal Residences, both to ensure the propagation of the program and to bring together partners sharing the same questions. The Museum of King Jan III's Palace at Wilanów (Warsaw) and the Conservation and Restoration Centre in La Venaria Reale (Turin) immediately embarked on the adventure. It was decided to present at the end of 2017 the results of the program as well as similar experiences around the world.

It was quite natural to organise these three days of exchange in Versailles, with the Association of European Royal Residences, which today gathers together more than ninety palace museums in fifteen European countries. And keeping with the great success of the conference devoted to "The Authenticity in the Conservation of Historic Houses" in October 2014, the International Committee for Historic House Museums (ICOM – DEMHIST) wished to collaborate with this project.

The ambition of the symposium was to initiate a new notion of preventive conservation in historic houses and palace museums, by gathering feedbacks and recent researches, including in the so-called hard sciences, that have opened new trails, from the Vatican Museums to Yale University, by way of the castles of Berlin-Brandenburg.

It was made possible thanks to The Pascal Fund from the French Ministry of Culture and seven international patrons – Arden-Plast, Boston University, Polygon, Testo, Abiotec, Ilti Luce and CTS – whom we would all like to thank.

However, the success of this symposium, that was quickly sold out, was a surprise. Professionals but also individuals weren't lacking, making the exchanges intense and exciting especially during the round tables. Recognised specialists in preventive conservation, such as the Canadian Museum of Nature in Ottawa, English Heritage, were able to interact with the Centre for Research and Restoration of the Musées de France, the Netherlands Cultural Agency, but also more faraway institutions like the Casa de Rui Barbosa Foundation in Brazil or the Indian Heritage Cities Network based in Mysore.

Even though the Anglo-Saxon world, which has been sensitive to these questions for several decades, and Italy, Germany and France were all well represented, we were delighted to witness the collaboration of specialists from four continents.

The issues are common to all and these exchanges, which remind us of the universal nature of the matters of heritage preservation, would not have displeased the philosophers of the Enlightenment.

Catherine Pégard
Laurent Salomé

01

Condition Survey and Risk Assessment: Methodologies and Applications

Preventive conservation has been studied a great deal over the last decades, nevertheless, we can observe the absence of an assessment method dedicated to the collections of historical houses, which provides a global picture of the causes of deterioration and consequent corrective actions.

How to observe the décors, the collections, the deteriorations, so that all the damage factors seem clear and hierarchised according to the importance of their impacts?

This classification is essential because it must guide us in the formulation of the diagnosis, the prioritisation of the actions and the rationalisation of financial resources.

How to detect the most at risk rooms among the length of a few miles of a Palace like Versailles?

Method is the key: the way of observing, collecting, treating and rendering the information from our condition reports as well as the analysis of the conservation conditions.

In the 1990s appeared methods for assessing collections. Coming from the business and finance fields for risk calculation and demographic studies, assessment methods were developed mainly for museum collections, archives and reserves.

For the first time, the collections from historic houses are at the heart of reflection and exchange thanks to the participation of international experts who have made assessment methodology their major activity. These professionals, intervening during this first day of the conference, describe their different approaches and the results obtained during several years of experimentation.

These experiments represent the *incipit* of the EPICO programme's research and are used as an introduction for the presentation of the new EPICO assessment method, developed by the Palace, the museum and the National Estate of Versailles in partnership with four other European institutions. The origins, the development and the results of the programme are presented by the European team working on the comparative analysis, the testing of different assessment methods and then the elaboration of the EPICO method, specifically designed for historic houses. Two approaches are particularly highlighted in this new assessment process: the causal relation of the deteriorations, sought in the calculation system of the aggressors in order to be able to justify the priorities of intervention according to the importance of the deteriorations caused on the collections; the identification of the distinctive criteria of historic houses and the palace museums for the development of a statistical sampling system to be used in the assessment of very large residences and collections.

Themes

1. The Anglo-Saxon school on risks: the theoretical basis of the assessment applied to heritage. The simplification of the model of Robert Waller and Stefan Michalski. The application of risk assessment to museums and historic houses.
2. Training in France, collection assessment and the condition report.
3. The crossing of two approaches. Theory and practical applications.
4. The EPICO programme: research results, presentation of the method.

SESSION 1

Chairman
Sarah Staniforth
Former IIC President, International Institute for Conservation

Speakers
Florence Bertin
Agnes Brokerhof
Denis Guillemard
Joel Taylor
Robert Waller
Amber Xavier-Rowe

Detail of the Queen's imperial chamber while being dusted, Palace of Versailles.
© Groupement Vrinat

Fundamental Requirements for Historic House Preservation Risk Management

Robert Waller
Senior Risk Analyst
Protect Heritage Corp., Canada
rw@protectheritage.com

Abstract

Risk assessment quantifies the value of expected events and processes. Applied to preventive conservation, it quantifies expected loss in value to a cultural property. The quality of risk analysis is broadly thought to depend on uncertainties in measures or estimates of risk factors. The usefulness of risk analysis is commonly thought to be most dependent on the accuracy, or even more mistakenly of the precision, of risk measures. Fundamental risk analysis understandings, as well as practical risk management experience, demonstrate that the precision of risk magnitude measures is less important than a useful underlying system model for both the assessment and management of risk. Underlying models can be constructed to clarify understanding of risks with special reference to one of the dimensions: time, space, or population. For the protection of historic houses and their contents each of these models has value. Models focused on time are best exemplified by severe weather and flood forecasts. Cultural property risk models focused on space are typified by the Risk Map of Italian Cultural Heritage but are now being developed to great benefit at the building level where they can identify locations of high risk to building, contents, or both. For building contents, and to a lesser degree for building components, a population focused model such as the Cultural Property Risk Analysis Model (CPRAM) is most appropriate and useful. In that model "population" refers to items within collections or to measures of building components. A risk assessment and management approach for the protection of historic houses must include features, hence benefits, of each of these modeling approaches. Further, it must be both comprehensive, so as not to divert resources from unidentified but serious risks, and informative in an instrumental way to all actors and systems influencing preservation.

Keywords

Preventive conservation, risk analysis, risk assessment, risk management.

To survive and retain authentic values over time, historic houses must guard against many diverse risks. Some of these are easy to compare and decide where to provide more protection. For example, guarding against visitor contact with a delicate china set will always be judged more important than guarding against visitor contact with a fixed fireplace mantel (fig. 1). Given similar levels of care

Fig. 1
Fragilities as different as delicate china and massive stone are within scope of historic house risk management.
(Source: 123rf.com)

in protecting these items from physical damage due to visitor contact (risk management) we would expect much more damage to the china than to the mantel (risk assessment).

Still, many of the risks to be assessed and managed are more difficult to compare. Light induced fading of many materials within a house may result in a visitor experience that fails to convey the sense of richness the space once had and is still meant to convey. Light damage is gradual but progressive and cumulative. In the other extreme, historic buildings can be lost completely, literally overnight in a catastrophic fire. Consider value as the positive emotion arising in visitors. Comparing the expected loss over time due to the chance occurrence of a major fire with the expected loss of value due to continued fading of interiors (risk assessment) is challenging. Yet deciding the importance and value of improving protection against each of these (risk management) requires that we know their relative importance.

When comparing more than just two different risks, in fact the hundreds of distinct risks we want to manage requires us to have a measure of each. Often these risk measures require expert judgments from many sources. These expert judgments are brought together using the language of mathematics, in the case of the Cultural Property Risk Analysis Model (CPRAM) using ratios. Control of the risks may also be in the hands of different specialists, light damage being controlled by conservators and room attendants while fire protection being contributed to by many but most controlled by estate management.

Fig. 2
Risks as diverse as total destruction by fire and fading by light need to be considered and evaluated. (Source: 1223rf.com b). Mary Perrin (1737-1815), Roxbury, Massachusetts, 1750, wool, silk and metallic thread on linen. Museum purchase with funds provided by the Henry Francis du Pont Collectors Circle 2016.66. Left: back showing vibrant colors. Right: front, faded by light, as seen on display. Courtesy Winterthur.

Fundamental Requirements

This paper focusses on the "fundamental requirements" for risk analysis and risk management methods applied to preventive conservation in historic houses. The two fundamental requirements considered most important for risk management are: first, being maximally informative, and second, being sufficiently comprehensive.

By *informative* we mean providing *useful, actionable* information as an outcome. This information can be applied to management systems, to all people who can influence preservation, and to our fundamental understanding of what we mean by preventive conservation, preservation management, risk analysis, and so on.

By *comprehensive* we mean fully inclusive of all risks, considering all significant factors, and engaging all people who influence preservation.

Informative

At this point, it is important for us to well define what is the meaning employed here for the term *system*. Each of us is comprised of many systems including skeletal, nervous, circulatory, and so on (fig. 3a). A system is simply a construct of parts, and their relations, to serve a goal. It is worth taking a few moments to reflect on the complexity, partial-independence, and inter dependencies of these systems within our own bodies before reading on.

Organizations, like each of us, also contain systems that are somewhat complex, independent, and interdependent (fig. 3b). The preventive conservation (preservation assurance or risk management) system is just one of these many systems, albeit an important one. These systems are made up of both people (hereafter called actors) as well as conventions and rules governing their actions and interactions. An effective risk management system must inform both systems and actors in ways that are instrumental in guiding decisions and actions. Effective risk communication requires us to recognize that informing systems and informing people are different challenges.

Take for example, the case of the Palace of Versailles, which is probably one of the most complex heritage institutions in France, and probably in Europe. If conservation of movable collections is the main responsibility of the Conservation Department, the preservation of the décor and of the architectural structures is the primary goal of the Architecture Department. But there are many decisions about the preservation of the Palace to be discussed together between these two Departments, and also probably with the Audience Department that is in charge of the management and organization of visits. It is essential that risk assessment addresses all these components and perspectives and also that it meaningfully informs both systems and actors in all these areas.

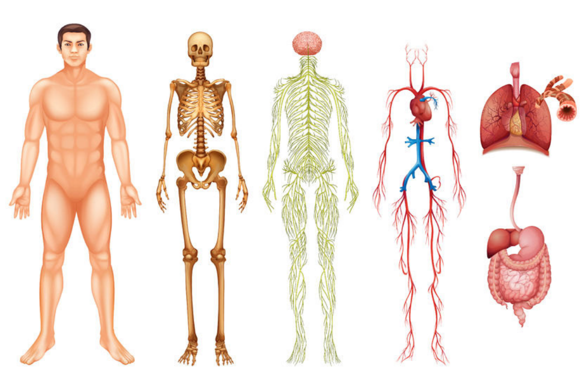


Fig. 3
a) Bodies are assemblies of many systems.
(Source: 123rf.com)
b) Organizations are also assemblies of many systems.
(Source: 123rf.com).

A heritage preservation system needs to be defined in the context of related systems [Waller, 2002, 2003]. Most closely related are the three systems that comprise heritage management (fig. 4):

– develop: accumulate, enrich, or enhance heritage value;
– preserve: maintain heritage value guided largely by risk analysis;
– use: interacting with heritage to provide benefits to society.

Fig. 4
The heritage management system includes three major sub-systems.
(© Protect Heritage Corp.)

Risk assessment results have value for many other systems within the institution including, as depicted here, guiding decisions on transfer of risk through negotiated insurance coverage.

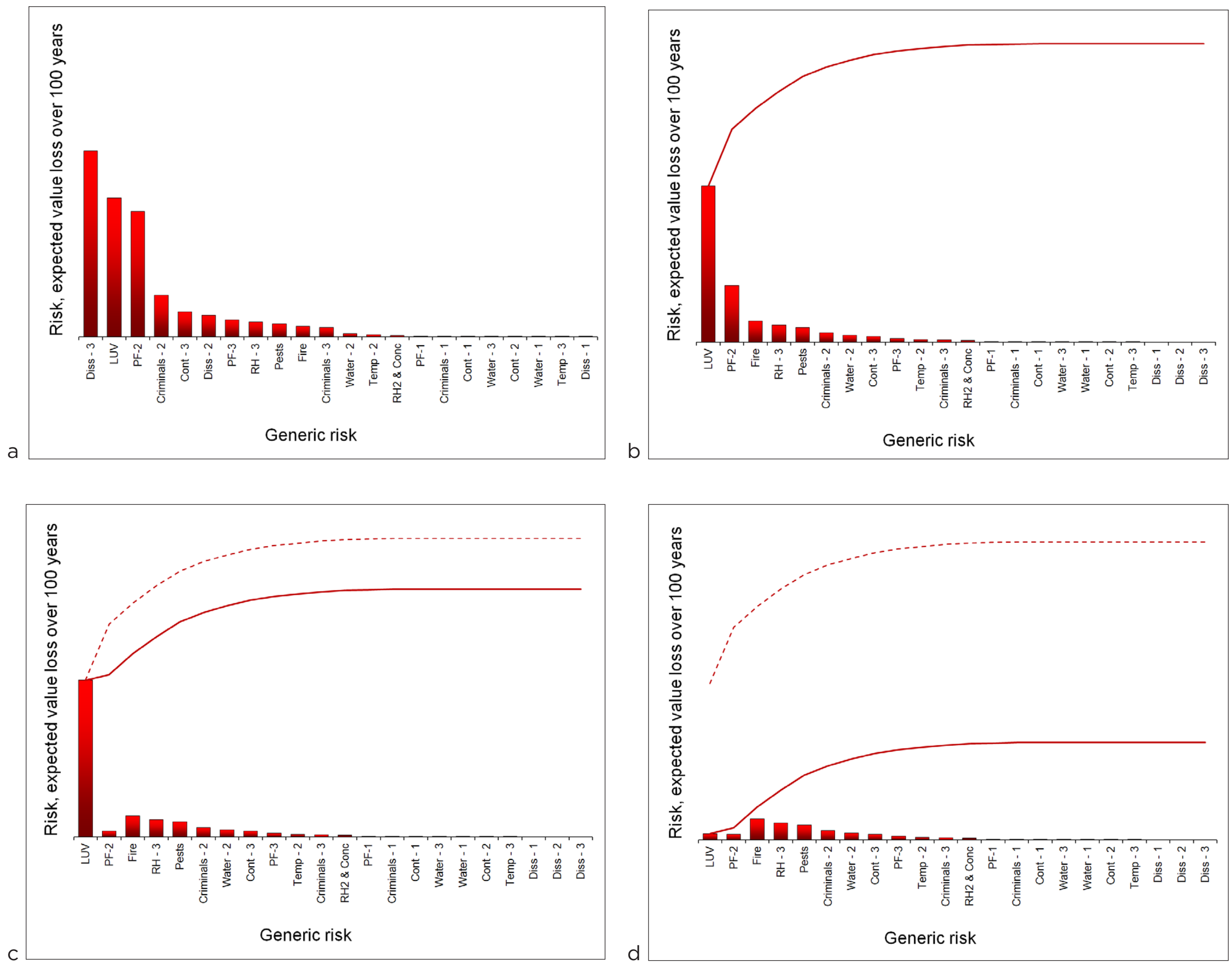
Although risk management approaches are systems themselves, they should not be command-and-control type systems. They involve relatively loose networks of actors, not independent but usually not tightly linked with respect to the goal of risk management. We rely on the expertise of many kinds of professionals to control factors influencing risks to collections. Our challenge is not to control or direct their activities but to inform them of how issues they control will influence risks to heritage.

An example is how the Canadian Museum of Nature's (CMN) risk assessments have informed facility management allowing that group to exercise professional judgment in directing resources to most reduce risks to collections.

Fig. 5
a) Magnitudes of risks to CMN collections by generic risks in 1998.
b) Magnitudes of risks to CMN collections by generic risks in 1998 after filtering to retain only risk controlled by facility management.
c) Magnitudes of risks to CMN collections by generic risks in 2003 after filtering to retain only risk controlled by facility management.
d) Magnitudes of risks to CMN collections by generic risks in 2008 after filtering to retain only risk controlled by facility management.
To enable clarity in scaling, risks specific to fluid preserved collections have been excluded. Only relative risk magnitudes are shown as those convey all important meaning and guard confidentiality.
(© Protect Heritage Corp.)

Figure 5a shows 1998 magnitudes of risks (magnitude expressed as expected loss in value over the next 100 years) to collections by generic risk. That is of limited use to facility management as it includes many risks that are completely outside of that departments control or even influence. Figure 5b shows the 1998 generic risk magnitude distribution after filtering to depict only how much of each generic risk facility management is able to control or influence. The remaining (filtered out) risk magnitudes would be controlled or influenced by other groups such as conservation, registration, etc. The solid line toward the top of the graph depicts the running total risk magnitude across the set of generic risks. It serves as a reference when depicting reductions in overall risk magnitude.

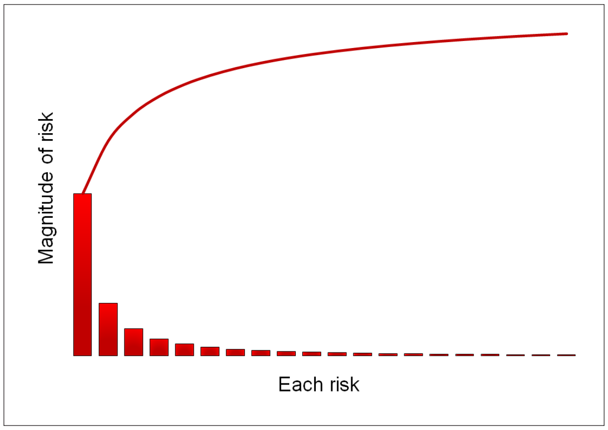
Figure 5c depicts the facility management-related risk magnitude distribution five years later (2003) after facility management was able to address the share of physical force issues it could mitigate. During those years both facilities management and conservation science worked on defining options for – and evaluating risks, costs, and benefits of – reducing collection light exposures in storage. Figure 5d shows the facility management-related risk distribution in 2008 after



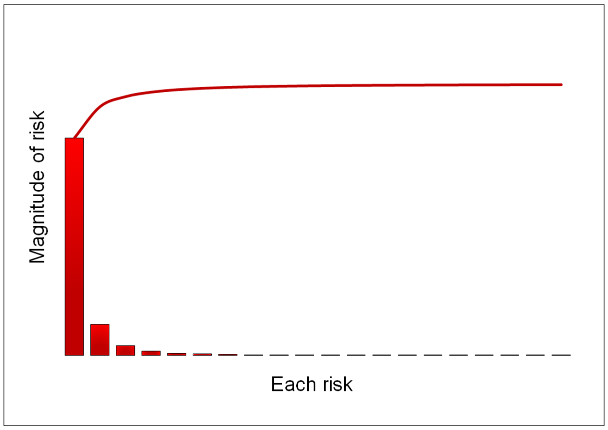
a strategy for reducing light damage was implemented. It is evident that facility management was able to focus effort and resources to achieve a substantial reduction in overall risk to collections. Arguably, the CMN facility management group did outstanding work in reducing the amount of risk they could influence.

Finally, in addition to informing institutional priorities, cultural property risk management can impact basic understandings at an individual, and a conservation field, level.

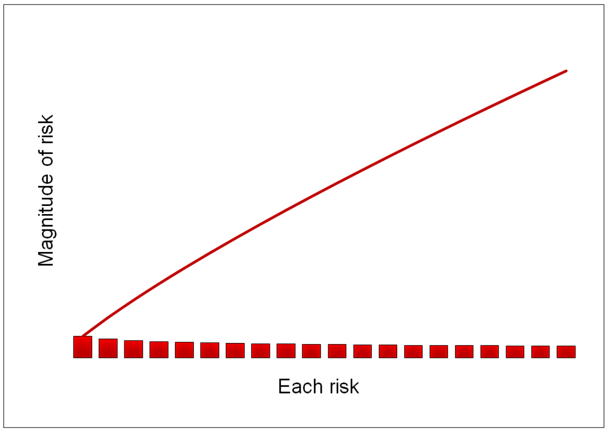
Based on hundreds of risk assessments completed or refereed, the great majority exhibit the form of risk profile depicted ideally in figure 6, as well as practically in figure 3. Figure 6a shows an ideal Pareto distribution indicating that 80% of the risk is associated with just 20% of generic risks. Occasionally, we find an even more skewed distribution where 90% of the risk is associated with just 10%, or even fewer, of the generic risks (fig. 6b). What has never been encountered is the form depicted in figure 6c where there are many generic risks of similar magnitude. Yet, choices and behaviors observed within the field of preventive conservation, including those this author has noted in moments of self-reflection, would indicate an underlying, albeit tacit, belief that magnitudes of diverse risks to cultural resources are much more evenly distributed than they truly are.



a



b



c

Comprehensive

If we consider the second fundamental requirement – that of being comprehensive – then we must consider being comprehensive with respect to: the heritage property being considered, values, and risks.

Regarding the heritage property being considered, it is essential to clearly delineate what is, and is not, considered "in scope" for the risk assessment. For historic properties this will mean clarifying whether, at the large scale, landscape architecture and gardens are within scope; at the medium scale, whether all elements of a building, including foundations, mechanical systems, etc. are within scope; at the detail scale, whether all furnishings and collection items are within scope or some are considered expendable props.

Having clarified the scope in terms of physical items included in the assessment, the issue of what values are to be protected must be addressed. Inanimate items do not themselves have value in isolation from sentient beings. Values result from people, individually or as social groups, attaching meanings to items [see, for example, Significance2.0; Russell and Winkworth, 2009]. Risk-informed preventive conservation now clearly recognizes that its responsibility is to safeguard current and future values of heritage as much as to slow or arrest physical, structural, and chemical changes in heritage items [Luger *et al.*, 2014; Bülow *et al.*, 2016; Brokerhof *et al.*, 2017]. Understanding, and rendering operational, means of representing values of heritage property remains a challenge, especially where both itemized and assemblage values are considered as for historic houses holding important collections [Meule, 2008]. Properly representing value structures of diverse social groups, such as academia and indigenous peoples, within a risk assessment context is another challenge that must be addressed [Tse *et al.*, 2018].

Fig. 6
a) Pareto distribution depicting an 80:20 distribution of importance vs categories.
b) Pareto distribution depicting a 90:10 distribution of importance vs categories.
c) Pareto distribution depicting a 50:50 distribution of importance vs categories.
(© Protect Heritage Corp.)

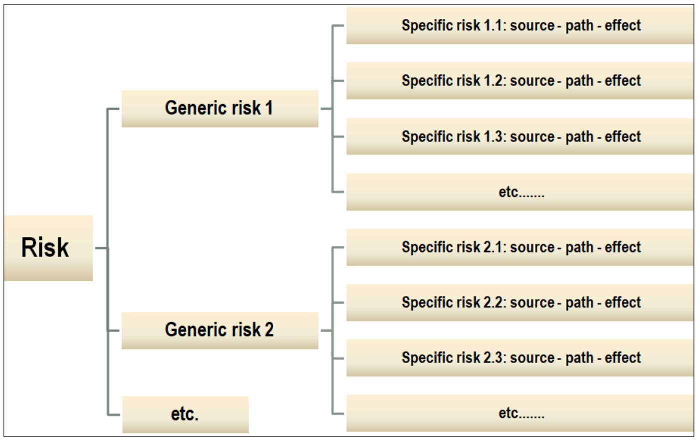
This will likely require parallel yet separate assessment frameworks. At present, the goal is to structure assessments to provide a best current understanding of values at risk knowing that this understanding is only intended to inform, and not dictate, preservation management decisions. It is also accepted that future assessments will hopefully, and almost certainly, provide better understandings.

Being comprehensive in identifying and defining all risks affecting a cultural property requires demonstrating the bases for belief in having achieved a degree of comprehensiveness (completeness, exhaustiveness). In risk analysis, this is achieved through hierarchical modeling (fig. 7). For cultural property, this process acts as follows:

– starts with combining sources of risk, such as a set of *agents of change* (based on CCI's 10 Agents of Change[1]), with a type of risk based on expected frequency of occurrence to establish a set of *Generic Risks*.
– Each of the 10 agents can be split into 3 *Types of risk*, potentially creating 30 generic risks.
– These generic risks must then be decomposed into a comprehensive set of *Specific risks* within each generic risk.
– Specific risks are defined in terms of s*ource, path* and *effect*.
– In some instances, specific risks are even further sub-divided into *Sub-specific risks*, where that is necessary or helpful as when even a clearly defined specific risk still refers to disjoint sources, paths, or effects that are best defined and quantified separately.

Figure 8 shows a set of 30 potential generic risks. Shaded areas represent our estimate of how comprehensive we are in identifying all specific risks making significant contributions to a generic risk. It is our best understanding of the degree to which ignored or unknown specific risks might contribute to a generic risk. By combining these estimates with calculated generic risk magnitudes we arrive at a quantitative estimate of comprehensiveness. Of course, this still depends on judgment of the risk analyst and remains subjective. Still, it affords a structured documentation of what is known and what is thought to be unknown, or even unidentified (the unknown unknowns). This provides measures of both confidence and credibility [Waller, 2008].

Employing a standard, three-part definition for any specific risk facilitates consideration of comprehensiveness through focussing primarily on one of the three parts (source, path, or effect) as the basis for building a set of specific risks within each generic risk. For example, for Physical Forces-Type-I, rare and potentially catastrophic events, the *source* of the hazard (e.g., seismic or geotechnical events, structural failures, explosions) is most useful for defining a comprehensive set



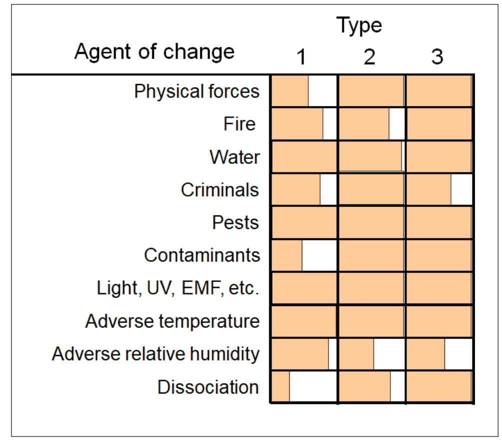


Fig. 7
The structure through which total risk is divided into generic risks then further divided into specific risks.
(© Protect Heritage Corp.)

Fig. 8
Best estimates of relative contribution of unidentified, unknown specific risks to each generic risk.
(© Protect Heritage Corp.)

of specific risks. For Criminals-Type-2, *path* (e.g., the route a criminal might take) is most useful, while for adverse relative humidity *effect* on the heritage property (e.g., corrosion or fracture) is most useful. It is also important that, in striving to ensure comprehensiveness, the exclusiveness of specific risk definitions is maintained. That is, the same expected value loss should not be accounted for within multiple specific risks as might happen when several factors influence damage rates. For example, the degradation of cellulose materials depends on adverse (high) temperature, adverse (high) relative humidity, and contaminants (low pH). To avoid double or triple counting of expected damage from this risk it must only be accounted for once. The specific risk for accounting for this will be the one more depended on for control of the risk. That could be adverse temperature if cold storage is the primary control as for film collections, contaminants if deacidification is the primary control as in some libraries and archives, or adverse relative humidity if moisture control is the primary preservation strategy available.

These combinations appear to be complicated but if worked through in a structured manner can be manageable [Waller, 2018]. On-line courses on cultural property risk analysis are also available through Museum Study.[2]

Being comprehensive with respect to factors during risk assessment means also:
– finding and documenting evidence to support every judgment.
– Fully appreciating the roles of all systems and people in influencing risk to heritage.

As Donella Meadows explains well in her book *Thinking in Systems* [Meadows, 2008,] there are many places in which one can intervene with a system to change its performance. She called those “leverage points." These range from very simple, low-level interventions like changing an input parameter, perhaps adjusting a thermostat or writing a procedure to support a policy, to much more challenging, high-level interventions such as changing a system goal or even a world view, such as exactly what is being preserved for whom.

Conclusion

Risk assessment and management are powerful tools. Like all powerful tools they can produce great results. For preventive conservation this can mean much better and more cost-effective preservation. Still, like all powerful tools, if misused or not skillfully applied they can cause great harm. In recent years diverse risk assessment and management approaches to preventive conservation are being developed and promulgated at a great rate, often without the benefit of professional risk analysis review. It is then incumbent on those who would adopt such methods to ensure the method chosen has proven itself to be sufficiently informative and comprehensive to cause more good than harm.[3]

Endnotes

[1] https://www.canada.ca/en/conservation-institute/services/agents-deterioration.html (accessed on 26 September 2018).

[2] http://www.museumstudy.com/courses/course-list/assessing-risk-to-cultural-property-1/ (accessed on 26 September 2018).

[3] I am very grateful to Nadia Francaviglia, European Protocol in Preventive Conservation and Centre de recherche du château de Versailles, and Emily Higginson, Protect Heritage Corp., for critical reviews and helpful suggestions for revising and improving this manuscript. I am also grateful to Allison Dunckel for providing the image of textiles (fig. 2).

Bibliography

Brokerhof A., Kemp J., Bülow A., 'Value Management Scan: Setting Priorities in Management and Care of Collections,' in J. Bridgland (ed.), *Preprints of the ICOM-CC 18th Triennial Meeting 2017*, 4-8 September 2017, Copenhagen, International Council of Museums, Paris, 2017.

Bülow A., Brokerhof A., Barry C., Chapman H., 'Pride and Prejudice: Developing a Shared Understanding of Priorities,' in *Journal of Paper Conservation* 17(3-4): 1-12, 2016.

Luger T., Brokerhof A., Hartog S., Huisman G., 'Assessing Museum Collections: Collection Valuation in Six Steps,' Cultural Heritage Agency of the Netherlands, Amersfoort, 2014. https://cultureelerfgoed.nl/publicaties/assessing-museum-collections (accessed on 26 September 2018).

Meadows D.H., *Thinking in Systems: A Primer*, Chelsea Green Publishing, 2008.

Meul V., 'Safeguarding the Significance of Ensembles: Value Assessments in Risk Management for Cultural Heritage,' in J. Bridgeland (ed.), Triennial Conference of ICOM-CC (International Council of Museums – Committee for Conservation), *Diversity in Heritage Conservation: Tradition, Innovation and Participation*, New Delhi, ICOM, 2008, pp. 1048-1055.

Russell R., and Winkworth K., *Significance 2.0 – A Guide to Assessing the Significance of Collections*, Collections Council of Australia, Canberra, 2009. http://www.environment.gov.au/heritage/publications/significance2-0/index.html (accessed on 27 September 2018).

Tse N., Labrador A.M.T., Scott M., and Balarbar R., *Preventive Conservation: People, Objects, Place and Time in the Philippines. Studies in Conservation* 63(S1): S274-S281, 2018.

Waller R.R., 'A Risk Model for Collection Preservation,' in R. Vontobel (ed.), *ICOM-Committee for Conservation, 13th Triennial Conference Preprints*, Rio de Janeiro, 22-27 September 2002, Earthscan Ltd., 2002, pp. 102-107.

Waller R.R., *Cultural Property Risk Analysis Model: Development and Application to Preventive Conservation at the Canadian Museum of Nature*, Göteborg Studies in Conservation 13, Göteborg Acta Universitatis Gothoburgensis, Göteborg. xvi + 189 pp., 2003.

Waller R.R., 'Comprehensive Risk Assessment: Applying the Cultural Property Risk Analysis Model to the Canadian Museum of Nature,' in I. Linkov, E. Ferguson, and V.S. Magar (ed.), *NATO Science for Peace and Security Series-C: Environmental Security: Real Time and Deliberative Decision Making*, Springer, 2008, pp. 179-190.

Waller R.R., *Assessing and Managing Risks to Your Collections*, Ottawa: Protect Heritage Corp., p. 90, 2018.

Assessing Risks in Historic Houses: Approaches and Benefits

Agnes W. Brokerhof
Senior Scientist,
Cultural Heritage Agency of the Netherlands, the Netherlands
A.Brokerhof@cultureelerfgoed.nl

Abstract

Over the years, an increasing number of heritage organizations have used some form of risk management. At a business level, it is already good practice to assess and manage financial, legal, business and reputational risks. For example, when exhibitions are planned and delivered the potential hazards that may threaten the project are taken into account. However, it is now common also to think about 'risks to cultural capital' as part of an organization's heritage management practice. Risk management is used in setting priorities and in providing arguments for decisions about affordable and adequate measures to manage and preserve heritage. It helps to answer questions such as: how do you exhibit objects responsibly? What are the priorities for the collection care plan? Are particular climatic conditions adequate? And, have appropriate security measures been taken? This presentation discusses general principles of risk assessment and management and different approaches such as a risk matrix, Cultural Property Risk Analysis Method, ABC-method, and QuiskScan. It looks at the advantages and applications of each method illustrated by case studies from historic house situations. All approaches have in common that the real benefit for organizations is the fact that all stakeholders involved in the process come to share the same insights, values and awareness and will more likely support the shared decisions.

Keywords

Cultural heritage, risk management, preventive conservation, decision making.

Heritage management, can be defined as the process of making well-argued decisions about the allocation of resources to most effectively and efficiently achieve the heritage profession's objectives. The main objective is passing on the heritage that is given in our care to next generations with optimum significance, values and accessibility. The heritage management triangle distinguishes three main activities to achieve that goal: development, preservation and use. Not just of heritage assets but of the values we attribute to them (fig. 1). Heritage management is really value management. On the one hand, there are opportunities to develop value. On the other hand, there are also threats that may cause loss of value. Heritage managers need to

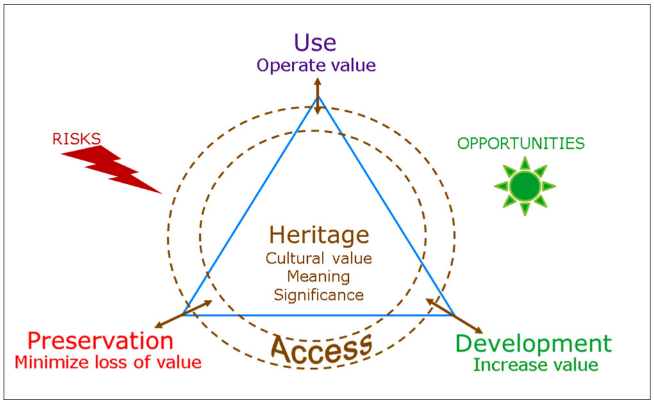


Fig. 1
Heritage management triangle.

balance acting on the opportunities and reducing the risks. The process of value management is described in Brokerhof, Kemp and Bülow (2017). This presentation will focus on the risk management part.

Risk Assessment and Management

Risk can be defined as the chance of loss of value. It tries to get a grip on an uncertain future. It deals with uncertainty, both about whether or not something will happen and what the loss of value will be if it happens. Risk is usually qualified or quantified as the product of, for example, chance x effect, or likelihood x consequence, or probability x impact. Or, to state it simple: how soon or how often is a loss of value expected to occur and how bad will that loss then be?

The steps of the general risk management process are described in the international standard ISO 31000 [ISO, 2009] as shown in figure 2. Most of the approaches follow this process or use parts of it.

Determining the context involves setting the scope, determining what the heritage asset consists of and assessing its value. For that purpose several value assessments method have been developed, for example, Luger *et al.* (2014).

Identifying, analysing, and evaluating risks together form the "risk assessment" in which risk scenarios are developed, likelihood and consequence are qualified or quantified, and risks are compared or ranked to set priorities (the yellow box in fig. 2).

Risk treatment involves developing options to reduce selected risks, to determine feasibility, effectiveness, and costs of options, and to select the optimal to implement. Options can be in the area of preventive conservation (avoid and block, proper storage solutions, safe use), may involve conservation treatment (stabilisation, consolidation to avoid further decay), or may deal with safety and security, facility maintenance, or training and education. This whole process takes place with ongoing monitoring and evaluation, and communication and consultation. It is the latter that really makes risk management so interesting. It brings people, knowledge and experience together and works towards shared objectives.

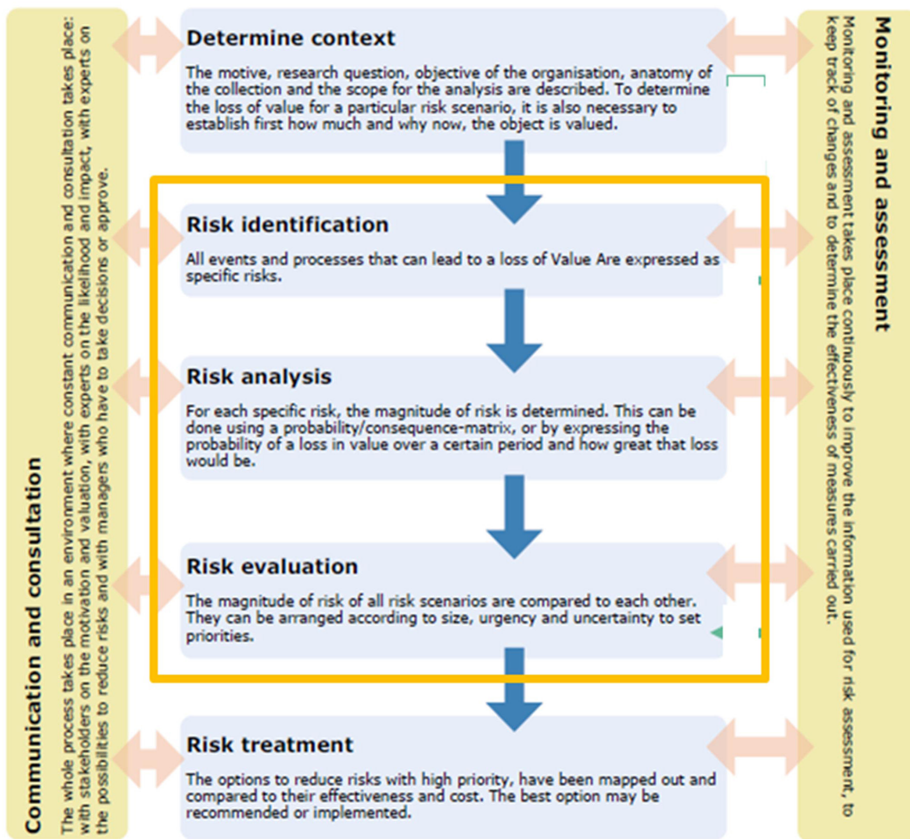


Fig. 2
ISO 31000 risk management process.

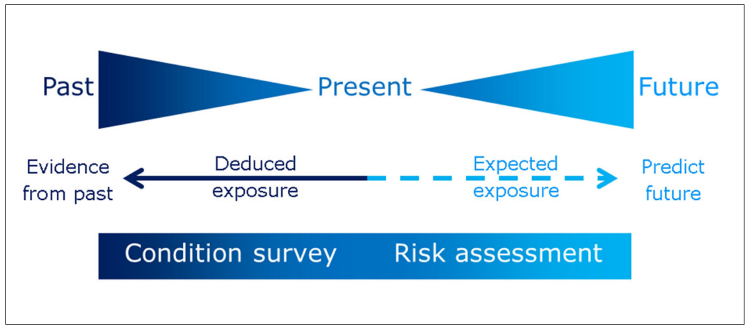
Risk assessment looks at expected exposure to threats and resulting future changes. It thus forms a logical counterpart of condition surveys, which assess present condition and correlate observed changes with past exposure (fig. 3). Risk assessment is also an extension of condition surveys. The information gained from past and present evidence is used to make predictions. Even though results from the past are no guarantee for results in the future.

Identifying Risks: Agents and Scenarios

Identifying generic and specific risks usually involves listing "all the things that can go wrong." To structure thinking for heritage most approaches use the agents of deterioration as a classification of causes or sources of threats: physical forces, water, fire, thieves/vandals, pests, contaminants, light/UV/IR, incorrect relative humidity, incorrect temperature, and dissociation [Michalski, 1990]. Description of the agents and information about them can be found on the website of the Canadian Conservation Institute and in Brokerhof, Ankersmit and Ligterink (2017).

To analyse the risks a risk scenario needs to be developed describing what is expected to happen so that likelihood and consequence can

Fig. 3
From deduction to prediction.



be assessed. A way to do this is thinking in a script which describes source-pathway-effect. Having such a script in mind also allows one to think about mitigation options such as avoiding the source (replace faulty electrical wires, forbid open fire), blocking the pathway (close curtains, place valuable objects in display case), or limiting the effect (have and rehearse an evacuation plan).

Why and How? Different Approaches

Conducting a risk assessment or embarking on a risk management process needs to serve a purpose. And the effort one puts into the exercise needs to be worth it. When crossing the street everyone is trained to do a fast and simple assessment which is good enough to get across in one piece. In the context of heritage management we also want to reach our goals effectively and efficiently and make the right decisions to get there. The complexity of the decision and the purpose of the outcome determine which approach is appropriate.

Choice Between Two Option: Pros and Cons

If the decision at hand is a choice between two options, comparing them on the basis of a number of relevant criteria is usually good enough. The criteria are always related to higher and lower objectives. For a historic house the question whether to use real or fake candles may concern creating a historic atmosphere and giving the visitor an enriching experience. However, other objectives are to preserve the house and provide safety for the visitors, hence have a low fire risk. There are also criteria (restrictions) concerning the budget, both for initial investments and subsequent operational costs. Listing these criteria and assessing the advantages and disadvantages of the two options, together with stakeholders, is usually enough to reach a decision (table 1). The option with the biggest gain in value (opportunist), the smallest risk (protectionist), or the most value for money (economist) will be the preferred one.

Risk Register and Risk Matrix

When more decisions are involved such as allocation of budget to act on a range of risks, a way to approach them is to list them and give scores for chance and effect. The list thus turns into a risk register and colour codes can be used to indicate their magnitude (fig. 4). A risk matrix of categories for chance and effect visualises what makes big or smaller risks. A 3x3 matrix with categories “small,” “medium,”and “large” results in nine cells where the combination of large chance and large effect results in a big risk (red cell). While a small chance and a small effect form a small risk (blue cell). It is beneficial if the assessment team defines the matrix beforehand and agrees on acceptable and non-acceptable risks. And they will need to agree what is “small,” “medium,” and “large.” This approach is often used in business and finance. Heritage organisations may use it to assess and manage business risks. If they do, it gives the heritage asset manager an opportunity to argue in a shared language fitting the organisation’s work method [Rogerson and Garside, 2017].

Cultural Property Risk Analysis Model (CPRAM)

Robert Waller was the first to develop a risk assessment and management method specifically for cultural heritage. His work started in the 1980s and culminated in his publication *Cultural Property Risk Analysis Model* [Waller, 2003]. It is the most comprehensive approach that we know in the heritage field, which offers a deep insight into heritage and organisation and can be applied for complex situations such as drawing up asset policies and conservation strategies. It determines the magnitude of risk as a product of probability of risk scenarios happening (chance) and the loss of value for the fraction of the collection that is susceptible in that scenario (effect). All the specific risks thus get a magnitude expressed as a number between 0 and 1. The results of the risk assessment can be shown in a 3D graph plotting the magnitude of risk of all scenarios per collection unit against the agents of deterioration (fig. 5).

Trained and coached by Waller staff of museum Our Lord in the Attic in Amsterdam and RCE (ICN at the time) applied the approach

Table 1
Listing pros (+) and cons (-) of options towards various objectives or criteria.

CRITERIA	**OPTION 1**	**OPTION 2**
	REAL CANDLES	**ELECTRIC CANDLES**
Historic atmosphere	+++	+
Visitor experience	+++	+
Risk of fire	- - -	-
Installation costs	-	- -
Power costs	+	-
Maintenance	- -	-

Nr	Source	Path	Effect	Chance	Effect	Risk
A	*blabla*	*blabla*	*blabla*	Small	Large	Medium
B	*blabla*	*blabla*	*blabla*	Small	Large	Medium
C	*blabla*	*blabla*	*blabla*	Small	Medium	Small
D	*blabla*	*blabla*	*blabla*	Medium	Medium	Medium
E	*blabla*	*blabla*	*blabla*	Large	Large	Biggest
F	*blabla*	*blabla*	*blabla*	Small	Large	Medium
G	*blabla*	*blabla*	*blabla*	Small	Medium	Small
H	*blabla*	*blabla*	*blabla*	Large	Small	Medium
I	*blabla*	*blabla*	*blabla*	Small	Large	Medium
J	*blabla*	*blabla*	*blabla*	Medium	Large	Big

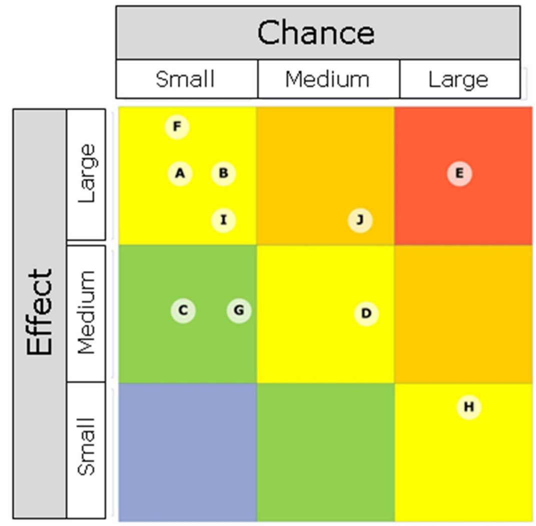


Fig. 4
Risk register and risk matrix to list and classify identified risks.

to assess the risks and develop a preservation strategy for the historic house with a hidden church in the attic (fig. 5) [Brokerhof *et al.*, 2005]. It took the combined team approximately three months to conduct the assessment. This considerable input was worth it. Not only was it a learning process for everyone, it also introduced a change in mind-set of the organisation. Everyone had a shared understanding of what the heritage asset was (a mixed collection AND a historic house), agreed on the values, understood risks and priorities and spoke the same language. The museum was also able to phrase arguments in such a way that external funders were willing to invest in thorough risk reduction plus development options. Where the original problem was fear of fast degradation of the 17th century staircase, the final solution was the redesign of the museum concept, returning the historic house to its original functions, and building an extension to house visitor facilities, supporting exhibitions, and community activities next door. The multi-million refurbishment project that ran over more than a decade had its roots in the risk assessment.

ABC-Method

During the years ICCROM, CCI, and ICN together with Robert Waller and other partners organised the international courses "Reducing risks to heritage," Stefan Michalski developed the ABC-method (fig. 6). It uses the agents of deterioration to identify risks and develop risk scenarios which are then quantified with three scores: *A* – for "how soon/how often," *B* – for "how bad for each affected item" and *C* – for "how much of the total heritage value." *A* thus looks at likelihood while *B* and *C* together make up the consequence for the entire heritage asset. The magnitude of risk for each scenario is the sum of *A*+*B*+*C* and since each can range from 1-5, the maximum magnitude of risk

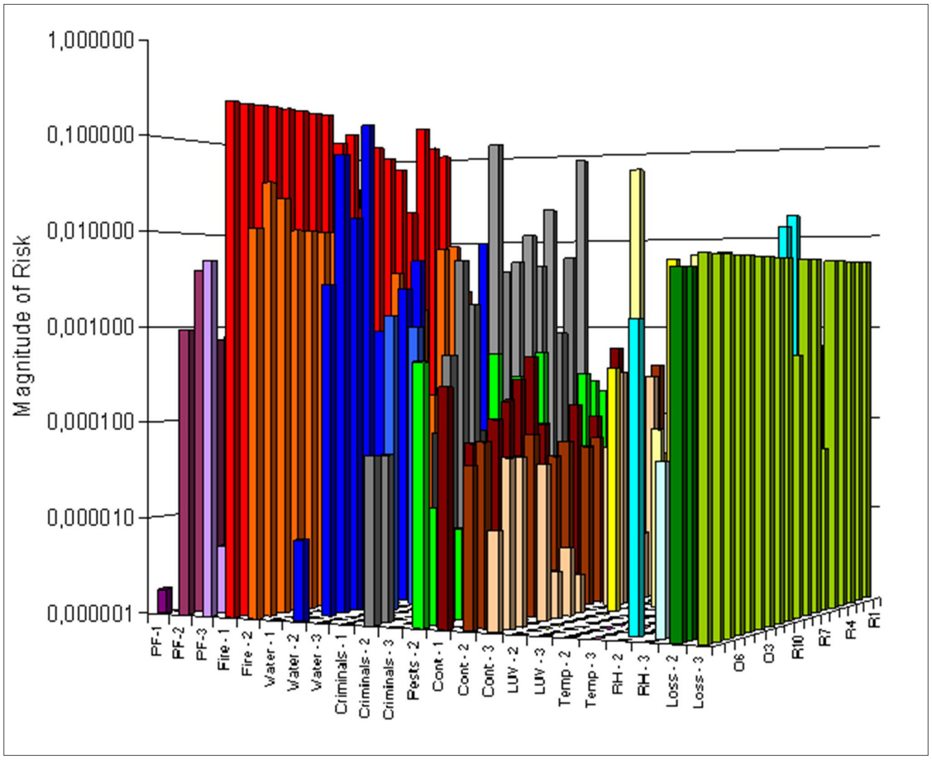
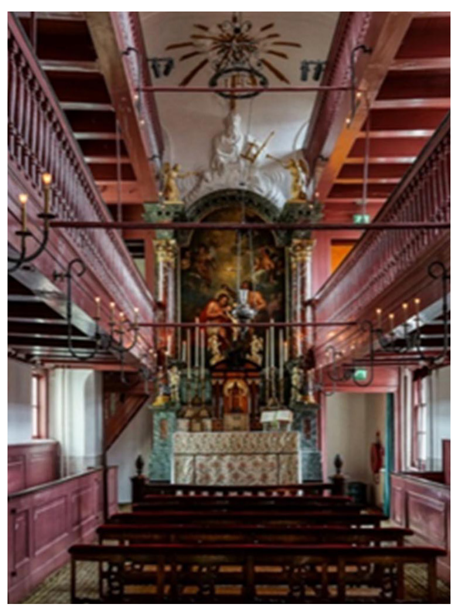


Fig. 5
Robert Waller's Cultural Property Risk Analysis Model applied at Our Lord in the Attic, Amsterdam.



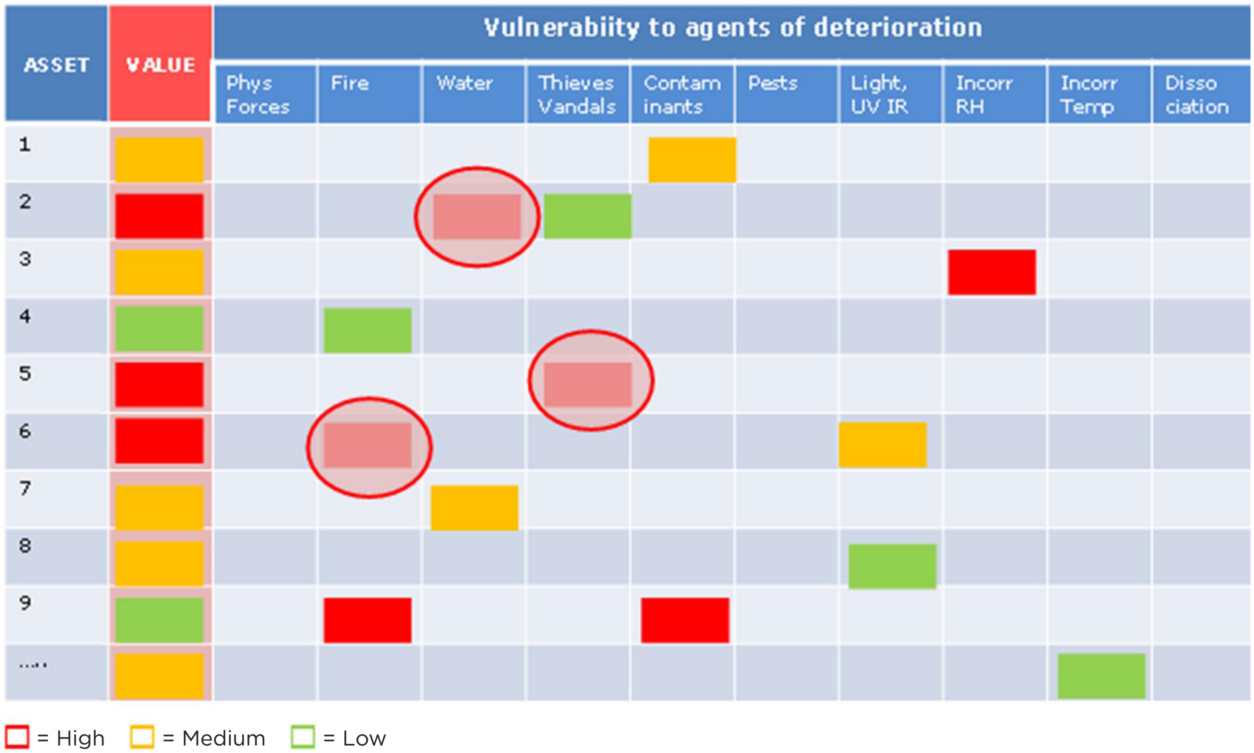
can be 15. There are methodological differences between CPRAM and ABC, for example the moment in the process when the overall asset or collection value comes into the ranking and decision-making. But they share the ISO 31000 set-up and the power of stakeholder involvement. The ABC-method may have an easier way of quantifying the risks and for many the resulting 2D graph is easier to interpret. Representing the magnitude of risk as stacked bar graphs of A, B and C has the additional advantage that one can easily spot the urgent risks (high *A*-score) and the big impact risks that may require a dedicated funding campaign (high *B*+*C* score).

The ABC-method proved suitable in the international ICCROM-CCI-ICN courses [Antomarchi *et al.*, 2014]. The experience was that participants and students found it relatively easy to understand and an assessment could be conducted in a few days to weeks, for example during a case study in the Sibiu Open Air Museum with historic houses and interiors (fig. 6). It allowed the participants to build a thorough overview of the assets and the risks and provided the museum with the foundations for a funding campaign for the recommended improvements.

QuiskScan

Despite training, coaching, and development of tools to support both CPRAM and ABC methods, organisations fear the effort that is required to carry out a systematic and detailed risk assessment. In addition, there can be feelings of inefficiency, when at the end much work is done and only a few risks are addressed. While organisations

Fig. 6
Stefan Michalski's ABC method applied during international course at the Open Air Museum, Sibiu.



that went through the process thought it was a mind-changing experience and well worth it, many just encountered a huge threshold to start. Museum staff with limited time needed a broad-brush approach that would enable them to identify potential risks and make a case for further detailed study. The challenge was to use the risk management foundations, designing a method that would lead a museum team through a process and provide insight into their cultural asset, the hazards and potential losses, open their eyes to the integrated approach, and induce an appetite for more in just a few hours. It led to the development of a quick risk scan, the QuiskScan, which was a stepping stone to a more in-depth analysis with one of the existing methods [Brokerhof and Bülow, 2016]. The design of the QuiskScan comes from the risk maps, such as earthquake risk maps, which show on overlapping maps where important assets are located and where exposure may happen. To form a relevant risk three parameters need to overlap: value of the assets, their vulnerability, and exposure. Valuable assets that are vulnerable to an agent of deterioration can undergo an unacceptable loss of value, however, only if they are exposed to that agent (fig. 7).

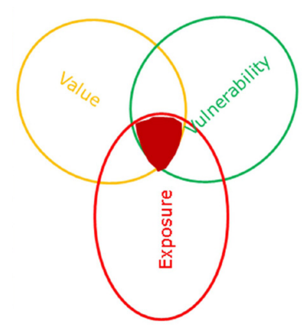


Fig. 7
QuiskScan matrix: vulnerable value = biggest potential loss that results in the analysis of exposure to the agent of deterioration and its principle of action.

Mapping Exposure and Assets

The actual risk mapping is also sometimes used. A good book that describes the approach within the context of emergency preparedness for communities and cities is by FEMA (2001). Figure 8 shows that drawing maps of a room showing where the valuable items are placed, how vulnerable they are for light and what the light exposure is, provides insight into which items are at risk and how relocating these items may reduce the risk. When communicating with people who are used to think visually or work with maps, such as facility staff and architects, this can be a very powerful approach to convey a message.

Combining Methods

Knowing that various approaches and methods exist allows one to not only chose the most appropriate method but also combine them. Experience shows that, when teaching preventive conservation and risk management to students, it is useful to start with mapping or a QuiskScan to select a number of risks that are subsequently analysed further with the ABC-method. It gives the students a quick overview of assets, values and vulnerabilities which allows them to then concentrate on in-situ conditions, assess exposure and determine whether and how specific risks should and can be reduced, keeping the integral view over the asset. The combined approach was published in the book *Risk Management for Collections* (Brokerhof, Ankersmit and Ligterink, 2017). The book also provides knowledge and information about agents of deterioration with a scenario scheme for each agent to assist identification and analysis of risks. Although the title suggests it is written for collections, it is also applicable other types of heritage.

In 2017, a group of 15 Master students from the University of Amsterdam applied the combined approach at the Modern Contemporary Museum (MOCO) in Amsterdam during a 1-week risk management module (fig. 9). The museum displays its art collection in a listed

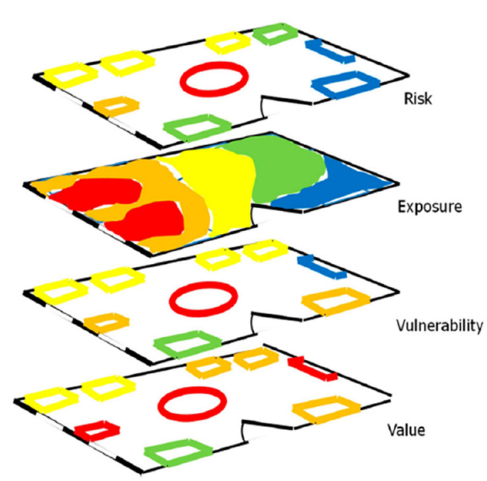
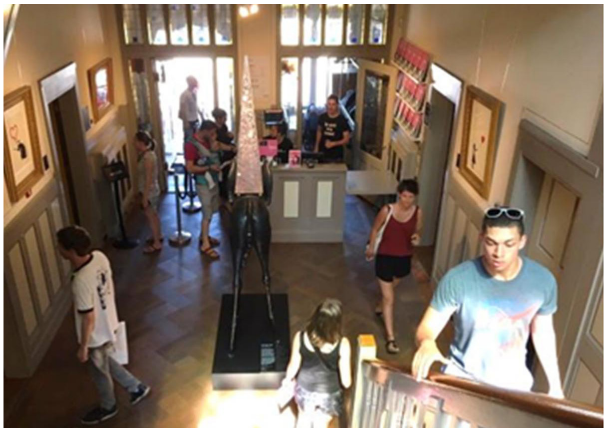


Fig. 8
Hypothetical light risks in an interior determined with stacked maps for value, vulnerability and exposure.



Deelcollectie	GW	FK	Water	Brand	C&V	Ongedier	Veront	LUV	onj RV	onjT	Disso
Werk op papier of karton	10,7										
Verf op doek	12,6										
Verf op hout	7,8										
Metaal met/zonder verf	3,7										
Steen en gips met/zonder verf	8,0										
Verf op kunststof	0,8										
Werk op perkament of leer	0,9										
Varia	5,5										
Vloeren 1000 m2 = 100 st	13,7										
Wanden	12,9										
Plafonds 1000 m2 = 100 st	2,7										
Glas-ramen	2,4										
Fixtures	18,3										

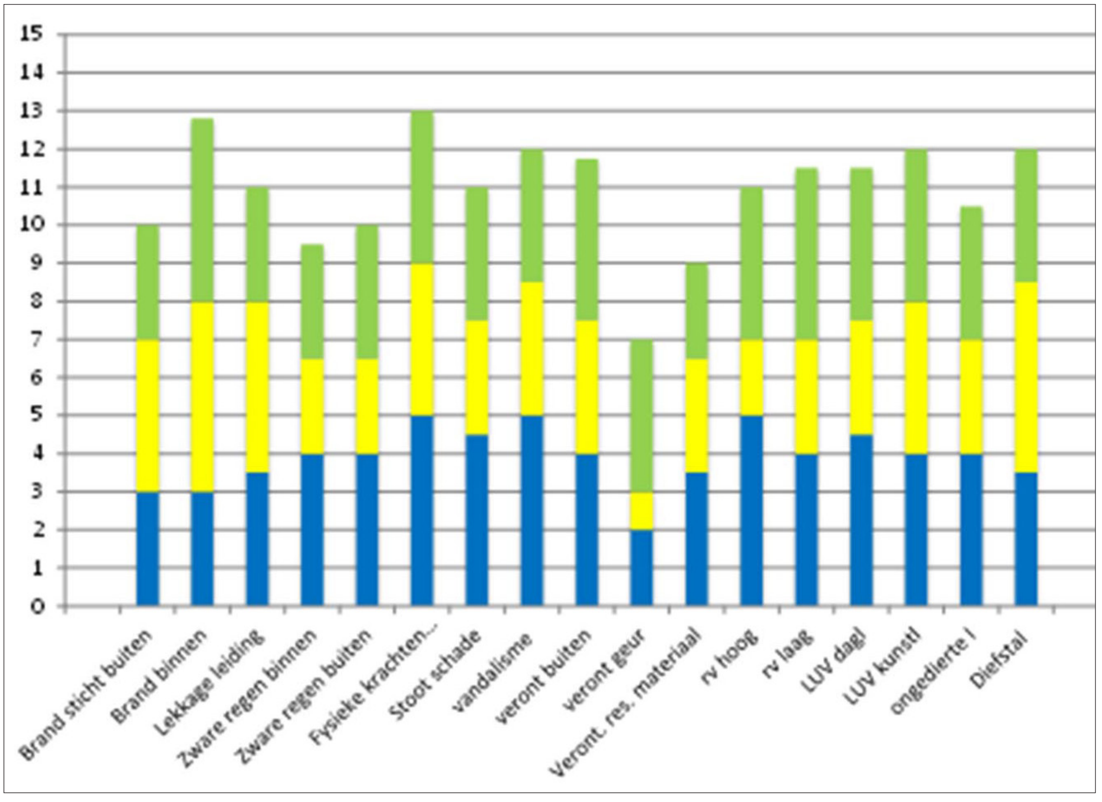


Fig. 9
Application of combined methods with students at MOCO, Amsterdam.

historic house. During the week, the students were able to produce an overview of built and moveable assets, their value and vulnerability, and potential risks. They selected the most relevant risks, analysed these in more detail, set priorities, and developed options for risk reduction. Altogether they were able to make sound, practical, and useful recommendations to the museum. It showed that they were able to apply their conservation knowledge at the level of heritage management and that they were able to consider use and preservation of the historic house and the collection from a holistic perspective.

Comparison of Approaches

Considering risk assessment to support decisions or risk management to improve preservation conditions, there is not one best approach or best method. As always, each method has its strengths and weaknesses. It depends on the context in which a decision has to be made, which approach is the most appropriate or fit-for-purpose. Table 2 lists the methods that have been discussed here with some comments on time needed to conduct the assessment, what the outcome can be, and when, what or for whom to apply it.

Just like with options for risk mitigation, choosing the appropriate approach or combination of approaches is a matter of benefits and costs, is the effort that you put into it worth the outcome? The more impact the outcome of a risk management process has, the more effort is justified and probably also required (fig. 10). After all, one needs well-founded arguments to convince others of proposed actions and options. Also the opposite is true: garbage in is garbage out. Too little consideration when doing a risk assessment will not provide useful results. They are either not convincing or simply wrong.

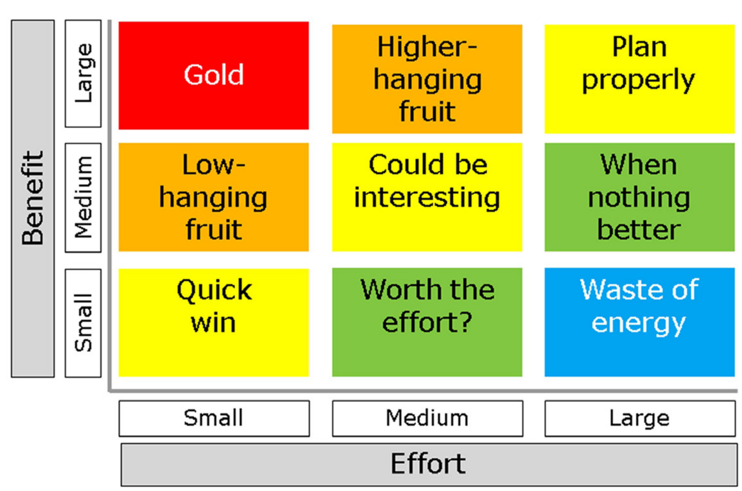


Fig. 10
Simple cost-benefit matrix.

METHOD	DURATION	OUTCOME	APPLICATION
Pros and Cons	Hours	Choice	Compare limited options
Register and Matrix	Weeks	Overview of risks Easy visual outcome	Make an inventory of a situation Connect with organisation, language of facilities and business administration
CPRAM	Months	Comprehensive insight Loss of value to units Priorities	Develop strategy or policy Requires data and data crunchers Outcome visualised in different ways
ABC	Weeks	Useful insight Loss of collection value Priorities	Develop strategy or policy Cost-effective mitigation Connect with bar chart readers
QuiskScan	Days	Rapid overview Rough insight Priorities	Basis for further analysis Indication of hot spots Fit for traffic light readers, managers
Mapping	Days	Visual overview Powerful insight	Assessing one or few agents Connect easily with map readers, facilities

Table 2
Various risk assessment approaches compared by time typically required to apply properly, type of outcome and suitability for situation or audience.

In Conclusion

Conducting a risk assessment is a very powerful approach to gain insight in a situation and identify where improvements can be made, for example in the area of preventive conservation. The most powerful aspect of risk assessment and risk management, regardless of the approach one chooses, is the fact that they bring together people with their knowledge and experience. This feature creates a joint understanding of objectives and challenges, and generates buy-in for shared decisions.

A few rules of thumb for selecting an appropriate approach:
– keep it cost-effective;
– build up in steps;
– be aware of shortcomings and biases;
– connect to existing systems and methods;
– include as many stakeholders as possible;
– communicate and engage;
– persevere and keep going.

Bibliography

Antomarchi C., Brokerhof A., Stevenson J., 'Reducing Risks to Cultural Heritage: Analysis of a Course Metamorphosis,' in *ICOM-CC 17th Triennial Conference Preprints, Melbourne, 15-19 September 2014*, ed. J. Bridgland, art. 0301, 8 pp., International Council of Museums, Paris, 2014. http://icom-cc-publications-online.org/PublicationDetail.aspx?cid=1d667ab5-c436-42b6-922d-8e43b-92c86c8 (accessed on 24 January 2018).

Brokerhof A., Ankersmit B., Ligterink F., *Risk Management for Collections*, Cultural Heritage Agency of the Netherlands, Amersfoort, 2017. https://cultureelerfgoed.nl/sites/default/files/publications/risk-management-for-collections_a.pdf (accessed on 24 January 2018).

Brokerhof A., Kemp J., Bülow A., 'Value Management Scan: Setting Priorities in Management and Care of Collections,' in *ICOM-CC 18th Triennial Meeting 2017, 4-8 September 2017 Copenhagen*, ed. J. Bridgland, International Council of Museums, Paris, 2017. http://icom-cc-publications-online.org/PublicationDetail.aspx?cid=4644ffc1-8abf-4f4f-8d19-4aadc68d4423 (accessed on 24 January 2018).

Brokerhof A., Kemp J., Bülow A., 'The QuiskScan – A Quick Risk Scan to Identify Value and Hazards in a Collection,' in *Journal of the Institute of Conservation*, 39(1), 2016, pp. 18-28. http://dx.doi.org/10.1080/19455224.2016.1152280 (accessed on 24 January 2018).

Brokerhof A., Luger T., Ankersmit B., Bergevoet F., Schillemans R., Schoutens P., Muller T., Kiers J., Muething G., Waller R., 'Risk assessment of Museum Amstelkring: Application to an Historic Building and its Collections and the Consequences for Preservation Management,' in *ICOM Committee for Conservation, 14th Triennial Meeting, The Hague, 12-16 September 2005: Preprints* , ed. I. Verger, James & James, Earthscan, 2005, pp. 590-596.

FEMA, *Understanding Your Risks: Identifying Hazards and Estimating Losses, State and Local Mitigation Planning*, How-to guide 386-2, Federal Emergency Management Agency, Washington, DC., 2001. http://www.fema.gov/media-library/assets/documents/4241 (accessed on 24 January 2018).

ISO, *ISO 31000: Risk Management – Principles and Guidelines*, International Organization for Standardization, Geneva, 2009.

Luger, T., Brokherof, A., Hartog, S., Huisman, G., *Assessing Museum Collections; Collection Valuation in Six Steps*, Cultural Heritage Agency of the Netherlands, Amersfoort, 2014. http://cultureelerfgoed.nl/publicaties/assessing-museum-collections (accessed on 24 January 2018).

Michalski S., 'An Overall Framework for Preventive Conservation and Remedial Conservation,' in *ICOM Committee for Conservation, 9th Triennial Meeting, Dresden, 26-31 August 1990: Preprints*, James & James, London, 1990, pp. 589-591.

Michalski S., Pedersoli J.-L., *The ABC Method*, Canadian Conservation Institute, Ottawa, Canada, 2016. https://www.canada.ca/en/conservation-institute/services/risk-management-heritage-collections/abc-method-risk-management-approach.html (accessed on 24 January 2018).

Rogerson C., Garside P., 'Increasing the Profile and Influence of Conservation – An Unexpected Benefit of Risk Assessments,' *Journal of the Institute of Conservation*, 40, 2017, pp. 34-48.

Waller, R., *Cultural Property Risk Analysis Model: Development and Application to Preventive Conservation at the Canadian Museum of Nature*, Göteborg Studies in Conservation 13, Göteborg: Göteborg Acta Universitatis Gothoburgensis, 2003.

The Assessment in Preventive Conservation, Searching for Values

Denis Guillemard
Former Director of the Master in Preventive Conservation, University Paris I Pantheon-Sorbonne
guillemard.denis@noos.fr

Abstract

The introduction of evaluation methods in the field of heritage conservation implies, although they are never explicitly stated, the question of the values by which organisations are judged. The evaluation is the product of a succession of classification operations, measurements and data selections. All these operations search for as much objectivity as possible in the description of conservation conditions and of degradation agents. Evolving by necessity between the quantitative and the qualitative, evaluations in the field of heritage conservation, even if they are meant to be pragmatic, cannot claim to offer a total rationality in the quest for data. This contingent part of the context in which they evolve is decisive in the construction of evaluation tools. While these allow to give a value to expected but measurable results, the attribution of the evaluation criteria remains partly subjective.

But the situations can be appreciated only in relation to the models that represent what is to be, what we want to tend to. The mirage of the quantification induced by the use of norms and appreciation criteria must not loose sight the fact that no value system has inherent objectivity. It only translates what momentarily corresponds to a dominant model in the search for results. Rankings, grids, scales of appreciation are only admissible if choice relativity is set down by those who build them because we are in the presence of open systems that schematisation must neither close, nor freeze.

Keywords

Preventive conservation, evaluation, values, norms, criteria.

The Need for Evaluation

For several years, evaluation has become a necessity, even an injunction that is spreading across all sectors, seeking to base decisions and actions on efficiency, conformity or rationality criteria. This need is now so widespread that we are talking about "fever or evaluative folly" [Prigent, 2009]. Through this symptom, we can observe the consequence of the development of the computer tool which allows to manage a large amount of data, but also the tendency in contemporary society to want to put the world in order, to impose quantification on it and submit it to algorithms.

Given the complexity of the functioning of contemporary institutions where the introduction to preventive conservation has led to a significant increase of parameters to be mastered, evaluation has to be the most effective tool for dealing with these new conservation developments and the dissemination of heritage collections.

The difficulty of creating an evaluation tool peculiar to the preventive conservation field lies in the fact that the evaluative practice has spread to the museum world only in the last twenty years. Previously, we mainly spoke of *Survey*, which was an evaluation without addressing the question of values. These were considered from the point of view of cultural property per se and not from the point of view of their conservation. The latter followed the heritage designation act as a technical answer after a piece or object had been recognised as carrying cultural value [Avrami, 2000, p. 8]. But the value given to the object does not induce the values on whose behalf the conservation process is organised to achieve its objectives: preserve to transmit. Until 1990, the methods that were used to assess conservation conditions took the form of decision support by drawing up an inventory revealing the weaknesses and strengths of the organisation. There was no existing comprehensive method of specific assessment for heritage institutions, with systemic evaluations being developed mainly in the education and the economic sectors. In these two sectors, in the interest of control or compliance, the focus was on reporting system performance, diagnosing weaknesses and proposing improvement solutions.

From Survey to Evaluation

Early museum evaluations focused on exhibitions and public reception and "many approaches can be read as ways to justify the activity rather than trying to better understand its value" [Mairesse, 2010]. They have a purely technical vision evading the meaning of the studied devices.

It was in 1990 that the talk on the conservation assessment started with the Getty Conservation Institute, which published *The Conservation Assessment: A Tool for Planning, Implementing, and Fundraising*, which was then followed eight years later by *The Conservation Assessment: A Proposed Model for Evaluating Museum Environmental Management Needs*. Even though Suzanne Keene does not decide in 1991, in her UKIC paper, to yet differentiate audit and *survey* [Keene, 1991], the aim of both Getty publications was to analyse and characterise conservation conditions, degradation causes and factors and then to propose a strategy and an action plan that goes beyond simply registering the condition report to which the survey was limited.

In 1992, with Michalski's publication *A Sytematic Approach to the Conservation*, risk management and an inclusive approach to conservation are suggested. This is a decisive step because we move from normative to predictive. The aim is to introduce the cost estimation of the value loss caused by a potential degradation, so as, it is specified in the text, to "reduce the total percentage of damage," over a whole collection and to take all the degradation factors into consideration. From then on, the scale and objective are changed.

It was only a short step towards risk evaluation, as developed from 1993 onwards by Robert Waller, then taken up by ICC/ICCROM, that leads to the ABC method in 2016, which claims a comprehensive knowledge and a comprehensive appreciation of all the risks to which a heritage collection is exposed.

At the same time, proposals for self-evaluation are being developed to identify, according to immediate and localised needs, analyses and diagnostics of conservation conditions such as in Belgium [Bonnier, 2003] or in Switzerland [Meyer, 2011]. Also in 2011, the ICCROM offers, with the help of Gaël de Guichen, *Re-org, outil d'auto-évaluation pour les réserves de musée* using forty-three evaluation criteria applied to four areas for reorganising the reserves.

Also, through all the evaluation methods that have been developed since the beginning of this century and whose very complete account and comparative evaluation are made in the *Cronache 7* publication [Forleo, 2017], we start to have an overview of the evaluations whose common point is to quantify through quantified indicators both the state of conservation conditions and the priorities, but without explicitly addressing the question of values.

But an evaluation is not only a report, and it differs from a survey, as it must sustain a relation with the value. It is therefore a question of identifying a scale of values that will make it possible to determine the relation of the organisations evaluated on this scale, because before judging, we must put this in the light of what we judge, in the name of which principles are heritage collections preserved and transmitted.

In 2009, Nathalie Heinich, in *La Fabrique du patrimoine*, showed the different levels and processes of value judgement that project heritage into the news and allow its improvement: "The value, she says, is 'administered' to the object, in the sense in which it is proposed and then attached to it, in a more or less effective and lasting way according to whether the object accepts, supports, integrates this operation" [Heinich, 2009, p. 259]. The value assigns and manages a status and this concept of *operating* value will be developed more widely by the same author in another book: *Des valeurs. Une approche sociologique* [Heinich, 2017]. But this question about value is crucial in historical monuments where the first object of the collection is the building itself. It is not only a repository, it is heritage in its container as well as its contents. It is the *catch* that makes that each object it receives makes the history of the place present and gives it its value of re-presentation and exhibition. When a loss of value is observed on an object from a collection or on the entire collection in a historic house, it doesn't only concern the value of the object but it is transferred to the values that situate it within the ensemble. The objects hold a value as much by their historical stature as because of their link to the site and its history (effect of presentification and representation).

The Introduction of Value

Value is the product of operations by which quality is assigned to a situation, an action or an object. Awarding a value, or the choice to use one or the other, is a complex, discontinuous and discreet process that is representative of the culture of which it is the expression. This is what makes conservation assessment operations contextual and variable.

The evaluations, that is, the judgment that awards a value, depend on the nature of the evaluated situations, the capacity and resources of the evaluators (their axiological equipment) and the context on which the analysed situations depend (constraints, determinations). By interacting with his culture, the evaluator uses the values indicated by his mental representations conditioned by his intellectual background and experience. Any evaluation therefore remains dependent on the rules and criteria that allow it to build and exist. Each act of evaluation proceeds with the choice of what is to be mobilised as referential, that is to say, the "effective interactions" between situations, objects, humans and contexts. Thus, improvement operations depend on the nature of the evaluated situations, of the evaluator's capacity and resources and the context from which result the constraints and determinations of the analysed situations.

It is in the recognition of the three operators – object, subject, context – and in the use of values [Heinich, 2017], that the practice of evaluation in preventive conservation evolves.

However, in our evaluation process, the values are never set down. They are implicit. We can nevertheless, by experience, designate some that control the use of cultural heritage collections and their conservation:

– The values applicable to the object (heritage values), which, without attributing an economic value, place it in a scale of cultural importance corresponding to its own network of designation: antiquity, authenticity, rarity, preciousness, historicity...

– These values recognise the object as heritage and worthy of preservation. They intervene in cost calculation of conservation of a set of objects or the loss of value caused by bad conservation conditions. Ultimately, they can intervene to define the relative importance of the objects within a set that involves classifying the prescriptions of an action plan [Keene, 1991, pp. 139-142].

– Values applicable to operating conditions (precautionary management values) that allow to establish in the long term the organisation of the development of the collections. These are the *principles* on whose behalf we act and make cultural collections efficient: availability, accessibility, mobility, visibility...

– Values applicable to conservation conditions (state values) by which the sets of collection pieces are organised to meet management values. These values are used as conformity criteria and they are decisive for the observation of the way we maintain: efficiency, integrity, durability, rationality, order, storage, classification, protection...

And overhanging everything, preside conservation and transmission values, in whose name the improvement of collections of objects recognised as heritage, is carried out through the values of use ensuring the **dissemination** and the option values and the legacy guaranteeing the **transmission**.

Three of these values are decisive in establishing conservation conditions.

First the availability that makes possible the use of cultural collection objects by protecting them by law, identifying them with the inventory and locating them in the institutions.

Second is accessibility, which includes all the provisions and the material operations that allow to grasp, see and consult collections. The accessibility covers three aspects:

1. There is accessibility to the meaning and the message conveyed by the objects. They mean something invisible: the past, the sacred, the memory [Pomian, 1987]. But for them to keep on being what they are, their form, defined by the material, must stay readable, and therefore accessible to knowledge. Also accessibility has for a limit the integrity of the material without which it is impossible to recognise and transmit the particular signification of which they are depositary;
2. There is accessibility to knowledge of the objects through inventory and documentation. Without recording the data concerning creation conditions, studies and interpretations, in a corpus made up of organised, available and accessible documentation, the objects cannot render their entire richness. Conservation also works on constituting and perpetuating this documentation;
3. Finally accessibility to the objects themselves through storage, location, handling and marking conditions. A heritage object that cannot be seen and is difficult to identify and locate cannot respond to the use for which it is intended.

Thirdly, the mobility which concerns all the operations or arrangements allowing the movement of the objects: handling, circulation, transport, hanging... Mobility ensures the utilisation of cultural pieces either in the form of the consultation or in the form of the mediation (exhibitions).

These values are not hierarchical but operate in interaction, the

CONSERVATION To enable future generations to dispose of collections in the same conditions as we have today		
Initial Values	Diffusion **Communicability** Consultation, dissemination, mediation, exhibition on which the mode of existence of cultural collections is based.	Transmission **Transferability** Articulation of knowledge, the sacred or the precious, without which there is no heritage.
Heritage Values <Appreciative Principles>	Social, symbolic, aesthetic, historical **Antiquity, rarity, preciousness, historicity...**	
Precepts Values <Operating Principles>	Values by which sets of cultural collections are managed **Availability, accessibility, mobility, rationality, security...**	
State Values <Evaluative Principles Compliance Criteria>	Values that characterise a situation and identify how cultural collection pieces are being exploited **Efficiency, integrity, durability, order, cleanliness, protection...**	

Table 1
Distribution of values for heritage conservation.

register of some affirming or invalidating the register of others.

Thus, if we consider the *accessibility* of a collection of objects in the reserve or in storage, the value judgment will be based on the *rationality of spaces* and the *order* (state values). The *order* value, which meets the conformity criterion, refers to the *accessibility* value as the acting principle of a well-organised and efficient reserve (which can be translated for example by the criterion of time required to dispose of an object).

If we take the more prosaic example of *cleanliness*, we can consider it as a value because the presence of dust has an effect on the appearance of objects and their exhibition value. It leads to the inability to satisfy the values of *integrity* (alteration of the appearance) and *availability* (the objects can not be exhibited or lent as they are). From the point of view of evaluation, the *cleanliness* value, as a conformity criterion, activates *availability* as a working principle, calling for a prescription.

Values, Norms and Criteria

A situation can only be appreciated in relation to a model that represents what is to be, what we tend to. To place the level of performance and determine the quality of conservation conditions, we use **norms** or **criteria.** These characteristics, which establish links and dependence between themselves and whose distinction with the values can be difficult to establish, have an *instrumental* role in the recognition of the system's state and the production of judgment value.

If these terms can seem interchangeable, they nonetheless play a specific role in the evaluation, explicitly clarifying the role values, the existence of which is often implicit. These technical aspects of the evaluation constitute what is most obviously rational in the process. A congruence is sought between the experience and the principles that manage the conservation, between the goals, the means and the foreseeable consequences of the action (finality), for the rationality supposes a set of means is adapted in order to reach a definite purpose.

The **norm** refers to a dictate that indicates that something must be or happen. It is the prescriptive side of value. The norm is always established for an end (result of a behaviour, consequence of an action). Therefore, in order to be in a normative necessity, that end and means must be wanted but there are choices to be made because all the means are not valid. For there to be a norm, there must be the *desire* to produce something. The norm is not an end in itself: "The standard does not want anything," says Kelsen, it is necessary to aim at something while laying down a norm [Kelsen, 1996, p. 13]. It is the norm that will signify the act and give it an end. The example of the climate norm is significant from this point of view: it is an appropriate humidity in relation to a context that must be the norm and not an imposed value: "50% for wood!" But the goal is to conserve the wood, it is not to reach 50% of RH. This example illustrates the confusion that can establish itself between the *necessary* and the *possible*, between means and the end. Oscillation between knowing what one **wants** to do and knowing what one **must** do, nuance between subjective end and objective end, between what is desired and what is obtained. In any case, if the end is well determined, the means to execute it are not. It is the whole question of norms and their effectiveness that arises. But also of the evaluation's purpose: to evaluate for what end? To comply with norms or make the collections available and accessible to the public?

Criteria are constant characteristics that allow the appreciation, the selection or the recognition of the qualities required to establish good conservation conditions. These are the specifications that are used to judge that something is consistent with the values [Heinich, 2017, p. 228]. Any evaluation remains dependent on the rules and criteria that allow it to be constructed and exist.

Criteria call for a scale of value allowing to classify facts according to their congruence with the desired order of things (conformity of a situation or of a given action with respect to a repository). The judgment can be expressed by numerical indicators (indices), classified on a scale from a positive pole to a negative pole. This quantified aspect gives the judgement an objective characteristic, although a bit artificial for, in the statements, quantifiable elements that want to be as objective as possible will coexist with elements in a subjective position that are induced by the mere fact of operating choices. But the fact remains that this numbering gives a tangible basis for what could only be a sensation or a feeling, various perceptions that can prevail in the same situation.

The evaluation, as envisioned here, goes beyond the mere control operation in its design and scope to make sense of conservation devices. What needs to be established is that evaluation must remain the tool of change and not the means to subject organisations to the dictates of the measurable or the quantifiable. It must stay a method, proposed for risk prevention and degradation causes, a tool adapted to the needs of knowledge and the control of the parameters of conservation conditions, targeting and adapting actions which need to be carried out in institutions. The tools and means of evaluation can be used as resources that can be mobilised to make systems evolve and not to make them subject to profitability or rationality of cultural behaviour.

Bibliography

Avrami E., Mason R., Torre M. de la, *Values and Heritage Conservation*, The Getty Conservation Institute, Los Angeles, 2000.

Bonnier B., Collin F., Pierpont G. de *et al.*, *Je gère un musée aujourd'hui pour demain, Questionnaire d'audit interne à l'attention des gestionnaires d'institutions muséales*, Roi Baudouin Foundation and Museums and Society in Wallonie, Bruxelles and Namur, 2003.

Forleo, D. (dir.), *Cronache 7, Epico European Protocol in Preventive Conservation - Évaluation de conservation des collections dans les demeures historiques*, Sagep publisher, Genova, 2017.

Heinich N., *Des valeurs. Une approche sociologique*, Gallimard, Paris, 2017.

Heinich N., *La Fabrique du patrimoine. De la cathédrale à la petite cuillère*, Maison des sciences de l'homme publisher, Paris, 2009.

Ipert S., Le Guen G., Meric L., Tapol B. de, *Une méthode d'évaluation des pratiques de conservation préventive dans un service d'archives*, La documentation française, Direction des Archives de France, Paris, 2002.

Keene S., 'Audits of Care: Collections Condition Surveys,' Storage: Conference Preprints, *UKIC*, 1991.

Kelsen H., *Théorie générale des normes*, Léviathan, PUF, 1996.

Mairesse F., 'Évaluer ou justifier les musées ?,' in *La Lettre de l'OCIM* (online), 130, 2010. URL : http://journals.openedition.org/ocim/130 ; DOI : 10.4000/ocim.130 (put online on 1 July 2012, accessed on 7 July 2018).

Meyer C., Mina G., A., *Un musée de qualité, Auto-évaluation*, Association of Swiss Museums, Zurich, 2011.

Pomian K., 'Entre l'invisible et le visible : la collection,' in *Collectionneurs, amateurs et curieux, Paris, Venise : XVI^e-XVIII^e siècle*, Gallimard, Paris, 1987, pp. 14-59.

Prigent M., *L'idéologie de l'évaluation, la grande imposture*, Cités, 37, 2009.

Reasonable Doubt: the Diagnostic Potential of Connecting Risk and Condition Data

Joel Taylor
Senior Project Specialist,
The Getty Conservation Institute, USA
jtaylor@getty.edu

Abstract

Decision-making in preventive conservation requires dealing with a range of uncertainties. Objects do not necessarily deteriorate in environments considered damaging, and can change in environments considered acceptable. Assessment methods can be better suited to some problems more than others. The believability of a conclusion may rest on standards or information that does not reflect the specific situation.

Collection condition assessments do not indicate unrealised damage and risk assessments are based on predictions of things that may not occur. If both are carried out, there can be disagreement because they assess different things. This paper, however, argues that discrepancy can be meaningful rather than problematic. Recognising and responding to disagreements in different data can lead to more nuanced conservation decision-making in practice. This helps identify where uncertainty lies, and prompts deeper analysis of the situation. Seeing discrepancy means that uncertainty can become a diagnostic tool.

The paper describes practical situations where discrepancy between risk and condition data can be meaningful, including the English Heritage collection audit which was able to diagnose problems and develop robust analysis by utilizing both risk and condition data.

Keywords

Condition, risk, preventive conservation, discrepancy, historic palaces.

Maps have provided a source of fascination since their first creation, often possessing aesthetic as well as utilitarian value. Even when the information they contain has long since been updated, they can become collectors' items and historic artefacts in their own right. Part of this enduring fascination is that maps tell us not just where we are, but they tell us who we are. The things that appear on a map indicate what was important to its creators and users. They tell us what features were worth documenting, the relationship between those features, of where there is danger or good fortune, and even where there is uncertainty (fig. 1). Although historic maps can reveal the limits of accuracy that people worked with, they must be acknowledged as essential tools that helped people look beyond the territory where they stood to places they might have never been.

This process of creating and using maps has many parallels to the

Fig. 1
An excerpt of the Carta Marina map depicting the west of Norway, geographical features and warnings of trolls, sea monsters, and whirlpools. https://no.wikipedia.org/wiki/Fil:Maelstrom,_Carta_Marina.png

ways in which we document collections. The expanse that we wish to chart is partly geographical but also temporal, as we try and better understand how collections have changed, and might change over time. How we make decisions about preservation depends on how we document these matters. Preventive conservation assessments examine a network of interactions and reactions, but in slightly different ways. Covello and Merkhofer [1993] introduced the notion of the risk chain (fig. 2), which moved from the existence of a hazard (Release), through its contact with an object (Exposure), through the interaction of object and hazard (Interaction), to the consequences of that interaction (Consequence, or "damage" in the case of preventive conservation in historic houses).

In terms of preventive conservation assessments, risk assessment focuses on the earlier steps, highlighting the progress of hazards. Condition assessment focuses on the later steps, highlighting the consequences. Moving this concept to application, causes have causes, and consequences have further consequences. Some interactions require more than one hazard, and in all cases the chain is really a close-up look at the network of the museum environment. These approaches ask questions about this network of interactions. We must make assumptions about the environment with high levels of uncertainty.

Uncertainties

The presence of a hazard doesn't necessarily mean there will be damage, and the presence of symptoms doesn't necessarily single out a cause. The museum environment is complex and damage can be the result of several factors acting together, synergistically, or compounding over time,

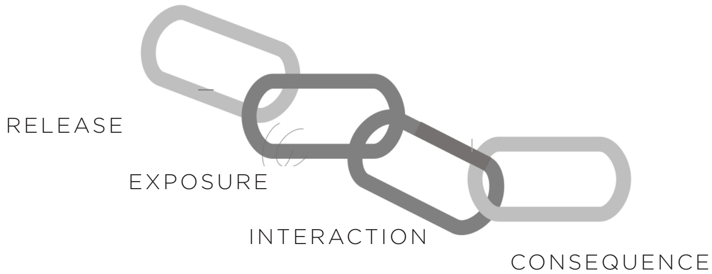


Fig. 2
Risk chain based on Covello and Merkhofer, 1993.

such as surface flaking increasing susceptibility to handling damage.

Taylor [2005] pointed out that objects don't always do what they are expected to do, identifying four broad categories that related to the kinds of uncertainties where expectations differed from reality:

– objects remaining stable in conditions considered "unacceptable;"
– objects deteriorating in conditions considered "acceptable;"
– objects of the same material responding differently to the same environment;
– object deterioration not always being visible or having evident symptoms.

These uncertainties affect different kinds of assessments in different ways. Object behavior that does not correspond to predictions of that behavior poses problems for risk assessment. Object deterioration not presenting identifiable symptoms poses problems for assessing condition. Both approaches have several areas of uncertainty.

The field has a representation of how materials responds to their environment, which does not (and cannot) provide a complete representation of every situation. The author Borges [1946] warned of the impractical aspiration of absolute accuracy in a short story about cartographers who became so fixated with reducing uncertainty that they created a 1:1 scale map. Realistically, conservators must deal with uncertainty in a variety of ways.

Different representations deal with uncertainty in different ways. Although this could be perceived as an opportunity to choose the approach with the least uncertainty, there is another opportunity. Instead of seeing different approaches as rivalrous, and conflicting results as problematic, the different assessments could be considered as mutually helpful supports against the inherent uncertainties of the other.

"Experts may be uncertain but feel forced into declaring certainty... [So] two people that agree, and share the same uncertainty, may appear to hold different opinions" [Ashley-Smith, 1999, p. 336]. By the same token, discrepancy between the outcomes of assessment methods might not mean that one of the assessments is wrong. It might mean that a difference in data is meaningful.

Discrepancy

When assessments measure different things, discrepancy can be expected. Approaches that focus on causes (risk) or effects (condition), hold assumptions that stem from their use (table 1).

Recorded causes are intended to tell us something about effects. Recorded effects are intended to tell us something about causes. Individual differences may be the result of one method being more accurate than another, but these methods are designed for broader perspectives. There can be a number of reasons for discrepancy that can be observed in practice, which can reflect the practicalities of preventive conservation assessment.

Risk Type

Waller (1994) classifies different kinds of risk: rare, rapid-onset hazards that can be catastrophic, like earthquakes, low-level hazards that are deterministic in nature like pollution or light, and those sporadic events like dropping an object or pest infestation that are neither rare nor constant. Condition assessment provides some certainty about deterministic risks – actual signs of impact rather than speculation. Risk assessment provides estimates on the probability of a fire or flood that cannot be gained from looking at the object.

Temporal Relationships

Different assessments look at different points in time, different parts of the risk chain. Latent damage, not yet observable to the assessor, will be expressed in a risk assessment. Visible symptoms may not be observed, but that does not indicate "no change." This could also be the case for catastrophic risks. The difference between recording what has definitely happened in the past and what is expected to happen in the future can provide a nuanced approach to planning.

Cause-Effect Relationship	Problems Associated with Inference
Cause implies Effect	A hazard that objects are exposed to may not affect them. All causes treated the same, regardless of their effect on the collection.
No cause implies No effect	Unusual phenomena would not be found, such as mold at moderate RH. Inherently unstable objects may deteriorate in environments considered suitable.
Effect implies Cause	Condition data do not differentiate between (multiple) causes. Past deterioration may also be visible but not causing problems.
No effect implies No cause	The effects may be latent, or simply hard to detect. Catastrophic risks are rapid onset phenomena.

Table 1
Kinds of inference and their potential problems in preventive conservation assessment [Taylor, 2005].

Objects not Behaving as Expected

All environments that house collections can be unpredictable. As mentioned, the theory of how an object should deteriorate does not always correspond to the reality. Predictions, by their nature, choose theory over the reality of what has happened. Although it can be compelling to state that objects will deteriorate at a certain rate, or last for a certain amount of time, only observation will reveal symptoms of deterministic risks on one material or another. If a collection is stable outside levels recommended as "safe," condition and predicted damage may differ. This could be the result of objects' previous exposure to high levels of a hazard, or simply being more robust than current theory suggests. Objects could be more sensitive than we know or their vulnerability could increase over time. Discrepancy highlights these issues.

Deterioration from inherent vice in the material, which can happen at moderate, stable environmental conditions that would not score highly on a risk assessment.

Past Damage

Past damage is not an indicator of what might happen in the future. A conserved object may behave differently after intervention [Waller, 2003]. Even the same object might differ under the lenses of observation and prediction. Symptoms may be present from previous risk exposure, such as accumulated fading from a number of different environments, or gradual deposition of a now-regulated pollutant. Considering expected change allows the implications of different symptoms to be parsed out and better understood in context.

Locations and Moving

Objects in historic buildings can move a lot, even the most embedded materials. The wall panels in Kew Palace, for example, were bought from France. Even staircases have moved in historic houses, and historic photographs have been known to involve moving ornaments into or out of frame. Objects that may appear to have been in one location for some time may have a varied history – damage cannot be connected to the location. Like museums, objects in historic buildings often have a history before they arrived at their location. Interpreting too much from damage can be misleading.

Predictions can often ignore past activity, sidestepping this problem. Concepts like "proofing" [Michalski, 2009], which use knowledge of a collection's history, though, can become limited by uncertainties related to objects' past locations, and objects that are about to be moved may mean that the identified risks belong to a location in which they are not located.

Synergistic Effects

Dividing risk into different agents can lead to unnatural separation of problems affecting collections. Much damage is the result of more than one hazard. Even if the damage is from a specific hazard, there may be influencing factors, such as temperature and relative humidity affecting the deposition rate of pollutants on objects. Taylor [2012] outlines a schematic example of relationships between hazards, based on the ten agents of deterioration (fig. 3).

Risk assessments present detailed overviews of these separate risks, spanning different collections. Condition assessments look at accumulated damage holistically from collection to collection. These approaches are complementary.

Data not Representative and/or Subjective Assessments

There are times when information may be recorded or interpreted differently in different contexts. This could be a problem with technical data gathered, or assessments being unreliable. Condition assessment cannot be assumed to be internally consistent and can be a large source of uncertainty [Taylor, 2013]. This has never been explored with risk assessments, but subjective judgements are required such as loss in value. Both assessments look at the impact of material change, which is not simply a percentage of material lost or altered. The ultimate aim of both assessments is related to the identified values of the collection, which are subjective, changeable, and inter-related.

There are occasions when certain kinds of data are not accessible – phenomena that are not monitored, or have not been monitored for sufficient time to make a sound prediction. English Heritage faced a problem when assessing some properties that had been newly accessioned. The collections were the main source of information because monitoring campaigns in begun shortly before the survey period. There are occasions where data is not available or accessible.

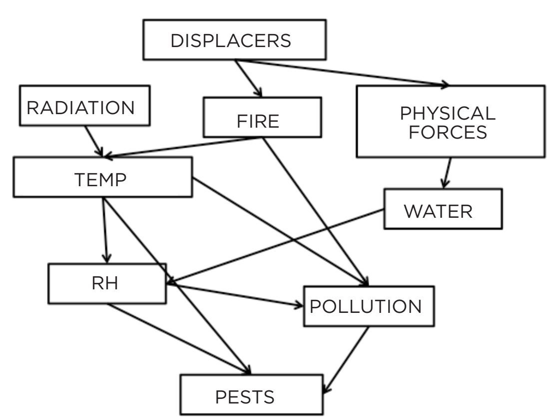


Fig. 3
A schematic of how some hazards, categorized into agents of deterioration, can affect one another – relationships that will be represented differently with different assessments [Taylor, 2012].

There are many things that can cause damage to an object, and not all of them are monitored in all locations. Consequently, presence of damage may be detected but risk related to the cause may be low.

There are also times when data may simply be erroneous. An uncalibrated or misplaced data sensor may provide data in the format desired and appear plausible. It is difficult to know without other kinds of data to compare.

Risk Mitigated

A discrepancy between condition and risk noted by English Heritage was that problems addressed in a first survey would not show damage in later surveys, due to successful mitigation. Although successful mitigation may imply that the risk should be reduced, risks such as pest infestations cannot be dismissed. High risk was a way of denoting training and resource needs, which were still required to maintain the level of successful mitigation.

Situations that have changed mean that temporal perspectives may relate to different matters. There may not be a risk in the present, but knowledge of pest levels in the past and the need for active management meant that past and future risks would not only differ from the present (and so, too, condition and risk assessments), but draw light on the situation.

Discovery Through Discrepancy

All of these examples show that discrepancy can reveal things about a collection that can help understand its needs. It is not limited to those examples, which are indications of broader themes. At the very least, analyzing discrepancies can help raise questions that can enlighten conservators and help them see more deeply into the situation and clarify data (be that risk or condition) which has inherent uncertainties, by using a different perspective.

Work in the field of cognitive psychology demonstrated that examining discrepancy can lead to high performance in reasoning tasks. Dunbar (1993) created a reasoning task based on a real world situation – experiments by the French biologists François Jacob, André Lwoff and Jacques Monod that contributed to their Nobel Prize in Medicine in 1965. Subjects examined those scientists' data – data that contained discrepancies and apparent contradictions. Attempting to explain them allowed subjects to uncover the insights that led to the discovery. The use of a complex, real-world problem meant that the approach was one that was able to acknowledge the nuances of the kinds of data and the kinds of reasoning involved. Up to that point, experimental work on reasoning tasks had shown a tendency to confirm hypotheses and biases towards initial beliefs (and a tendency to stick to those beliefs in the light of falsifying evidence).

In one study, subjects were presented with a task based upon a set of experiments that Jacob and Monod used to discover how genes are controlled. Using a simulated molecular genetics laboratory on a computer, they were taught some basic facts about molecular biology and experimental techniques. Following this brief training, they were asked to discover how genes were controlled by other genes. Some attempted to confirm their initial hypothesis, none of whom discovered the rule. Those that noticed evidence inconsistent with their current hypothesis set a new goal of attempting to explain the cause of the discrepant findings, and were successful in finding the rule. When asking subjects to test two mechanisms for control, one consistent and one inconsistent with their initial hypothesis, the success rate for rule discovery doubled. Dunbar's [1993] experiment revealed that deeper questioning and further, insightful analysis came from subjects trying to explain the *discrepancies* in data, rather than trying to test hypotheses or rules.

This real life simulation holds parallels for preventive conservation. When data are not certain, it is easy to confirm a compelling hypothesis. When viewing data, one can seek out patterns. Uncertain or ambiguous data, however, can support more than one explanation or pattern. Seeking to learn about causes by only studying effects, or about effects by only studying causes can lead to various practical limitations [Taylor, 2005, table 1]. The way a question is asked can have large consequences on the outcome.

Integrating risk assessments and condition surveys can highlight any disparity in preventive conservation data provides diagnostic opportunities. High RH, but no damage and physical damage where none was expected are real-life findings from integrated risk-condition assessments [Xavier-Rowe, 2017]. Having different kinds of data allows real-world inferences to be made, and deep questioning of the situation to be brought to the foreground.

Triangulation

Returning to the theme of maps, this integration echoes a long-established and effective way in which people have overcome uncertainty in their surrounding territory; by literally taking different perspectives of the same territory. An example is the use of watch towers for forest fires, where one tower might spot smoke but remain uncertain of the distance and of the extent of the problem [Taylor, 2018]. Calling a tower that sees the same territory from a different perspective allows the fire to be confirmed (or questioned) and its location pinpointed (fig. 4). This method has been used since Antiquity, and remains a practical approach to such problems.

In preventive conservation terms, it comes down to the inherent uncertainties in the representations we use. Using data to corroborate an explanation can lead to incorrect assumptions being validated by ambiguous data. Eliminating possible explanations requires certainty if one is to avoid dismissing real causes. Examining causes to draw conclusions about effects places a burden on our theoretical understanding of deterioration that cannot be supported. Returning to table 1, the problems of using only one perspective, regardless of which one, come to the fore. Like the fire towers, these problems can be avoided by triangulating risk and condition to clarify. Identifying similar causes of damage amongst different materials can also help refine condition data and connect to risk assessment [Taylor, 2002]. Complex environments can benefit from embracing nuance and identifying uncertainty. Recognising the value of discrepancy in preventive conservation data is a step in this direction.

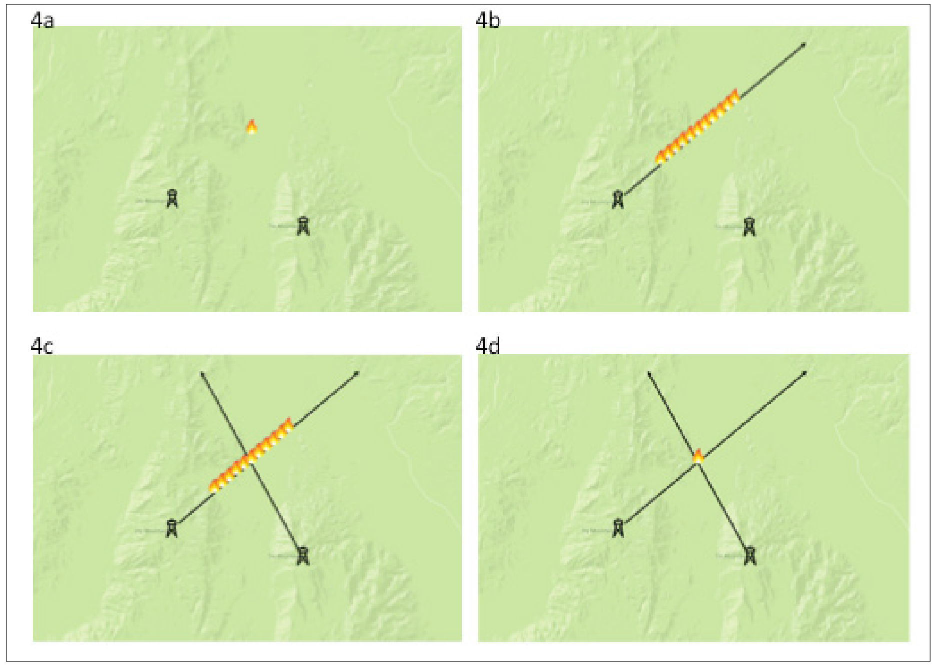
In Practice

An embodiment of this can be seen in the national collections audit of English Heritage which was actually designed to integrate risk assessment and collection condition assessment [Taylor, 2002, 2005]. During the audit, data from some storage areas in the same region showed similar discrepancies: a low risk score and a high damage score for relative humidity [Xavier-Rowe *et al.*, 2008]. This could be because objects were more sensitive than recommended levels, that the recorded damage was old, that there was a general error in the visual assessment of the collection or a number of other reasons, all of which would have different implications. By seeking to explain the discrepancy, it transpired that the RH data loggers were systematically recording RH as lower than it actually was. This could be examined efficiently because materials were documented as well as possible causes of damage [see Taylor, 2005]. As well as the monitors, different materials, with different damage processes, could be reviewed to check this. The finding led to improving the monitoring and calibration protocol as well as altering the risk assessment [Xavier-Rowe and Thickett, 2017]. Other risks had a degree of certainty, as both perspectives saw the same situation, be that the presence or absence of a risk.

Application of this approach has led to other benefits in practice. An advantage noted in a historic property where non-specialist trustees were involved in the assessment: that relating matters of risk and condition together made it easier to convey preventive conservation issues to non-specialists [Boersma, 2017]. Their knowledge was essential for the understanding of the values of the collections and the practices of the institution, and the final decision for priorities was theirs, but they needed to understand preventive conservation issues better before they could really engage with the process and use the information.

A problem in a storage area at the National Museum of Wales housing a mineral collection was addressed with a risk-condition survey [Baars, 2016]. By triangulating the data, it was possible to determine the kinds

Fig. 4
A schematic overview of a simple-but-effective approach to managing forest fires using coordination between different towers with different perspectives [Taylor, 2018].



of causes that could have created the corrosion products observed during collection assessment, and through risk assessment it was possible to identify the kinds of collection items that were most vulnerable. Without triangulating the data, the survey would have required much more time and resources to identify the problem. Differences between collection types and knowledge of their deterioration provided a conclusion that could have eluded assessments with a single perspective.

Conclusion

What may appear to be an inconvenience or problem for preventive conservation can actually be a strategic advantage that increases depth of understanding at all levels.

This paper has used a map-based analogy to demonstrate the benefits of widening perspectives, but another way to look at this analogy is to consider the future prediction (risk) as the map – a representation of the things we should know going forward, and observed damage (condition) as the territory – a specific view of the actual land at a specific point in time. Navigating with only one can lead to misinterpretation or missed opportunities. Risk assessment can determine the theory of what objects are supposed to do, not what will happen. Condition assessment reveals the state, but not all the potential for change. If these assessments are independent of one another, used to clarify explanations of the other, there is an opportunity to find things that could not be found before.

Bibliography

Ashley-Smith J., *Risk Assessment for Object Conservation*, Oxford, UK, Butterworth-Heinemann, 1999.

Bars C., *Investigation into Damage to Multiple Mineral Species in a Museum Store*, Unpublished dissertation, Cardiff University, 2016.

Boersma F., Personal communication, Los Angeles, January 2017.

Borges J. L., 'Del rigor en la ciencia,' in *Historia universal de la infamia* (1954), 1946, pp. 131-132.

Covello V. T., Merkhofer, M.W., *Risk Assessment Methods: Approaches for Assessing Health and Environmental Risks*, Boston, Springer, 1993.

Dunbar K., 'Concept Discovery in a Scientific Domain,' in *Cognitive Science* 17(3), 1993, pp. 397-434.

Michalski S., 'The Ideal Climate, Risk Management, the ASHRAE Chapter, Proofed Fluctuations, and Towards a Full Risk Analysis Model,' in *Alternative Climate Controls for Historic Buildings*, 2009. http://www.getty.edu/conservation/our_projects/science/climate/paper_michalski.pdf.

Taylor J., 'Cause-Effect System,' in *Internal Memorandum as Employee at English Heritage*, 2002.

Taylor J., 'An Integrated Approach to Risk Assessments and Condition Surveys,' in *Journal of the American Institute for Conservation,* 44(2), 2005, pp. 127-141.

Taylor J., 'Distinguishing Between the Map and the Territory: Synergy in Agent-Based Approaches to Risk Assessment,' in *Collections: A Journal for Museums and Archives Professionals,* 8(4), 2012, pp. 297-306.

Taylor J., 2013, 'Causes and Extent of Variation in Collection Condition Survey Data,' in *Studies in Conservation,* 58(2), 2013, pp. 95-106.

Taylor J., 'In the Quest for Certainty: Tensions from Cause-and-Effect Deductions in Preventive Conservation,' in *Journal of the Institute of Conservation,* 41(1), 2018, pp. 16-31.

Waller R. R., 'Conservation Risk Assessment: a Strategy for Managing Resources for Preventive Conservation,' in *Studies in Conservation,* 39(sup2), 1994, pp. 12-16.

Waller R. R., *Cultural Property Risk Analysis Model: Development and Application to Preventive Conservation at the Canadian Museum of Nature*, Goteborg, Sweden, Acta Universitatis Gothoburgensis, 2003.

Xavier-Rowe A., Fry C., Stanley B., 'Power to Prioritize: Applying Risk and Condition Information to the Management of Dispersed Collections,' in *Studies in Conservation,* 53(sup1), 2008, pp. 186-191.

Xavier-Rowe A., Thickett D., *Personal Communication and English Heritage Risk-Condition Audit*, Teleconference, August 2017.

International symposium: "Preventive Conservation in Historic Houses and Palace Museums: Assessment Methodologies and Applications," auditorium of the Palace of Versailles. (© EPV/ Colombe Durel)

EPICO programme publications: *Assessment Methods and Preventive Conservation of the Collections of Historic Houses.* (© EPV/ Danilo Forleo)

Life After a Collections Risk and Condition Survey

Amber Xavier-Rowe
Head of Collections Conservation, English Heritage
amber.xavier-rowe@english-heritage.org.uk

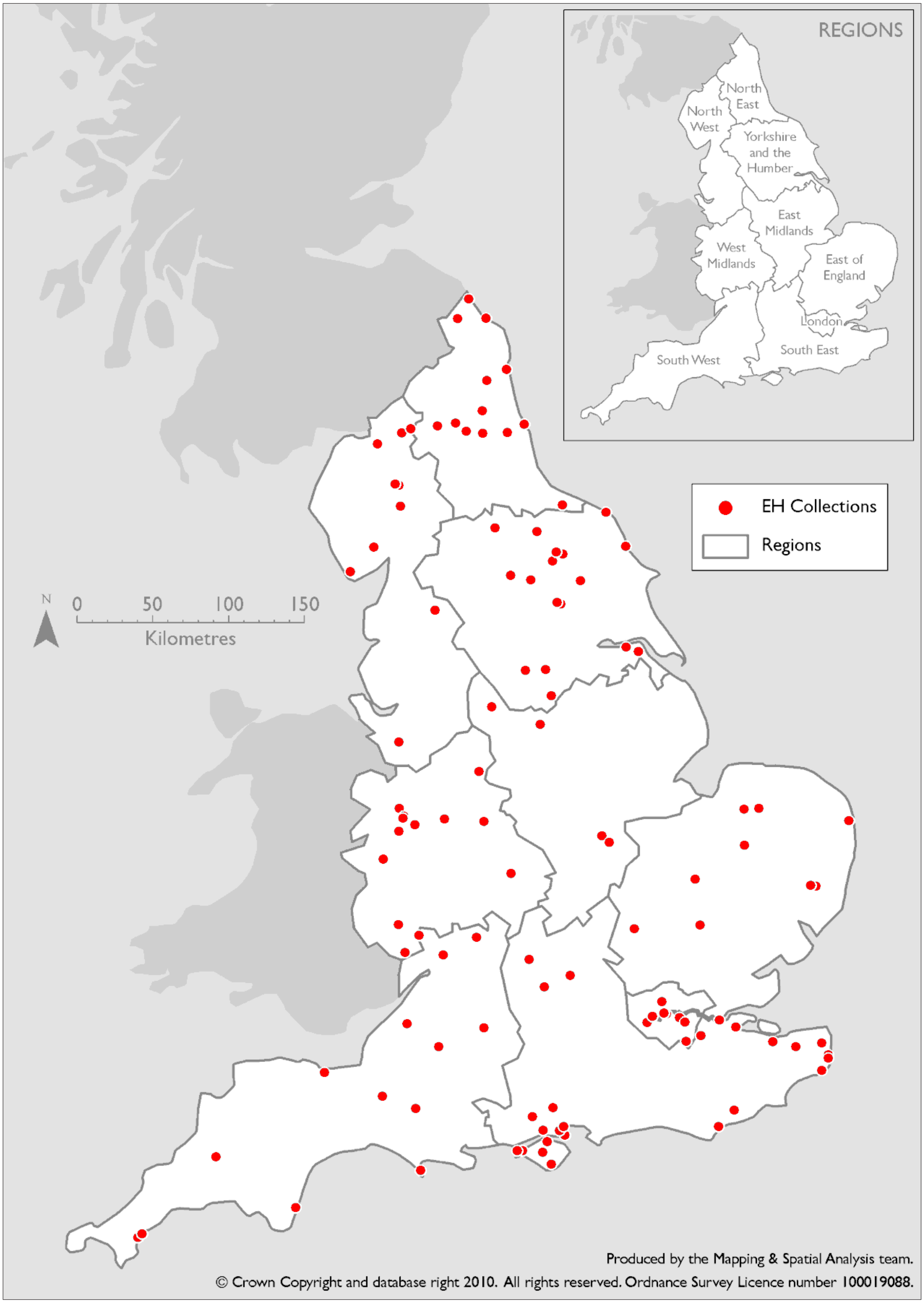
Abstract
In 2010, English Heritage published internally the results of a national risk and condition survey called the State of English Heritage Collections Report which has had a fundamental positive impact on resources directed to preventive conservation. Using evidence from a condition and risk survey of over 12,000 objects located in 115 properties, risk factors responsible for causing damage were ranked providing a powerful tool for prioritising preventive conservation actions nationally, by territory and by property. The survey methodology is summarised. The paper focuses on how and why the "State of Collections" survey and report has been such a force for change over the past seven years. Impacts have been wide ranging from improvement in stores and showcases to investment in conservation cleaning and conservations science. With effective management of risks, led by conservators and conservations scientists, care and access to collections whether in store or on display has been transformed. The approach taken to complete a follow up national survey is also described.

Keywords
Preventive conservation, combined condition and risk survey, collections care, heritage collections.

In 2010 English Heritage (EH) completed a national collections risk and condition survey. Results were presented in the State of EH Collections Report which defined the priorities for preventive conservation over the following 10 years to 2020. This report was followed up with a mid-plan progress review completed in 2016. Following a summary of the survey methodology which is already published [Xavier-Rowe and Fry, 2011], this paper then focuses on the impact of the survey results on helping to put preventive conservation onto a sustainable footing at EH. It then finishes with a brief review of plans to complete the second national survey by 2020.

Survey Methodology
English Heritage is a charity responsible for the care of over 400 sites and half a million objects across England. Collections are housed in 115 historic houses, museums and stores (fig. 1). Caring for such a

Fig. 1
The location of 115 English Heritage sites housing collections.



REGIONS
North East
North West
Yorkshire and the Humber
East Midlands
West Midlands
East of England
London
South West
South East
EH Collections
Regions
N
0 50 100 150
Kilometres
Produced by the Mapping & Spatial Analysis team.
© Crown Copyright and database right 2010. All rights reserved. Ordnance Survey Licence number 100019088.

Risk Factors	Examples
Dust, dirt and handling	Dust on an object due to insufficient conservation housekeeping; physical damage due to inappropriate handling, such as chips, scratches or losses.
Light	Fading of dyes and paints, embrittlement.
Incorrect Humidity	Cracks, splits, distortion due to low and fluctuating relative humidity (RH); corrosion and mould growth due to high RH.
Pests	Damage and soiling due to insect pests, birds, rodents and bats.
Display/Storage conditions	Tarnishing of silver due to inappropriate display case materials; crushing due to overcrowding in storage; Abrasion caused by an inappropriate support.
Disasters and Security	Fire, flood, theft or vandalism.
Inherent Deterioration	Some materials deteriorate due largely to their composition rather than the conditions in which they are kept. Examples include photographic film and plastic.
Documentation	Incomplete or missing documentation, no identifying number marked on an object. A lack of documentation for some objects, e.g. archaeology or natural history specimens can mean a loss of research value. This can be symptomatic of poor collection care and may result in further neglect.

Table 1
English Heritage risk factors 2010 [Xavier-Rowe, 2011].

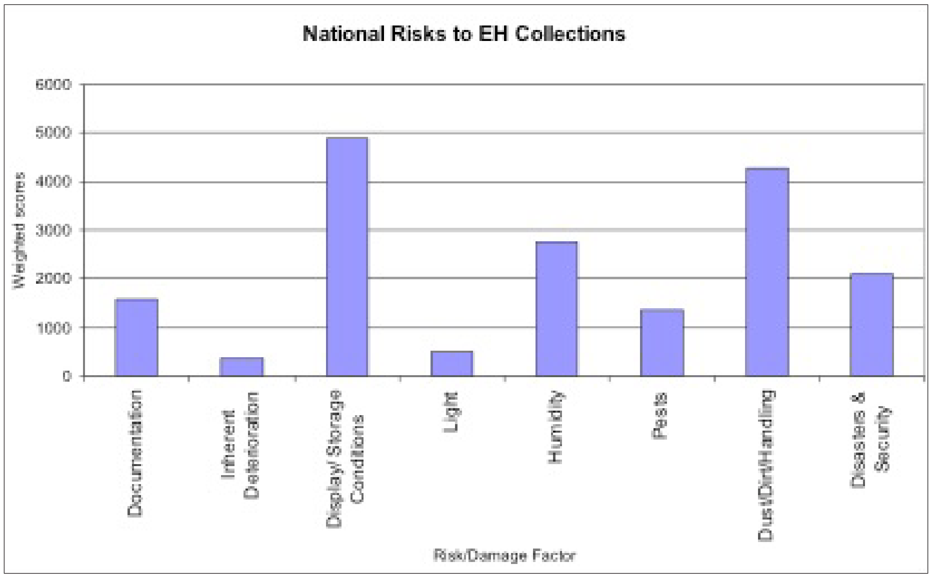
dispersed collection across multiple sites and housed in a range of building types from castles, museums, historic houses and underground tunnels, is a challenging task.

The collections risk and condition survey completed from 2004 to 2009 was undertaken by the EH collections conservation team working with external consultant conservators Frances Halahan and Jennifer Dinsmore. It produced baseline data to identify the principal risks facing over ½ million objects in the care of EH and produced prioritised action plans to address these risks for the following 10 years up to 2020.

Combining information from a site risk assessment and the condition of a sample of objects from the collection was informed by the work of Dr Joel Taylor. Taylor argues that the condition of the collection has a role to play in assessing which risk factors are actively or highly likely to result in damage. “Corroboration between a risk assessment and condition survey indicates both exposure and consequence of risk” [Taylor, 2005].

The survey methodology integrates object condition, site based risk assessment and collection significance to define and rank preventive

Fig. 2
National overview of risk factors facing English Heritage collections.



solutions across a range of sites [Xavier-Rowe, 2011]. It does this through quantitatively combining evidence of damage, provided by a sampled object condition survey (resulting in a damage score) and risk levels provided by a risk assessment (resulting in a risk score).

The condition audit and risk assessment used a common set of risk factors (table 1). These were adapted from risks to museum collections developed by others, namely Michalski's agents of deterioration [1990], Waller's risk types [1994].

The same experienced conservation consultants completed each site survey alongside EH conservators to ensure a good degree of consistency was established.

The risk assessment for each site was structured around the eight EH risk factors listed in Table 1. A questionnaire completed by a representative of the site operation team was used to assess whether a particular collections care system was in place, e.g. insect pest monitoring. If a system had been implemented and maintained the potential of a risk factor causing damage was then judged to be largely reduced. If a risk question however received a 'no' indicating a collections care system was not in place, then the likelihood of damage occurring was judged to be higher and the recommended solution and cost was recorded. The level of risk to a collection was measured by a risk score. This was calculated by multiplying; the probability of the risk factor occurring (P) by the quantity of the collection at risk (Q) by the potential loss of display or research value (LV).

The condition survey was completed on a random sample of objects from each site (5% for a mixed historic house or museum collection and 2% for a store). Over 12,000 objects were condition assessed

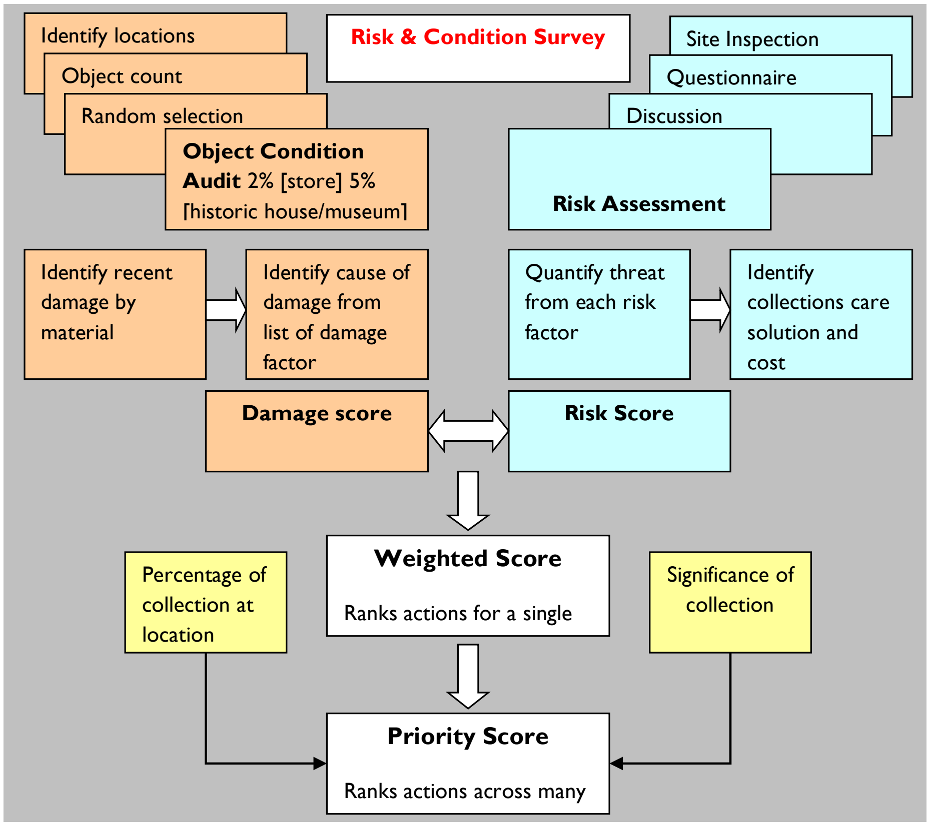


Fig. 3
Risk and Condition Survey – methodology [Xavier-Rowe and Fry, 2011].

across 115 locations. Pre-defined damage types were recorded for each material component of an object. The cause of the damage was then identified from the standard list of risk factors (table 1). Only recent damage (judged to have been caused within the past 10 years) was recorded.

Combining the data from both the risk assessment and object condition survey resulted in a weighted score. The weighted scores for each risk factor were then totalled resulting in a national overview on the risks facing EH collections (fig. 2). This overview helped to define and highlight where resources needed to be focused.

In order to rank preventive conservation action across multiple sites the weighted score was multiplied by the significance of the site based collection and the number of objects at each location. The resulting priority score was used to generate prioritised collections care and conservation plans for each territory (table 2). The methodology is summarised in (fig. 3).

Impacts

The impacts of the State of EH Collections Report 2010 have been both wide ranging and specific and are outlined below.

Preventive Conservation

The first impact of the State of EH Collections Report 2010 has been to highlight the role of preventive conservation as the principal strategy for mitigating the high and medium risk factors. This resulted in conservators and conservation scientists in the collections conservation team leading on the planning and delivery of preventive conservation programmes relating to:

1. Storage environment, packing methods and storage materials.
2. Technical design, manufacture or refurbishment of showcases.
3. Conservation cleaning .
4. Protection strategies relating to visitor access during functions, filming, photography and building work.
5. Object moving and transport.
6. Environmental monitoring relating to humidity, temperature, light, dust and pollutants.
7. Insect pest management.
8. Emergency salvage planning and training.
9. Targeted condition surveys and risk assessment.

Control of Resources

The collections conservation team has been able to move from influencing others (usually those who held the budgets) to raise standards of preventive conservation to direct control of staff and budgets. Central leadership of conservation with teams based in the territories has encouraged the targeting of resources in an expert, flexible and effective manner. It has also resulted in an increase in resources both financially and in terms of staff (more conservators, conservations scientists and collections care assistants).

Conservation Science

Linking preventive conservation practice and conservation science in the collections conservation team has raised the quality and cost effectiveness of preventive conservation in our properties and stores. Fundamental questions for example relating to safe relative humidity levels to store and display archaeological iron and copper alloys have been answered by EH scientists, directly impacting on the technical design of our showcases and the type of plastic storage boxes we use, how high they are stacked and how frequently moisture absorbing silica gel needs to replaced. The preventive conservation expertise across the team has been strengthened and continues to be a priority to maintain and develop.

Corporate Impact (Influencing Directors)

English Heritage became a charity in 2015 entering into a lease arrangement with the UK government to conserve and operate the

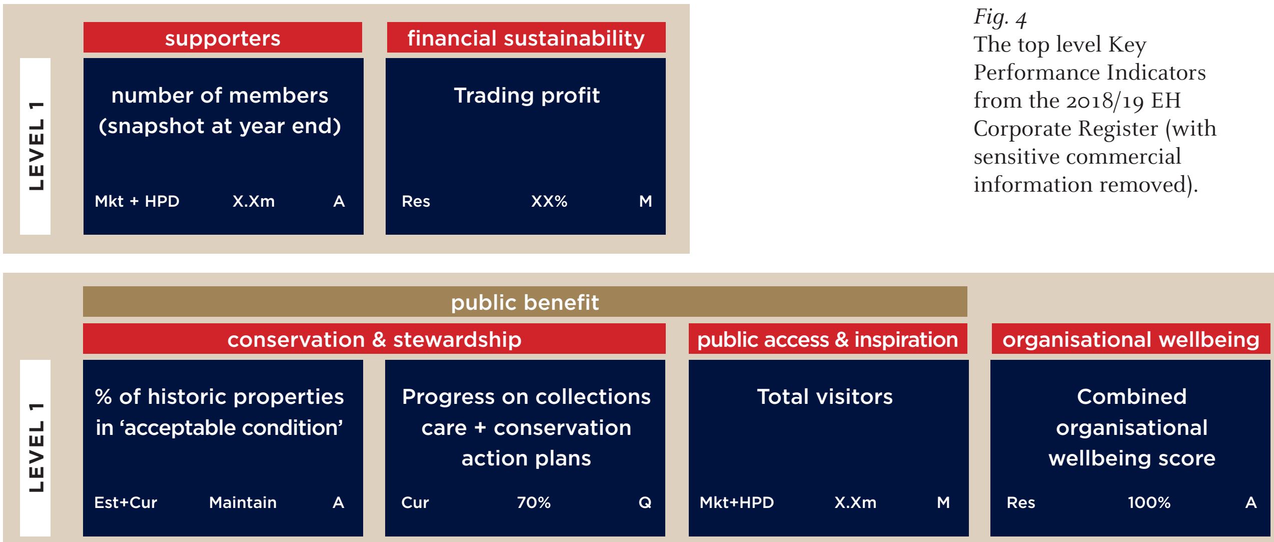


Fig. 4
The top level Key Performance Indicators from the 2018/19 EH Corporate Register (with sensitive commercial information removed).

national collection of properties, monuments and collections. The standard to be achieved relating to the conservation of the collections is outlined in an appendix to the lease agreement titled "Standards on historic chattels care and conservation." The State of Collections Report directly informed the creation of a key performance indicator (KPI) to judge achievement of the standard which states: "The data from the collections risk and condition surveys completed in 2010 will be used to draft and update territory and national collection conservation plans. Over a cycle of five years the Charity will aim to make progress against 70% of the actions as listed in territory and national plans." A summarised version of this KPI has also been captured in the EH Corporate KPI register for 2018/19 at the top level as "Progress on collections care and conservation 70%" (fig. 4). This is the first time at EH that collections conservation has been specifically highlighted in a corporate planning document.

A five year progress review was completed in November 2016 titled "State of English Heritage Collections Plan 2010-2020 – 5 year progress review." This provided the opportunity to highlight the messages from the 2010 report aiming to influence new directors and trustees. The review was presented by the author to a full house of Trustees and Directors including the Chair and Chief Executive on 15 June 2017. Using a carefully crafted presentation focusing on the message that the State of Collections Plan has led to sustainable long-term conservation resulted in strong positive support from the board of Trustees and Directors. To attract attention at the start of the presentation a story about the damage caused by off gassing storage materials to a copper alloy roman coin was used to great effect.

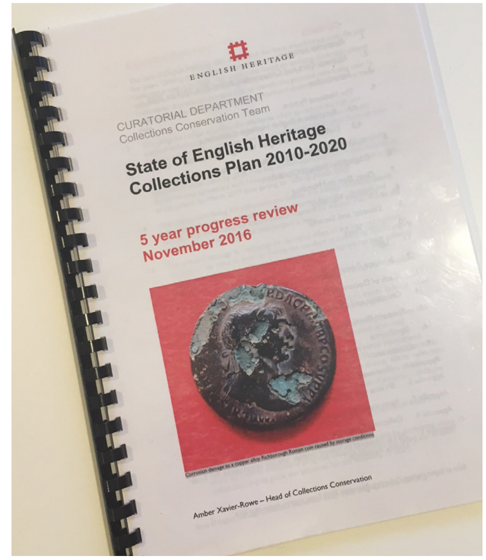


Fig. 5
The front cover of the State of EH Collections Plan 2010-2020 with the image of a copper alloy roman coin suffering from corrosion caused by off-gassing from the paper envelope it was stored in.

Conservators need to use examples like this to help illustrate the complexity of risks facing historic materials and why expertise in preventive conservation is essential to understanding and mitigating them. This coin has become a mascot for the State of Collections concept and was used on the front cover of the mid plan review (fig. 5).

Resources Prioritised Towards Addressing Highest Risks

An objective national perspective of the risks that have or are very likely to cause damage to EH collections was achieved (fig. 2). Display and storage conditions, closely followed by dust, dirt and handling, are the two highest risks. Incorrect humidity in third place is also causing damage. Disasters and security, pests and inadequate documentation represent a medium risk to EH collections. The risk of damage caused by light and inherent deterioration is low.

Display and Storage Conditions

Display and storage conditions proved to be the highest risk to EH collections in 2010. Damage was actively being caused by poor packing and support methods as well as off-gassing from storage and display case materials.

The majority of EH collections are in store at 38 locations and a substantial number of archaeological objects are on display in 550 showcases at 59 sites. Conservation resources have therefore been focused towards mitigating this risk factor over the past five years aiming to substantially reduce the risk from Display and Storage Conditions by 2020.

Since 2010 excellent progress has been made on addressing the state of our stores. Investment in four stores (Wrest Park, Fort Brockhurst, Helmsley and Temple Cloud) has improved environmental

Fig. 6
Primary school education visits to Wrest Park Collections Store.

conditions and packing standards for around 70% of our stored collections (as estimated 296,367 objects). Conservators and conservation scientists have been at the heart of this undertaking ensuring that sustainable, cost effective solutions based on scientific evidence were delivered for building design, environmental control, packing and transport. The remaining 30% of our stored collections in poor conditions, predominately made up of material from West and Southeast sites, we are aiming to address by 2020.

The positive side effect of improving storage conditions has been the associated documentation overhaul which has unlocked greater access for research by curators and visiting experts. The other significant impact has been access by school children and public tours (fig. 6).

The EH Conservation Science Research Strategy 2016-2020 will continue to address the risk posed by display and storage conditions through research themes, including preventing damage to archaeological materials, storage methods and appropriate enclosures for physical protection of robust objects vulnerable to wear from touching.

Showcase materials used in new showcases are carefully policed and tested to ensure that off-gassing is prevented. Old showcases have been retrofitted to reduce the amount of off-gassing and when this has not been possible vulnerable objects have been removed from display.

Dust, Dirt and Handling

Evidence from the risk and condition survey revealed that significant damage was being caused to collections from dust, dirt and handling by staff/visitors/hospitality/filming resulting in chips, marks and scratches. It is our second highest risk factor.

Keeping collections and historic interiors free of dust and dirt remains a challenge at all our sites with collections on open display. Not only will dust bond to surfaces if it is not regularly removed but the visual presentation of the site is compromised. With the increase in collections care assistants (CCA's) the capacity to undertake conservation cleaning across all sites with collections has become achievable. The number of CCA's has increased from nine part-time posts in 2010 to ten full time posts in 2015. Based at a territory hub site the CCA's managed by the collections conservators can now deliver conservation cleaning and collection care tasks across the smaller sites in the territory. Our London collections and interiors are benefiting from this development with a noticeable improvement in dust levels raising the overall standard of presentation. The team is now in the position to achieve a step change in the standard of conservation cleaning across all 115 sites over the next three years.

However, help from historic properties stewards who open and operate the sites is still required to vacuum visitor routes and undertake daily conservation cleaning tasks. After unsuccessfully following a strategy of training and supporting site teams to help carry out conservation cleaning over the past ten years a new direction was implemented in 2016. It was agreed with historic properties Directors that historic properties stewards would vacuum the visitor route and that collections care assistants would carry out the conservation cleaning of the objects and interior fixtures "behind the ropes."

Where additional hours are needed for daily and monthly conservation cleaning tasks historic property stewards would be selected, trained and paid to complete these additional hours directed by the collections conservator. A trial of this approach took place in 2016-2017 with an allocated budget of 20k and has continued with mixed results as finding additional hours during the busy summer season has been a challenge.

There is also the potential to engage local volunteers to help clean our collections and interiors. A volunteer cleaning programme has been set up at Boscobel House, Dover Castle, Down House, Kirby Hall and Wrest Park Store. Initiatives are being investigated for Helmsley Stores, Temple Cloud Store and Audley End House.

Damage from accidental knocks, spills and touching also needs to be prevented. Practice relating to the staging of hospitality events has improved following the implementation of site 'Memorandums of Understanding' based on risk assessments. Management of filming and photographic shoots has been transformed under the newly configured Hospitality and Filming team. Collections conservators are consulted from the first enquiry which has improved the planning and delivery of protection supported by the employment of freelance conservators. We have also contributed to the EH filming and photography guidelines 2016 which will help establish good practice, preventing accidental damage.

The practice of recruiting project conservators for major capital and conservation maintenance projects involving interiors housing collections has proved successful in preventing damage during building works and ensuring that collections care programmes can continue across the territory.

Incorrect Humidity

Incorrect humidity caused by damp and dry internal environments is resulting in damage to EH collections. It is our third highest risk factor.

Fundamental to preventing damage from incorrect humidity is precise information about the daily levels provided by continuous monitoring. The data however must be expertly interpreted and then used to inform actions that can help control the conditions. In 2013, we took the decision to bring in-house the maintenance of sensors which allowed us to recruit a second conservation scientist. Over the past five years there has been significant progress in environmental monitoring and management, driven by major heating and humidity control projects and Government Indemnity Scheme (GIS) Guidelines for non-national institutions (July 2012) to which the EH as a charity must now comply to be eligible for cover against loss or damage to our loans (of which we are responsible for over 17000). Temperature, relative humidity and light sensors have therefore increased to 309 and blue wool light dosimeters to 61. With the addition of a third conservation scientist and working as a team with the conservators and collections care technicians a system for replacing batteries, calibrating, archiving and interpreting the data has been established.

We have also been able to upgrade our software to allow remote access to check environmental conditions. The research value of this data to understand the deterioration rates of materials is also essential and directly feeds into the Conservation Science Research Strategy.

EH Showcase standards have been transformed over the past five years since we undertook research to optimise showcase design. They now deliver precise control for vulnerable archaeological objects displayed at our site museums which are often damp or dry (or both). The conservation scientists working with the collection conservators now lead on the technical design of new showcases and are responsible for manufacture and installation to ensure they perform to specification. All cases are now tested in-house to confirm that the air exchange rate meets the specification. This ensures that humidity control is optimised and maintenance time and cost is sustainable long-term.

Archaeological iron followed by wood and then archaeological copper alloys were the most damaged materials identified by the sampled condition survey. Incorrect Humidity registered as significantly contributing to this damage. Research has therefore continued to focus on understanding the tolerances of these materials to relative humidity in order to develop practical mitigation methods.

For major heating or Mechanical and Electrical (M&E) infrastructure projects involving properties displaying or storing collections a conservation scientist is now part of the project team working alongside the M&E consultants. This has resulted in systems being designed to meet the need for humidity control.

Conservation heating where the temperature is controlled by relative humidity via a humidistat is our principal means of control for furnished properties where vulnerable collections are on open display. For stores however we have proved that using dehumidifiers and internal insulated rooms provides good control without the need for using heat. Lowering the humidity levels in our small finds

Priority Order	Property	No. of Objects	Significance of collection	Priority Score	Risk/Damage Factor	Solution	Lead	Progress			Comments
								20%	50%	100%	
1	Apsley House	1863	A - International	7.65	Dust/Dirt/ Handling	Assess housekeeping schedule and amend	Conservator				
						Investigate measures to prevent public handling	Conservator/ Curator				
						Improve system of recording damage	Conservator				
						Staff to attend housekeeping course	Site staff				Training provided for London staff in 2009, 10 and 11. CCA attendance on site periodically and localised training for new starters as necessary.
						Implement programme of cleaning and backing paintings	Senior Conservator, Fine Art				
						Investigate improvements to sealing of display cases	Conservation Scientist				
2	Kenwood House	1887	A - International	6.69	Dust/Dirt/ Handling	Check chimneys are capped and cleaned	Estates				Chimneys were capped and cleaned as part of Caring for Kenwood projects. Chimney cleaning is now on Estates Maintenance planned maintenance list each year
						Replace gravel on drive and south front	Estates				
						Revise housekeeping plan to persuade visitor operations to use	Conservator				HP fund contract cleaners which work to our HK schedule in house for floor cleaning and robust surfaces. Time available is still insufficient.

						Train site staff	Conservator				CCA now based at the site and training provided for contract cleaners.
3	Eltham Palace	1698	A - International	4.12	Dust/ Dirt/ Handling	Check chimneys are capped and cleaned	Estates				
						Revise housekeeping plan	Conservator				
4	Apsley House	1863	A - International	3.9	Display/ Storage Conditions	Install dust seals to windows on front of building	Estates				A trial of dust seals is underway and introduction of these for other windows will form part of future maintenance projects.
						Repack banners	Conservator				
						Replace fabric in display cases	Conservation Scientist/ Conservator				This has been completed for all cases with silver objects displayed.
						Assess store and improve conditions	Conservator				Objects in store are now accessible and on racking, and the majority have been repacked in more suitable methods / boxes.
5	Kenwood House	3564	C - Local	3.4	Display/ Storage Conditions	Improve packing and protection of objects	Conservator				
	(Réserves)					Provide racking	Conservator/ Technicians				
						Improve access	Conservator/ House staff				
6	Down House (Second Floor)	1309	A - International	3.13	Display/ Storage Conditions	Ensure all objects correctly packed and protected	Conservator				Most objects packed and stored correctly but recent additions to the store need to be rearranged to ensure these are suitably stored

Table 2
A section of the London Region Collections Care and Conservation Plan 2016.

rooms is also essential if we are to optimise the lifetime of moisture absorbing silica gel in thousands of plastic boxes storing metal finds. In showcases a range of active and passive control is used.

Remaining Risk Factors

Risks associated with poor disaster planning and poor security measures as well as insect pests scored lower as good systems are in place. Light as a risk scored low as a substantial percentage of the collections are not susceptible and again systems of preventing damage using light plans, blinds and ultraviolet absorbing widow film are in place. Lack of documentation scored low as did inherent deterioration related to our collection of plastics, photographs and photographic film.

Prioritising Preventive Conservation Actions

Prioritised Collections Care and Conservation Plans have been produced for each territory (table 2). These help conservators to focus on actions that deal with the highest risk factors alongside delivery of project related work. These plans are used to plan annual work priorities and inform annual budgets.

Clarity on Roles

The State of Collections report has helped to clarify roles and responsibilities between conservators, conservation scientists and curators and has led to the internal publication of a Conservation Policy.

State of Collections 2020

As we are reaching the end of ten year State of EH Collections Report and plan we have commenced our second national survey aiming to issue the next State of EH Collections Plan towards the end of 2020. The same methodology will be used. Survey forms for condition survey and risk assessment have been designed in Excel to replace the Access database used last time round. It will be undertaken by our in-house conservators supervised by three core conservators to help maintain consistency. The team has completed two days of training focused on judging condition score and cause of damage. Pilot surveys have been completed to help improve reliability [Taylor, 2013].

The risk factors have been adjusted. Dust, dirt and handling have been split into dust/dirt and handling/use. Disasters and security have also been separated. The associated risk questions and solutions have been revised. The other change is to not record costs for preventive conservation or treatment solutions identified as part of the condition surveys and risk assessments. The cost information proved not to be useful or impactful in terms of planning or for highlighting the conservation resources required. It was also time consuming for the surveyors to add this information. Rather conservators and conservation scientists will draw up costs for both maintaining current systems of care and delivering new measures as highlighted in the new survey results on a site by site basis.

The survey data will be used to prepare ten year site and territory collections care and conservation plans and a new State of Collections Report and Plan 2020-2030.

Conclusion

Looking back over what has been achieved in terms of preventive conservation at English Heritage, the results from the collections risk and condition survey has had a major impact on the care and conservation of our collections. The resulting State of EH Collections report has been successful in raising the profile of preventive conservation to senior management. It has also helped to centralise and increase conservation resource under the head of collections conservation. The ability to prioritise actions across multiple sites has proved to be a powerful tool for conservators and conservation scientists to focus resources on the highest risks over a sustained eight year period. Ultimately the survey results have helped to achieve sustainable long-term conservation for EH collections.

Bibliography

MICHALSKI S., 'An Overall Framework for Preventive Conservation and Remedial Conservation,' in Grimstad K., *ICOM-CC 9th Triennial Meeting Preprints, Dresden*, 26-31 August 1990, London, International Council of Museums, 1990, pp. 589-591.

TAYLOR J., 'An Integrated Approach to Risk Assessments and Condition Surveys,' in *Journal of the American Institute of Conservation*, 44, 2005, pp. 127-141.

TAYLOR J., 'Causes and Extent of Variation in Collection Condition Survey Data,' in *Studies in Conservation*, 58(2), 2013, pp. 106-95.

WALLER, R., 'Conservation Risk Assessment: a Strategy for Managing Resources for Preventive Conservation,' in *Preventive Conservation: Practice Theory and Research*, preprints of the contributions to the Ottawa Congress, 12-16 September, London, International Institute for the Conservation of Historic and Artistic Works, 1994, pp. 12-16.

XAVIER-ROW A., FRY C., 'Heritage Collections at Risk – English Heritage Collections Risk and Condition Audit,' in *ICOM-CC Lisbon 16th Triennial Conference Proceedings*, International Council of Museums, Lisbon, 2011, 11 pp.

SESSION 2

EPICO PROGRAMME: RESEARCH AIMS

Chairman
Laurent Salomé
Director of Musée National des Châteaux de Versailles et de Trianon

Speakers
Danilo Forleo
Nadia Francaviglia
Roberta Genta
Agnieszka Laudy
Marco Nervo
Béatrix Saule
Noémie Wansart

Queen's Chamber,
Palace of Versailles.
© EPV/Christophe Fouin

The Stakes in Preventive Conservation Research Applied to Historic Houses

Béatrix Saule
General Curator of Cultural Heritage, former director of the Museum of the Palace of Versailles, today President of the Fondation des Sciences du Patrimoine – Patrima
beatrix.saule@icloud.com

In what way do historic houses present, in terms of preventive conservation, a specific case in relation to the museum? Do the challenges at stake justify new research? And in this case, what can the head of collections expect? It is to these questions that I will try to answer with examples drawn from my experiences. I will start with a case with a large financial and heritage stake, that of climate treatment at the Palace of Versailles, to then broaden the subject.

A Present Case: the Climatic Treatment of the Central Body of the Palace of Versailles

View from the Queen's Room

This Queen's room, is the context of a miracle, the "Versaillais miracle," according to Gaël de-Guichen's word. And the miraculously saved is the extraordinary cabinet placed in the alcove: the Queen's jewel case. Delivered by cabinetmaker Schwerdfeger in 1787 for Marie-Antoinette, it has regained its original place. The prestige of its provenance is matched only by its fragility due to the composite nature of its materials, mother-of-pearl, painting on vellum, etc. The successive condition reports attest to quite a satisfactory conservation state.

And yet, it is in one of the Palace's places that presents the most unfavourable climate conditions: southern exposure, high windows, attendance (18,000 visitors on average a day that stop to look), which is translated by catastrophic hygrometry curves that justify the climate treatment installation project. The observation of this anomaly is at the origin of my request concerning the last state of preventive conservation research, which Danilo Forleo would transform into the EPICO programme.

Now, allow me a flash-back of preventive conservation in Versailles, a series of realisations that can shed light on the current situation.

From one Realisation to the Next

Awareness of a General Need

In 1975, when I arrived in Versailles, preventive conservation was an ignored concept. The first course at ICCROM on the subject is precisely in 1975. Meanwhile, at the École du Louvre, the contribution of scientific techniques applied to heritage, that were taught in museology, exclusively focused on the criticism of authenticity and on restoration.

The notion of preventive conservation appeared in France in the 1980s and only became apparent in professional circles during the following decade.

Then Versailles became aware of the general need to modify the climatic conditions inside the palace. But in front of the scale of the task, we were resigned to be always restoring (the ceilings every 50 years). It is only after the creation of the EPV (Etablissement public du château, du musée et du domaine national de Versailles) in 1995 and the considerable contribution of human, technical and financial resources that we could take into consideration the Palace of Versailles' development masterplan.

One of its many components provides for a total refurbishment of the facilities, including the heating system, of which some of the base heaters date back to the reign of Louis-Philippe generating real fire hazards. So there is a consensus to not miss this opportunity and deal with all the problems, in particular, climate control.

The requirements issued in 2003 by the Conservation correspond to the standards commonly accepted in museums: a 50% RH tolerating a 5% difference on the + or on the -, requirements further increased during the restoration of the Hall of Mirrors where, according to the architect, dips to 10% RH are recorded close to very degraded vaults.

Awareness of a Specific Need

The realisation of infrastructures means that the details of the project only came out in 2012. It is based on the requirements expressed in 2003 and on a temperature stratification scheme that justifies air circulation in addition to a hygrometric treatment. Engineers at the technical office in climate engineering applied their standards: so much metre cubed of air need treating according to the volume and the attendance, its implies this duct size and so many traps for return air. Focused on the ceilings question, the furniture collections were not taken into account, which resulted in aberrations: an air return under the Queen's bed, but more generally, air returns on the edges of the rooms and on the historic spot of most of the furniture on display...

Faced with such disparity between real needs and what was offered, it was clear that the ideal conditions for a museum could not be applied. This resulted in a second realisation, the need to research specific methods for historic houses so as to have a fair estimate of the risks.

From One Research to the Next

Support Research

In the immediate future, in consultation with the architects, correctives measures were adopted:

– widening of the temperature range from 45 to 65% RH, which has allowed the reduction of duct diameters as well as the number and placement of air returns;

– reduction of the air treatment application perimeter by the exit of the project for the Queen's cabinet, less exposed to temperature variations, as well as the attic floor.

And a whole series of measures has been developed by a multidisciplinary team of conservators, managers, internal and external conservators to preserve the collections.

The scale of the project and the heritage stake have often led them to come up with novel solutions, in particular for the protection of painted and textile decorations remaining in situ or for the control protocols to be ensured during the building work in terms of security, fire safety, and other menaces such as shocks, vibrations, dust and after the building work, in anticipation of tests to avoid a thermo-hygrometric shock to the collections.

All these studies and considerable research were founded on very fine risk evaluation analyses, according to a question that met EPICO's programme then under development.

Preventive Research

All the studies I just mentioned are done off the cuff, if I may say so, in addition to pre-programmed work. The continuation of the project, that concerns the North Central body, the symmetrical wing housing the King's Grand Apartment, will benefit from feedback that will be rich on lessons concerning the pieces reactions in their new climatic environment, well, provided, to observe a necessary deadline.

However, even in the case of satisfactory results, a simple transposition would not be risk-free because from one space to the next the parameters differ. The challenge of applying the EPICO method is to provide irrefutable and coherent data that will answer the following question: knowing that the refurbishment of the heating system (repair work) remains essential, should the same climatic treatment solution be retained while, in the first place, the conditions are not the same, such as northern exposure and sunshine?

Here is a good challenge for the EPICO method but its field of application is not limited to the construction site at Versailles. Its ambition is broader because it concerns the collections of historic houses in general.

Broadening the Subject

I now propose to leave the case of Versailles and to widen the subject to historic houses that present a great diversity. The Château de Maintenon, which is not a castle-museum but a private home classified as an historic monument, offers a good example. It turns out that this beautiful castle, 70 km south-west of Versailles, currently concerns me because the CDEL (Conseil Départemental d'Eure-et-Loire) who manages it, asked me to participate in the drafting of its scientific and cultural project. It is a good observatory to estimate why and on what conditions would a specific scientific research on preventive conservation be profitable.

Fig. 1
View of the Château de Maintenon – Conseil départemental d'Eure et Loire. (© Danilo Forleo)

The Complexity of Protecting the Collections in an Historic House

What strikes me is that I find, on another scale, of course, the same issues that I faced in Versailles. Whether large or small, the historic house presents peculiarities which means that the standards of preventive conservation observed in the museums cannot be practised without adaptation. It turns out that the protection of the displayed collections is more complex. First, because of the configuration of the place and the very nature of the collections, which generate specific degradation risks; second, because of other constraints related to the history and usages.

Related to the Configuration and Nature of the Place and the Collections

This view of the Maintenon Castle highlights what are called external constraints:

– an immediate high impact environment (a running watercourse, the Eure which moats the castle, a garden) and around the countryside and the forest;

– an old building (itself a work of art that needs protection), rearranged from the 17th to the 19th centuries. The building's bodies are composed of various materials. Complex in its orientations and distribution, the facades are pierced with wide openings and, what we do not see in the figure, frames without thermic isolation but thick walls offering a natural inertia.

And inside, the way of presenting the collections is in close connection with the architecture, which is characterised by:

– the coexistence of fixed decorations and mobile collections;

– decors and collections that form a whole, an inseparable group, from floor to ceiling (from the original floor tiles and carpets to the painted beams).

All are composed of various materials which have their own constraints (hangings of Cordova leather or tapestry, panoramic wallpaper, cabinet pieces, lacquered cabinets, gilded bronzes, Chinese vases, painted portraits, etchings, drawings).

Specific Degradation Risks

Before mentioning specific degradation risks that threaten all this heritage, I will mention, without dwelling on them, the most serious ones, destruction by fire or disappearance by theft: the collections managers' obsession, whether in museums or in historic houses.

Fig. 2
Château de Maintenon, view of the moat.
(© Danilo Forleo)

Fig. 3
Château de Maintenon, Madame de Maintenon Bedroom.
(© Danilo Forleo)

At Maintenon, the damage generators that are already identified (and which will be studied) are:

- the dustiness stimulated by the height of the walls and the visitor attendance arriving from the gardens;
- exposure to sunlight through the windows;
- infestation in the lumber and in the seats' upholstery;
- humidity that generates mould and varnish cracks (in the summer) because during the winter the heating ensures regulation, or even dryness causing cracks and risings in the marquetry;
- furniture handling by volunteers, and even their use, during events and shows;
- vandalism most often unconscious, careless (I support myself), curious (I touch) or affectionate (I caress).

Faced with this, we know the entire proven panel of museography devices and actions designed for the conservation of collections (from dehumidifiers to barriers to keep distance via UV resistant glass, from micro-aspiration to public awareness including the movement of the pieces) but the head of the institution that I was, will tell you that many of the means accepted without reluctance in museums, will be rejected for reasons that relate to the identity of the house or to the various activities it accommodates.

Towards a New Method

Other Stakes to Integrate

If, just like in a museum, the purpose of preventive conservation is, in an historic house, to ensure the long-term preservation of the decorations and the collections, even if it is more difficult to achieve for the reasons we have seen, it also has to integrate the existence of other challenges, such as:

– historical veracity, which is based on inventories and the usage of the positions linked to the objects function that impose their rules on the presentation of the collections;
– concern for authenticity, which raises the question: when does the nature of the risk justify storing and replacing by a copy?;
– an aesthetic research, which often does not fit well with certain museography devices;
– the public's satisfaction, who comes to experience the atmosphere of an inhabited house, which we risk losing by trying to protect too much;
– the bustle of the house through receptions, concerts, shows, etc., which perpetuate a tradition but, by multiplying themselves, present threats to the collections, threats that need to be objectified.

For the discipline of preventive conservation, the integration of such issues is a novelty.

Thus these studies specific to historic houses will face two new challenges.

The first one is the number of parameters to be taken into account (with their interactions) for the establishment of the fairest and the most complete possible risk diagnosis.

The second one relates to the final phase of the recommendations which must be conceived, no longer in a systematic approach, but in a realistic and pragmatic project.

The Head of Collections Expectations

For the head of collections, the result of all these research works are a considerable decision aid during his arbitrations.

What can he expect from these new approaches for maintaining or improving the conditions of heritage conservation?

I will conclude five verbs that will be able to express them:

– **to understand:** which assumes a clear diagnosis;
– **to know**: which supposes a clear vision of the cartography of the risks;
– **to exploit**: which presupposes feasible recommendations both for the management of the collections and for the orientation of the projects;
– **to prioritise**: this involves a hierarchisation of the needs for programming and budgeting;
– **to persuade, finally:** which supposes solid bases for discussions and consultations with the partners.

The EPICO Programme: Preventive Conservation in Historic Houses and Palace Museums

Danilo Forleo
In charge of preventive conservation and head of the EPICO programme, National Museum of the Palace of Versailles and Trianon
danilo.forleo@chateauversailles.fr

Abstract

The EPICO (European Protocol in Preventive Conservation) research programme starts in 2014. The idea of this research was born from a reflexion thought over in the field: the work of collection caring carried out daily at the Palace of Versailles, was a privileged experimental field for the application of preventive conservation strategies developed in France.

The research on their adaptation to the peculiarities of historic houses then represented the *incipit* of the EPICO programme.

From 2014 to 2017 the objectives of the EPICO programme have been included in the scientific and cultural programming of the Palace of Versailles and its Research Centre. Thanks to the dissemination provided by the Association of European Royal Residencies, the Palace of Versailles joined forces with two other European partners: the Palace of King Jan III Museum in Wilanów (Warsaw) and the Foundation Centre for conservation and restoration of Cultural Heritage at "La Venaria Reale" in Turin.

EPICO aims to meet a need, which is prioritising preventive conservation actions in historic houses, thus avoiding to respond solely to conservation emergencies on a case-by-case basis.

The Objectives of the EPICO Programme

Literature and field experience in this area are very rich and diversified: the assessment methods have been developed for museum collections, the storage rooms, the archival warehouses and archaeological deposits.

Our research shows that there is not at present a method perfectly suited to the collections in historic houses. Hence the need to develop a new assessment method able to meet these criteria: simple, adapted to the exhibited collections in the historic houses and the palace museums, conducted according to a systemic approach, able to provide a synthetic and global image of priorities for intervention, reproducible and transferable to other houses, whatever the size or complexity of the institution.

Based on this observation and in order to identify the priority actions, it seemed essential to start by establishing a diagnosis of the conservation conditions of the house and the state of conservation of the collections.

And in the face of hundreds of objects and exhibition rooms, it has proved necessary to have an assessment method.

Fig. 1
Examples of methods developed for museums, reserves, archives...
(© Danilo Forleo)

Following the three stages of the program: survey, test, elaboration, an interdisciplinary team of 15 professionals focused on the research and then the analysis of the 21 assessment methods that can be adapted to the EPICO's objectives.

Four methods were then selected and applied 3 times during life-size tests in the program's partner residences.

The goal was to identify the strengths and weaknesses of each method following a scientific approach, and then develop our own assessment system: the EPICO method.

Our experimentation field will have included a total of 40 museum rooms, 700 art pieces in the painting, sculpture, furniture and art object collections from the Palace of Versailles, the Wilanów Palace (Warsaw), the Pitti Palace (Florence) and the Stupinigi Hunting Palace (Turin).

This congress opens phase 2 of the EPICO program which is the application and experimentation of the method in the Palace of Versailles along with its dissemination within the member institutions of the network of the Royal European Residencies and the heritage conservation institutes in Europe.

The Assessment of Risks

Historic houses and palace museums are particular conservation systems that imposes specific risks on the collections.

These risks are closely linked to the very nature and use of these buildings: originally places of power, delectation and representation, they now become museums, reception spaces, places for contemporary and institutional events.

The whole of these activities often coexist inside the same house.

The Palace of Versailles is an emblematic example: a museum since 1837, it currently hosts several million visitors a year, it is the seat of the Parliamentary Congress, presidential receptions and the setting for numerous cultural events of different nature (shows from the Royal Opera, film shoots, professional meetings, round tables organised as part

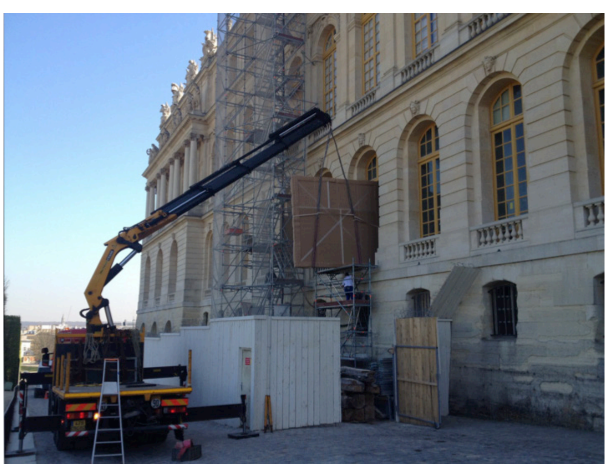


Fig. 2
Château de Versailles, Galerie des Batailles, the largest hall of the Musée d'histoire de France, inaugurated in 1837. (© Didier Saulnier)

Fig. 3
Concert in the Galerie des Batailles. (© Didier Saulnier)

Fig. 4
Château de Versailles, filming in the Galerie des Glaces. (© Didier Saulnier)

Fig. 5
Relocation of the king's Louis XV's roll-top secretary for the exhibition "18, aux sources du design," Château de Versailles, 2014. (© Didier Saulnier)

Fig. 6
Relocation of large-size paintings for the new museography of the Galerie d'histoire of the Palace of Versailles. (© Danilo Forleo)

of this congress which will take place in historic rooms).

This implies a different management of collections from that of a museum for which the conditions of use and visit are designed ad hoc.

Tools for analysing deterioration sources such as climate, light or the manipulation of collections and the management of visitor flows are widely documented in scientific literature. Many experiments have been conducted since the 1970s when the practice of preventive conservation was developed in the heritage community.

But how to adapt these tools to the scale of a house the size of Versailles?

It is difficult for managers of collections to have a global vision of deterioration sources in their interaction with each other and at the scale of the house:

– which artworks should we focus on as a priority?
– which rooms present major risks?
– in particular, to which priority subjects should we allocate our time and financial resources?

The value of these unknowns, multiplied by the vertiginous figures of the Palace of Versailles (17,000 exhibited pieces, 1000 museum rooms, 5 million and a half visitors a year) makes the equation we face complex.

At the same time, even if in the private house of a modest size, the number of collections presented seems to make things easier, the "how" remains the most difficult question to grasp.

Often, due to lack of resources or expertise, it is difficult to identify priorities for action in a simple and transparent process.

Reacting to conservation emergencies turns out to be the only possible answer for most cases and institutions. Often the method is effective and allows to establish an observation of the most sensitive areas.

– But, how can one be sure not to forget a latent risk, or worse, a cause already active in a room among the few thousand of a castle like Versailles?
– How to justify, with scientific data, the right conservation directions?
– How to compare in time and in different spaces the results of our analysis and the effectiveness of our corrective actions?

Critical / Innovative Aspects

One of the most important aspects but also the most difficult aspects of our program was the search for a system that could shed light on the existing relationship between causes and visible effects of deteriorations, which we believe is the safest way to assess and legitimise any corrective action taken on the environment and the material of the collections.

To better contextualise this fundamental point of our program, the characteristic and common elements of our houses have been identified and have allowed us to understand how the methods already developed for the collections of museums, archives or reserves are not directly applicable to our case.

These risks are related to the particularity of the presentation of the pieces and the conservation system that the house represents. Indeed, displayed according to the use for which they were designed, part of an inseparable group of collections and immovable decors, the collections from historic houses escape any thematic scheduling that would be accompanied by museum equipment designed for the preservation of collections.

The piece thus looses its character of *unicum* because it exists in relation to the neighbouring objects, its decor and its architecture.

It is obvious that its isolation in a showcase would break the spirit of the place.

In addition, the architectural envelope, itself a work of art, is also difficult to modify and cannot adapt to modern technologies of preventive conservation.

On the other hand, this privileged link between collections and building informs us about the particular relation thus established between the deteriorations of the material in the collections and the surrounding conditions that could potentially be the cause.

And this is the interest of the exercise. This is the characteristic point of the collections from historic houses and that we tried, in the framework of the EPICO program, to highlight with an innovative approach that we will develop further.

As we will see later, the second complex aspect of the research was the development of the statistical method to identify the representative sample of the rooms (the conservation conditions) and of the collections (conservation state).

We assume that beyond 500 objects we do not have the means and the time to make an analysis object by object or room by room. Thus it was necessary to identify the distinctive criteria of the house and its collections (the *mother population*, in technical jargon) in order to be able to choose the statistically representative sample of the different conservation zones in the castle-museum.

Conclusion

The methods presented in this congress formed the basis of our research. Above all, the methodology developed during 20 years of studies and experiments at the Master in Preventive Conservation at the Sorbonne made it one of the most comprehensive courses in Europe.

Of course, this methodology is echoed in England, Canada and the United States where the expertise in risk assessment is a reference for the international scientific community.

For example, we can cite the studies conducted by Joel Taylor and

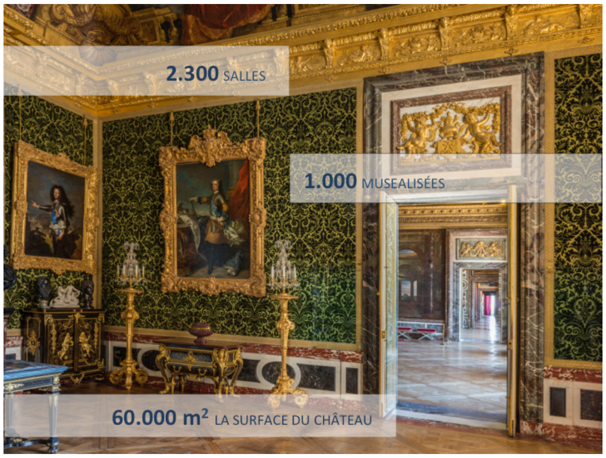


Fig. 7
Tapestries removed during building works on the collections of the southern central body of the Château de Versailles.
(© Danilo Forleo)

Fig. 8
The collections of the Château de Versailles in figures.
(© Christophe Fouin)

Fig. 9
Château-Musée Museography: collections exhibited in their creative context.
(© Christophe Fouin)

Fig. 10
Château-Musée Museography: collections exhibited in galleries retracing the history of the Château.
(© Christophe Fouin)

Amber Xavier Rowe on the intersection between risk assessment and deterioration causes, based on the condition report, which represents one of the foundations of our research.

It is not risky to identify in these different approaches the sometimes well-defined traits of the great schools of thought that were developed during the 1990s.

These different approaches are revealing, according to the latitudes of the different administrative contexts which demanded, for each one, the most adapted method to persuade the recipient of the assessment the accuracy of the diagnosis.

Should we analyse the risks or the state of the collections? Is it possible to cross the two approaches?

We tried to answer these questions.

On the basis of our experience, the fact of starting from the damages and therefore the observation of the symptoms and then deducing by a scientific method the plausible causes, represents the most convincing way of legitimising any corrective action recommended for the environment of the collections.

Comparative Study of Assessment Methods: In Situ Tests and Critical Analysis in the EPICO Programme

Agnieszka Laudy
Biologist, specialised in micro-biology, at Museum of King Jan III's Palace at Wilanów (Warsaw)
alaudy@muzeum-wilanow.pl

Agnieszka Pawlak
Conservator at Museum of King Jan III's Palace at Wilanów (Warsaw)
apawlak@muzeum-wilanow.pl

Noémie Wansart
Research assistant in conservation at Palace of Versailles National Museum
noemie.wansart@chateauversailles.fr

Abstract

The first phase of the EPICO programme was dedicated to bibliographic research and the analysis of the existing assessment methods focused on the preventive conservation methodology.

At the end of the first phase, four methods that correspond at best to the EPICO programme's objectives, were chosen to be tested at such locations: the Palace of Versailles, the Wilanów Palace (Warsaw) and the Pitti Palace (Florence).

1. The pilot inspection method developed by Agnoko-Michelle Gunn at the Chateau de Chantilly.
2. The ABCD risk evaluation method, developed by the Canadian Conservation Institute in collaboration with the ICCROM and the Netherlands Institute for Cultural Heritage.
3. The combined evaluation method of the risks and the state of the collections developed by the English Heritage.
4. The CAT method (Conservation Assessment Tool) developed by the Scottish Conservation Studio for the Scottish Museum Council.

In order to compare the results of the different methods, it was decided to carry out a complete sanitary check of each room inside the perimeter of the tests. This systematic report formed the backbone for evaluating the effectiveness and the adaptability of the four methods tested on the historic houses, according to the EPICO programme's objectives. The décor of each room (woodwork, ceilings, wall hangings…) were also included in our sanitary check.

After having detailed the implementation tests (in particular the choice of perimeter), we endeavoured to compare amongst themselves the results of the tests (by classifying the deterioration causes) and verify the coherence of the methods compared to our sanitary check. Each method was also evaluated in terms of the necessary human resources, the time for the application and the adaptability to EPICO objectives. This critical analysis of the tests formed the basis for the elaboration of the EPICO evaluation method.

Keywords

EPICO, historic house, preventive conservation, assessment of the state of the collections, assessment of the preservation conditions, causal relationship, risk evaluation, damage causes.

EPICO's approach and critical analysis were presented in depth at the conference *Les nouvelles rencontres de la conservation préventive*, June 8-9, 2017, Association Aprèvu, Original title: "Assessment Methods for Collections: Comparative and Test Study Toward their Application to Exhibited Collections of Historical Houses and Castle-Museums EPICO Research Program," co-presentation by Danilo Forleo, Nadia Francaviglia and Noémie Wansart.

Introduction

The first research phase (2015) focused on the different assessment methods of the existent collections (Forleo, Francaviglia, De Blasi, Pawlak, 2017). The second phase (2016) was devoted to testing the methods that were taken on, following the objectives of the EPICO, whose first results are presented here.

Assessments of the Collections with Regard to the Objectives of the EPICO Program

The statistical method proves to be necessary when there are too many objects, making an item to item survey approach very difficult. Nevertheless, if this method adapts perfectly to a storage assessment, where the items are, in theory, assembled by homogeneous categories, this approach has proved to be more difficult to apply to the rooms of a house: the diversity of the collections, the presence of the decorations, themselves a collection, would entail a very close sampling, the price of the representativity of the statistical profile would be too costly in terms of time.

In the wake of teaching at the Master of Preventive Conservation at the University of Paris 1, our attention focused during the literature research phase on types of evaluation methodologies: the methods whose starting point is the observation of the collections, their state and conservation conditions, and the risk evaluation methods, where the condition report of the collections is a limited part of the evaluation approach.

Four methods, according to the objectives of the EPICO research program, have particularly held our attention.

- A pilot inspection method designed by Agnoko-Michelle Gunn [Gunn, 2001];
- an ABCD risk assessment methodology, developed by the Canadian Conservation Institute in collaboration with ICCROM and ICN [Michalski, Pedersoli, 2016; Karsten, Michalski, 2010];
- a condition report and risks assessment cross method developed by the English Heritage [Xavier-Rowe, Fry, 2007 and 2011];
- the CAT – Condition Assessment Tool software, even if it's not a real assessment method, but rather an observation tool that implies a method [Murray, Edwards, 2002].

Object Number	Type	Author	Designation	Materials and techniques	Last movement	Materials
OA 5312	Decorative art	Pierre-Philippe Thomire	Chandelier	Engraved and gilded bronze, biscuit, green porphyry	2012	Metal

Damaged material	Damage	Gravity	Extension	Generic factors	Specific factors	DIAGNOSTIC
metal	Corrosion/oxidation, tarnish	1	3	Interaction with climate	High stable RH	Building characteristics (lack of insulation, inertia)
metal	Dust/Surface dirt/ Grime/Soil particles/ Encrustation	3	2	Pollutants/ dust accumulation	Dust/visitors flows	Inadequate management of the flow of visitors (airlock, locker rooms, regulation of the number of visitors…)

Tables 1a, 1b
Example of a condition form produced by the EPICO team and used as part of the tests. Table 1a: identification and description of the object: extract of the computer database. Table 1b: condition report and identification of damage causes. (© EPICO team)

All the methods cited require a more or less a thorough observation of the collections and, in particular for the ABCD method, the objects' conservation context. The CAT tool and the English Heritage method require making a report, on each object (CAT) or on a statistical basis (EH) in order to identify the action priorities in terms of preventive conservation that are to be programmed. A. M. Gunn's pilot inspection also requires a condition report of the items on a statistical basis, all typologies combined, but concentrates on the prioritisation calculation of the deterioration causes.

Fig. 1
Assessment of the Collections in the Dutch Cabinet at the Wilanów Palace in June 2016. (© EPICO team)

In order to compare the results of the different methods (some using statistical calculation systems), it was decided to carry out a comprehensive sanitary check of the rooms, subject to the test, by carrying out a condition report of all the items. Using Excel® sheets as support for data collection, we also provided possible causes, corresponding to each deterioration observed on each material constituting the items (see image, input table example). The decoration of each room (wood panelling, ceilings, panelling, wall hangings) has also been included in our sanitary check.

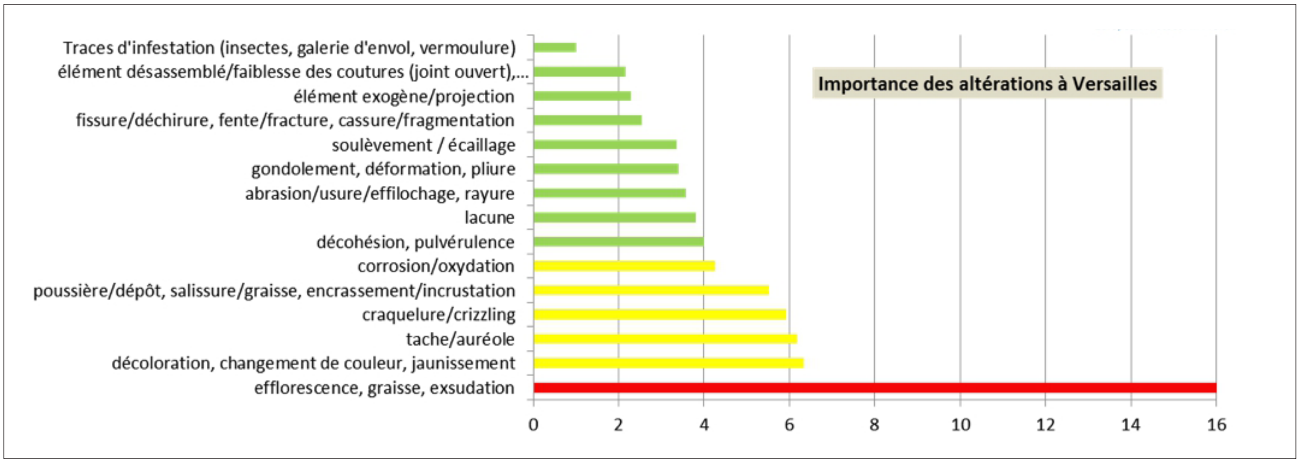
The preparation of a reference glossary of deterioration indicators requires a considerable effort to establish comparable reports: all the objects from the assessed rooms using the methods, were analysed based on sixteen indicators we developed in order to measure the observed damage. The glossary was all the more valuable as the teams made up of museum professionals from different specialties and from three different countries (fig. 1).

For the choice of the scope of the test, several criteria were taken into account, for the sake of comparability, between the different sites:

- history of the locations, typology, the number of objects and presence of the decorations in the same room, the reflexion was based on "zoning" criteria proposed by Gaël de Guichen and Benoît de Tapol as part of the training organised by the ICCROM during the 1990s;
- conservation condition of the objects (it was necessary to avoid collections recently restored);
- type of attendance (free or guided tour, number of visitors, opening hours);
- accessibility for the condition report (maximum observation height: 180 cm): the condition report had to be able to be done correctly without moving or manipulating the object;
- surface and orientation of the rooms;
- availability of climatic parameter recordings: in order to make assumptions about the causes of deterioration and the risks related to the climate of the rooms (this criterion did not discriminate because the recordings were not always available).

Test Results

We present here an overview of the results of the tests carried out on the collections of the Palace of Versailles and the Wilanów Palace. The results are presented in the form of graphs from the calculations carried out applying each method to the three selected rooms. Doing a comparison is complex; the methods tested follow different approaches since they measure with different parameters, the active or past causes and the potential causes. While recognising this difference, we



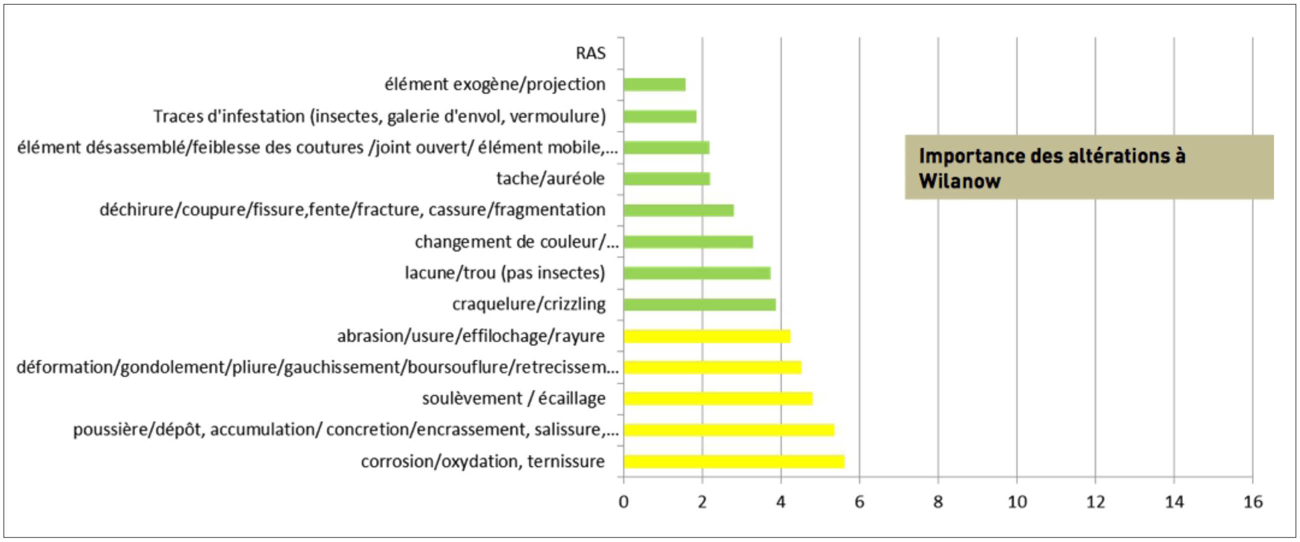


Fig. 2
Results of the importance of the deteriorations during the sanitary check at Versailles and Wilanów. (© EPICO team)

believe it is essential for our objectives to look at these results using a single lens, in order to understand the relevance of the methods and their effectiveness in identifying solutions that arise from the assessment in the specific case of the collections of an historical house.

The results presented here (fig. 2) are those from the condition report forms made on all objects during the test sessions. The importance of the deteriorations is calculated by multiplying the extent and the severity of the deterioration. This reasoning seemed to us the most relevant one because it highlights the most serious deteriorations even if they appear only on a small number of artworks (for example, in the case of Versailles, the significant efflorescence on the lower part of a bookcase).

Figure 4 is another formatting of the results from Versailles, which can easily distinguish both the number of occurrences of the causes of alteration (whose sums are in the abscissa) but also their gravity,

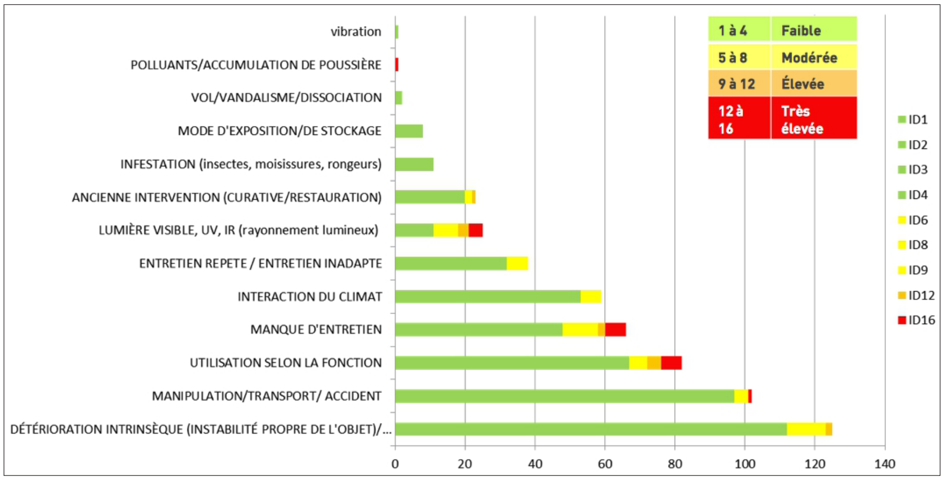


Fig. 3
Results of the importance of the deterioration causes during the sanitary check at Versailles. (© EPICO team)

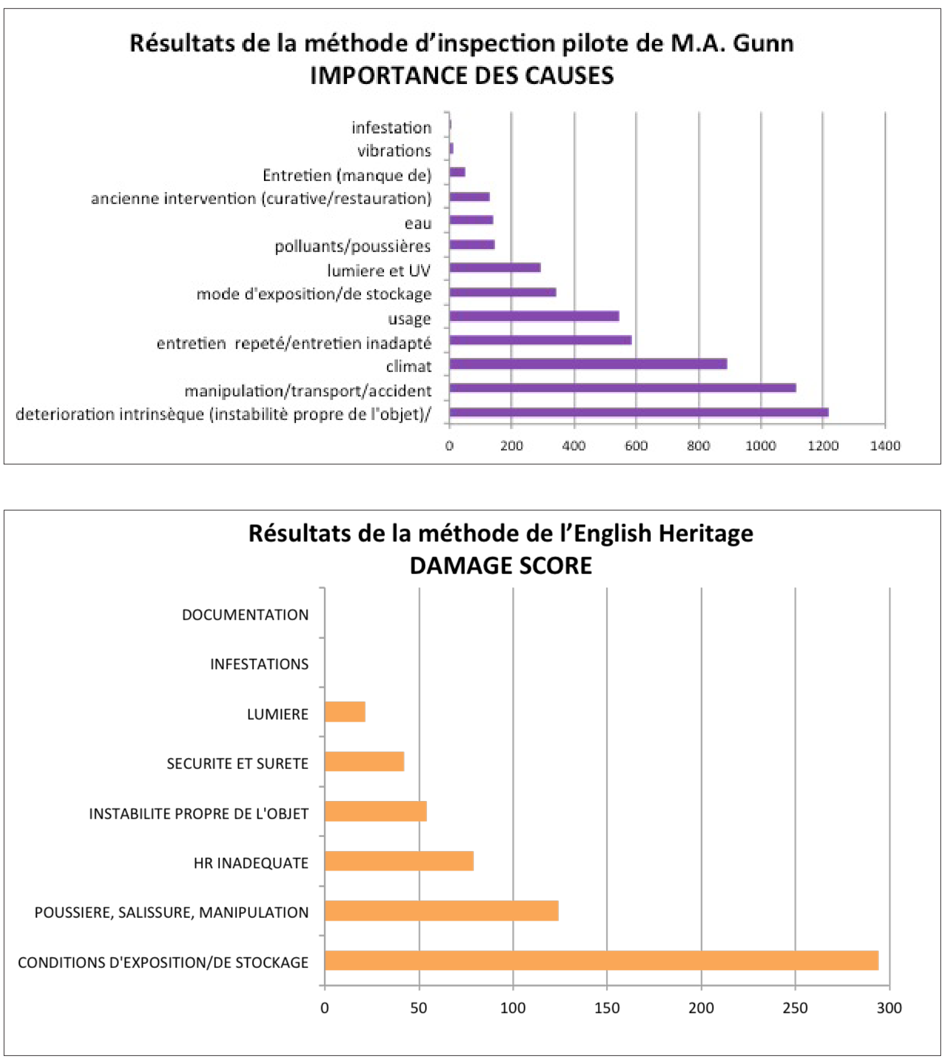


Fig. 4
Comparison of the results of the English Heritage method and the method elaborated by Agnoko Gunn applied for the first time in the Chantilly Château. The problems linked to handling and maintenance seem to be the most important in both cases. (© EPICO team)

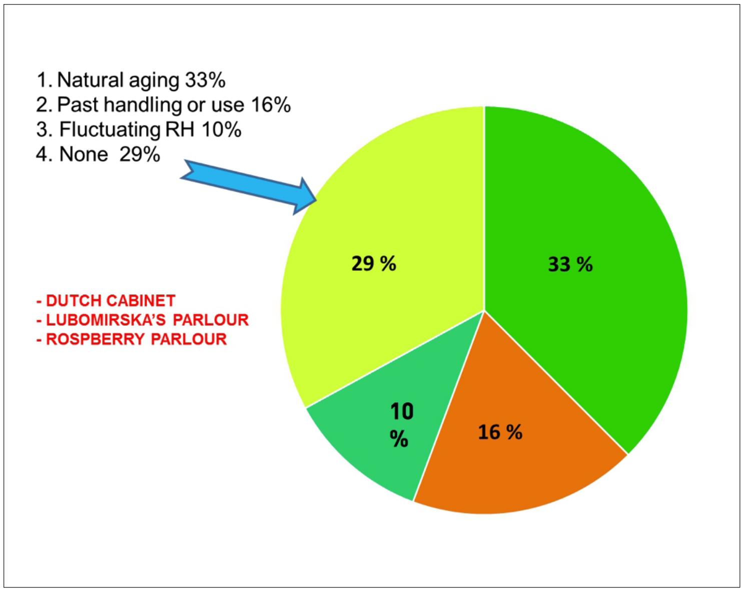


Fig. 5
Result of the application of the CAT software at the Wilanów Palace.
(© EPICO team)

thanks to the colour scheme. This graphic allows collections' managers to quickly visualise deterioration factors in order to plan with the preventive conservation specialists corrective actions.

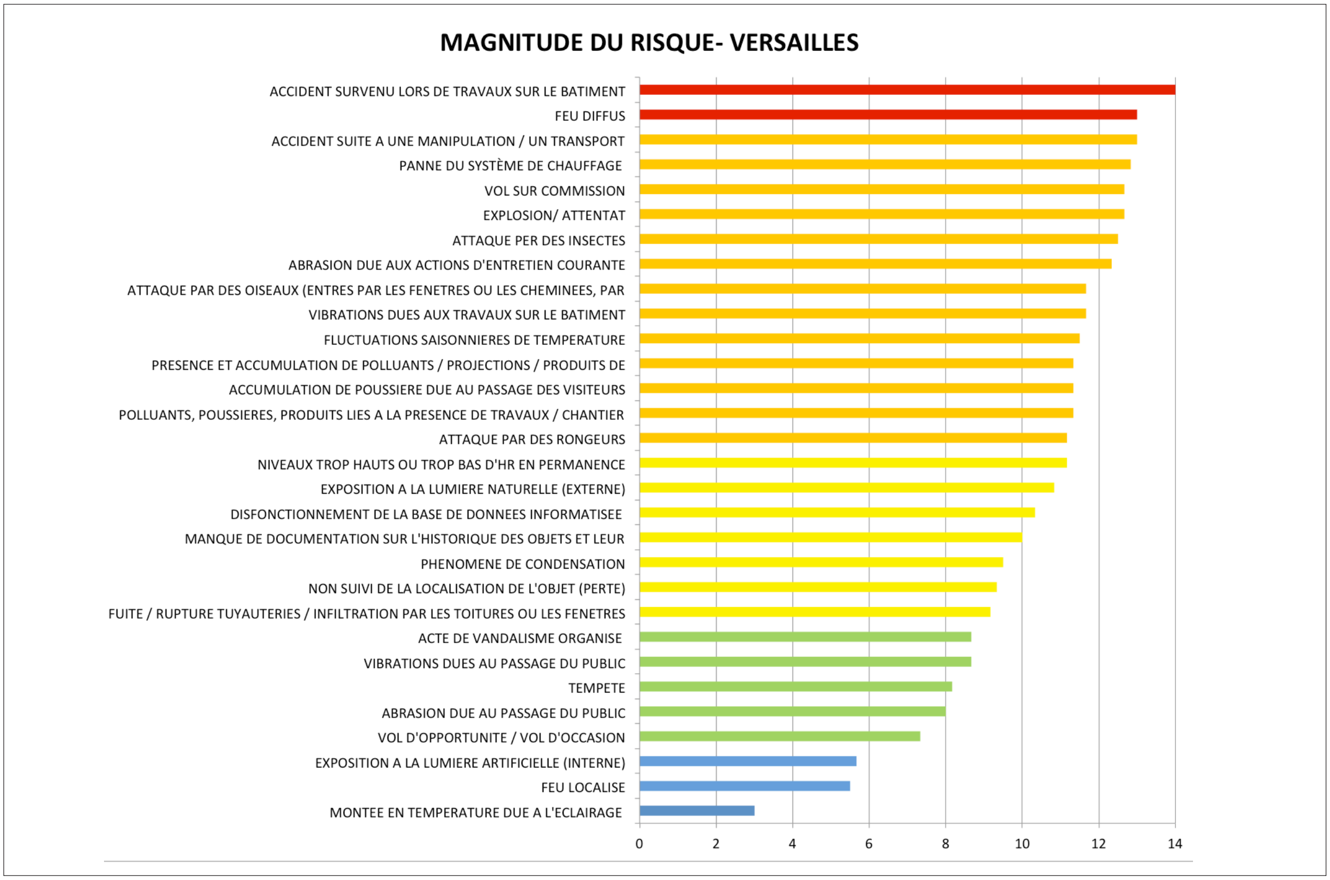
Here we present the results of the tests with the CAT software (fig. 5) and the ABCD method (ICCROM-ICC-ICN) (fig. 6) tested at the Wilanów museum in June 2016. Here also preliminary analyses and a complete evaluation by condition report were made. The tests at Wilanów lasted 2 to 5 days and mobilised conservation teams from Italy, France and Poland that worked together, a total number of 9 people divided into groups, each group tested a different method.

For the sake of uniformity and comparability, the choice of the tested perimeter was strictly studied. In fact, it was important to find rooms to study in each residence which had a similar number of works, objects with similar characteristics, etc. One of the important factors was also the presence of the public – which rooms were visited continuously, intermittently or even used in the context of particular events. It is a conjunction of these different factors that resulted in the choice in Wilanów of the Dutch Cabinet, the Lubomirska Salon and the Raspberry Salon, three very different spaces within the Palace.

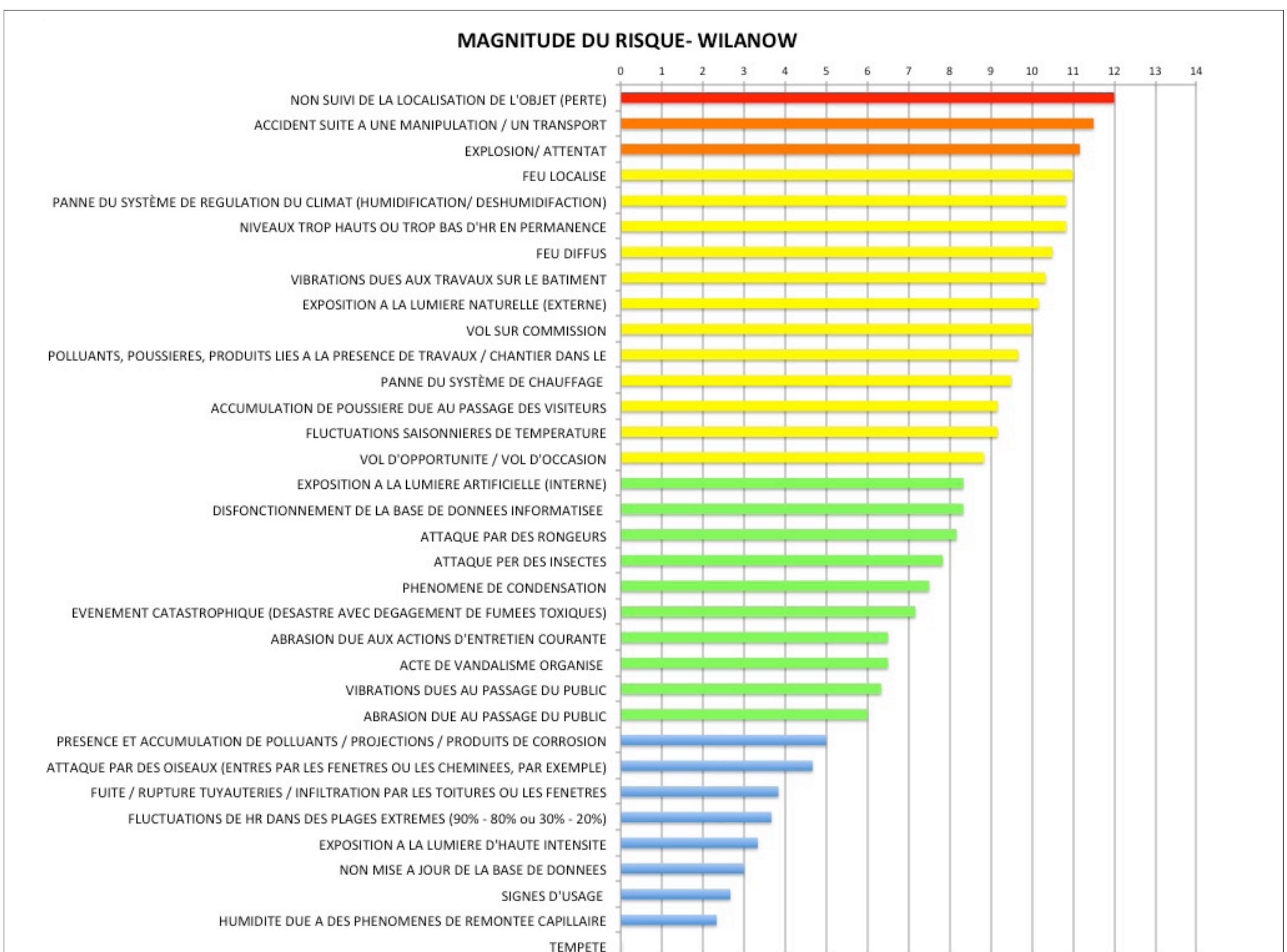
The tests with the CAT software (fig. 5) were carried out following the first evaluation. This method was also based on the conservation reports (the condition report). Thanks to this evaluation tool, it was also possible to analyse the conservation conditions and determine the potential damage causes. This method makes it possible to determine the deterioration cause and its relation with the exhibition space where the object was reported. The application of this tool presents sometimes

Fig. 6
Result of the application of the ABCD method at the Palace of Versailles.
(© EPICO team)

Fig. 7
Result of the application of the ABCD method at the Wilanów Palace.
(© EPICO team)



MAGNITUDE DU RISQUE- VERSAILLES
ACCIDENT SURVENU LORS DE TRAVAUX SUR LE BATIMENT
FEU DIFFUS
ACCIDENT SUITE A UNE MANIPULATION / UN TRANSPORT
PANNE DU SYSTÈME DE CHAUFFAGE
VOL SUR COMMISSION
EXPLOSION/ ATTENTAT
ATTAQUE PER DES INSECTES
ABRASION DUE AUX ACTIONS D'ENTRETIEN COURANTE
ATTAQUE PAR DES OISEAUX (ENTRES PAR LES FENETRES OU LES CHEMINEES, PAR
VIBRATIONS DUES AUX TRAVAUX SUR LE BATIMENT
FLUCTUATIONS SAISONNIERES DE TEMPERATURE
PRESENCE ET ACCUMULATION DE POLLUANTS / PROJECTIONS / PRODUITS DE
ACCUMULATION DE POUSSIERE DUE AU PASSAGE DES VISITEURS
POLLUANTS, POUSSIERES, PRODUITS LIES A LA PRESENCE DE TRAVAUX / CHANTIER
ATTAQUE PAR DES RONGEURS
NIVEAUX TROP HAUTS OU TROP BAS D'HR EN PERMANENCE
EXPOSITION A LA LUMIERE NATURELLE (EXTERNE)
DISFONCTIONNEMENT DE LA BASE DE DONNEES INFORMATISEE
MANQUE DE DOCUMENTATION SUR L'HISTORIQUE DES OBJETS ET LEUR
PHENOMENE DE CONDENSATION
NON SUIVI DE LA LOCALISATION DE L'OBJET (PERTE)
FUITE / RUPTURE TUYAUTERIES / INFILTRATION PAR LES TOITURES OU LES FENETRES
ACTE DE VANDALISME ORGANISE
VIBRATIONS DUES AU PASSAGE DU PUBLIC
TEMPETE
ABRASION DUE AU PASSAGE DU PUBLIC
VOL D'OPPORTUNITE / VOL D'OCCASION
EXPOSITION A LA LUMIERE ARTIFICIELLE (INTERNE)
FEU LOCALISE
MONTEE EN TEMPERATURE DUE A L'ECLAIRAGE
0 2 4 6 8 10 12 14



MAGNITUDE DU RISQUE- WILANOW
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
NON SUIVI DE LA LOCALISATION DE L'OBJET (PERTE)
ACCIDENT SUITE A UNE MANIPULATION / UN TRANSPORT
EXPLOSION/ ATTENTAT
FEU LOCALISE
PANNE DU SYSTÈME DE REGULATION DU CLIMAT (HUMIDIFICATION/ DESHUMIDIFACTION)
NIVEAUX TROP HAUTS OU TROP BAS D'HR EN PERMANENCE
FEU DIFFUS
VIBRATIONS DUES AUX TRAVAUX SUR LE BATIMENT
EXPOSITION A LA LUMIERE NATURELLE (EXTERNE)
VOL SUR COMMISSION
POLLUANTS, POUSSIERES, PRODUITS LIES A LA PRESENCE DE TRAVAUX / CHANTIER DANS LE
PANNE DU SYSTÈME DE CHAUFFAGE
ACCUMULATION DE POUSSIERE DUE AU PASSAGE DES VISITEURS
FLUCTUATIONS SAISONNIERES DE TEMPERATURE
VOL D'OPPORTUNITE / VOL D'OCCASION
EXPOSITION A LA LUMIERE ARTIFICIELLE (INTERNE)
DISFONCTIONNEMENT DE LA BASE DE DONNEES INFORMATISEE
ATTAQUE PAR DES RONGEURS
ATTAQUE PER DES INSECTES
PHENOMENE DE CONDENSATION
EVENEMENT CATASTROPHIQUE (DESASTRE AVEC DEGAGEMENT DE FUMEES TOXIQUES)
ABRASION DUE AUX ACTIONS D'ENTRETIEN COURANTE
ACTE DE VANDALISME ORGANISE
VIBRATIONS DUES AU PASSAGE DU PUBLIC
ABRASION DUE AU PASSAGE DU PUBLIC
PRESENCE ET ACCUMULATION DE POLLUANTS / PROJECTIONS / PRODUITS DE CORROSION
ATTAQUE PAR DES OISEAUX (ENTRES PAR LES FENETRES OU LES CHEMINEES, PAR EXEMPLE)
FUITE / RUPTURE TUYAUTERIES / INFILTRATION PAR LES TOITURES OU LES FENETRES
FLUCTUATIONS DE HR DANS DES PLAGES EXTREMES (90% - 80% ou 30% - 20%)
EXPOSITION A LA LUMIERE D'HAUTE INTENSITE
NON MISE A JOUR DE LA BASE DE DONNEES
SIGNES D'USAGE
HUMIDITE DUE A DES PHENOMENES DE REMONTEE CAPILLAIRE
TEMPETE

a subjective evaluation in the deterioration input system and their relation with the causes (for example, 29% of the causes could not be clearly determined). In 33% of the cases, natural ageing was the deterioration cause. Very often, the deterioration reason was indicated as manipulation or use depending on the function (16%), which is coherent with the damage risk due to moving as highlighted in the ABCD method.

The risk assessment methodology called ABCD was also tested in Wilanów. This scaling method takes its name from the main components that determine the importance of each defined risk factor. The results obtained (fig. 7) proved to be consistent with our experience. Tests have shown that the highest risk evaluated by this tool was the damage risk resulting mainly from moving (handling/transport) and the risk of dissociation or loss. Of course, the most dangerous being the fire hazard risk. A somewhat surprising position is the terrorist attack – which has never taken place in Wilanów, while taking into account the political situation, the risk was highly probable.

It is interesting to note that Wilanów's risk factors are very close to those highlighted by the application of the ABCD method in Versailles (fig. 6). They seem consistent with the report from the analysis of the collections' condition reports and the experience of the people working in this institution.

The ABCD method is also interesting for the EPICO members because it highlights the risks and thus allows to project oneself in the future, which is not obvious with the other tested methods.

Appraisal of the Tested Evaluation Methods

In conclusion of this study on the different assessment methods, we can conclude with an assessment attempt of these methods' effectiveness in relation to the objectives set at the beginning of our research (table 1).

The application time and the human resources to be deployed are also fundamental elements in the assessment of each method (table 2).

Conclusion

The testing sessions have made it possible to verify on the field the adaptability and the effectiveness of the methods and draw the following conclusions:

– the assessment method, namely the way of collecting and processing data is a crucial element for achieving reliable results. The comparison of the graphs of the tested methods clearly shows that the

Criteria for evaluating the methods in relation to the EPICO objectives	**Pilot Inspection** M. A. Gunn Paris 1 University	**Cross Method** A. Xavier- Rowe, C. Fry English Heritage	**ABCD** S. Michalski *et alii* Canadian Conservation Institute	**CAT** Conservation Studio Scottish Museum Council
The method must provide a global vision through a systemic approach	✓	✓	✓	×
It must be specific / adaptable to the collections of historic houses open to the public	✓	✓	✓	✓
The method must be simple and reproducible (on large-scale residences as well as in smaller houses)	✓	✓	✓	✓
It must highlight the causal relationship of the alterations	✓	✓	×	✓
The method must be usable with any medium: paper, Excel spread sheets, database (e.g. Filemaker®), but also adaptable to existing collections management IT systems (e.g. The Museum System – TMS®)	✓	✓	✓	×
Comparability between rooms / sites: the calculation system is not influenced by the number of displayed objects in the rooms	×	✓	✓	×
The results of the assessment with this method are consistent / comparable with the data from report campaign done object by object	✓	✓	×	×

Table 2
Summary table of the criteria of the assessment methods. (© EPICO team)

TIME STEPS IN THE ASSESSMENT/METHOD	**SANITARY REPORT**	**ABCD**	**GUNN**	**ENGLISH HERITAGE**
Preparation of the report tools at the office and on the spot	**1 day** 2 people	**1 day** 2 people	**2days** 1 person	**1/2 day** 1 person
Data collection on the spot	**3 days** 2 people	**3.5 days** 3 people	**3 days** 2 people	**3 days** 2 people
Data treatment on the office	**3 days** 1 person	**1 day** 1 person	**1.5 days** 1 person	**2 days** 1 person
Interprétation des résultats au bureau	**3 days** 2 people	**1 day** 2 people	**1 day** 2 people	**1 day** 2 people
Interpretation of the results at the office	**10 DAYS**	**6.5 JOURS**	**7.5 DAYS ***	**6.5 DAYS**
ESTIMATE FOR 12 ROOMS	28 DAYS	18 DAYS	7.5 DAYS	20 DAYS

Table 3
Summary table of the estimated application time temps for each method. (© EPICO team)

*NB: if we consider that the results of the GUNN method are representative for twelve rooms – thanks to the pilot inspection – the method proves to be more efficient.

relevance of the results of the assessments is related more to the data processing system than to the level of expertise of the examiners (for the tests it was the same team composed of conservators, an art historian, a registrar, a physicist and preventive conservation specialists). Thus, it is permissible to allocate less energy to the observation of the object in its singularity, but we must not be mistaken in the data calculation system concerning the whole collection.

– The history of the location of the items is a decisive factor when taking into account the causal relationship. Even if the Gunn and the English Heritage methods evaluate the causes according to the observed deteriorations, the tested methods do not take this parameter into account. In an historic house, the interpretation of the deterioration and its causes is facilitated by the relation that the objects maintain with the conservation conditions of the rooms for which they have been conceived or assigned. The recent history of their location (between 0 and 100 years) is more easily recognizable.

– The factors of active (cause) or potential (risk) deterioration must be evaluated and interpreted as distinct but complementary elements, which publications and experiments encourage us to create a dialogue within a same method that has a systemic approach.

Bibliography

Brokerhof A., 'Risk Assessment of Museum Amstelkring: Application to a Historic Building and its Collections and the Consequences for Preservation Management,' in *ICOM-CC Committee for Conservation, 14th Triennial Meeting: Preprints*, The Hague, 12-16 September 2005, James & James, London, 2005, p. 590-596. All of Agnes Brokerhof papers are available on the website www.academia.edu (accessed on 19 December 2016).

De Guichen G., De Tapol B., *Contrôle du climat dans les musées - Manuel pour le participant*, Tome 1 and 2, Rome: ICCROM, 1997.

Edwards D., Murray W., *Condition Assessment Tool Manual: a Manual for Using the Condition Assessment Tool (CAT) Database*, Scottish Museums Council, Edinburgh, 2002. The tool and the manual are downloadable for free at http://www.scottishconservationstudio.co.uk/cat-download (accessed on 19 December 2016).

Forleo D., Francaviglia N., De Blasi S., Pawlak A. (ed.), 'Méthodes d'évaluation de l'état et des conditions de conservation des collections dans les demeures historiques,' in *Cronache 7*, Centro Conservazione e Restauro La Venaria Reale, Sagep Editori, Genoa, 2017.

Forleo D., Francaviglia N., Wansart N., 'Les méthodes d'évaluation des collections : étude comparative et test en vue de leur application aux collections exposées des demeures historiques et des châteaux-musées. EPICO Research Program,' in *Les nouvelles rencontres de la conservation préventive*, June 8-9, 2017, Pierrefitte, Aprévu, 2017, p. 125-148.

Gunn M-A., 'Bilan des conditions physiques de conservation des collections, Château de Chantilly,' DESS in preventive conservation dissertation, directed by Denis Guillemard, Paris 1 University Panthéon Sorbonne, 2001.

Karsten I., Mishalski S., Case M., 'Balancing the Preservation Needs of Historic House Museums and their Collections Through Risk Management,' in ICOM-DEMHIST, *The Artefact, its Context and their Narrative: Multidisciplinary Conservation in Historic House Museums*, The Getty Research Institute, Los Angeles, 6-9 November 2012, Paris, ICOM-CC, 2012. Available at: http://www.icom-cc.org/ul/cms/fck-uploaded/documents/DEMHIST%20_%20ICOM-CC%20Joint%20Interim%20Meeting%20 2012/10-Karsten-DEMHIST_ICOMCC-LA_2012.pdf (accessed on 19 December 2016).

Michalski S., Pedersoli J. L. Jr, *La méthode ABC pour appliquer la gestion des risques à la préservation des biens culturels*, Ottawa: Institut Canadien de Conservation, 2016 (unpublished).

Taylor J., 'An Integrated Approach to Risk Assessment and Condition Surveys,' in *JAIC – Journal of the American Institute for Conservation*, vol. 44, n° 2, 2005, p. 127-141. Available at: http://cool.conservation-us.org/jaic/articles/jaic44-02-006_indx.html (accessed on 19 December 2016).

Waller R., 'Conservation Risk Assessment: a Strategy for Managing Resources for Preventive Conservation,' in Roy A., *Preventive Conservation, Practice, Theory and Research*: *Preprints of the Contributions to the Ottawa Congress*, 12-16 September 1994, London, IIC - The International Institute for Conservation of Historic and Artistic Works, 1994, p.12-16.

Waller R., *Cultural Property Risk Analysis Model, Development and Applications at the Canadian Museum of Nature,* PhD Thesis in the Discipline of Conservation, Goteborg University Institute of Conservation, Acta Universitatis Goteburgensis, Goteborg 2003.

Waller R., Michalski S., 'A Paradigm Shift for Preventive Conservation, and a Software to Facilitate the Transition,' in *ICOM-CC Committee for Conservation, 14th Triennial Meeting: Preprints*, The Hague, 12-16 September 2005, James & James, London, 2005, p. 733-738.

For a summary of the evolution of predictive approach see also: Antomarchi C., Michalski S., 'L'approche prédictive ou évaluation des risques: un outil d'aide à la décision en conservation préventive, in Association des Restaurateurs d'Art et d'Archéologie de Formation Universitaire,' in *Constats, diagnostics, évaluations: la conservation préventive en action*, X days and debates organised by the Master in Preventive Conservation at the Paris 1 University - under the direction of Denis Guillemard, Paris, June 14 and 15 2006, acts published in *Conservation-Restauration des Biens Culturels*, Technical guidebook n° 15, Paris: ARAAFU, 2007.

Xavier-Rowe A., Fry C., 'What's Causing the Damage! The Use of a Combined Solution-Based Risk Assessment and Condition Audit,' in *Museum Microclimates, National Museum of Denmark and ICOM-CC preventive Conservation Working Group,* Copenhagen, 2007, pp. 107-114. Available at: https://www.english-heritage.org.uk/content/imported-docs/k-o/musmiccfauditpaper.pdf (accessed on 19 December 2016).

Xavier-Rowe A., Fry C., 'Heritage Collections at Risk: English Heritage Collections Risk and Condition Audit,' in ICOM-CC, *16th Triennial Conference,* September 19-23, 2011, Lisbon. International Council of Museums, Lisbon, 2011. Available at: http://www.english-heritage.org.uk/content/learn/conservation/2543455/2543024/Heritage_Collections_at_Risk.pdf (accessed on 19 December 2016).

Warning Signs of Alteration: a Key Element for the Assessment Method. Objectives and Research

Roberta Genta
Head of textile conservation studio, Centro Conservazione e Restauro "La Venaria Reale"
roberta.genta@centrorestaurovenaria.it

Marco Nervo
Head of Scientific Laboratories of La Venaria Reale, Conservation and Restoration Centre
marco.nervo@centroresataurovenaria.it

Abstract

The research on observable alteration indicators on historic houses' collections represents a fundamental step in the EPICO programme, in line with the objectives all partners share. Supervised by the Versailles team, who provided a visual glossary of alteration as a support tool for the in situ testing, the research focused on two key elements for the EPICO programme: the cause–effect relationship of alteration and the assessment method's systematic approach.

Alteration indicators research was conducted with the understanding that it would facilitate the examiner's object observation work during the in situ assessment. Thus it was essential to propose indicators easily observable and measurable with the naked eye or with simple tools (cameras, magnifying glass 10x, visible/UV light torch, caliber, etc.).

The research carried out by the CCR team in 2016 saw the collaboration of a multidisciplinary team of conservators-restorers, specialised in several materials, experienced in the maintenance and treatment of the collections of the royal residences of Savoy. This explains why although some indicator definitions were found in the literature, many others are derived from the direct observation of this type of collection, in order to create an immediate access vocabulary.

This research needed to go beyond a simple vocabulary of definitions: for each alteration indicator it was necessary to identify the specific phenomena that would cause it, to identify the plausible causes, to bring into focus the cause–effect relationship of alteration. This exercise was sometimes complex because a single type of alteration can have several causes.[1]

Keywords

Alteration indicators, alteration cause.

A global approach to the preventive conservation of Cultural Heritage necessarily implies that the research activity aimed at studying the state of preservation of the works of art in the historical houses should start from the analysis of the object within its "environment system," from which both the equilibria and the alterations of the materials may depend.

The Centro Conservazione e Restauro La Venaria Reale has selected an interdisciplinary team composed of conservators-restorers

Table 1
Classification of alterations in a selected list according to the type of alteration.

Abrasion / Wear / Scratch / Fraying
Burn
Corrosion / Oxidation
Craquelure / Crizzling
Pulverulence
Yellowing / Fading / Colour change
Efflorescence / Exudation
Disjoints, detached / Moving element, lost element
Exogenous material
Crack / Tear / Split / Fracture / Crack / Disjoints
Warping / Deformation / Crease
Graffiti / Tag
Hole / Loss
Dust / Surface dirt / Grease / Grime / Soil particles
Presence of mould
Cleavage / Flacking
Stain / Mark
Tarnishing / Dulling
Signs of insect attack

specialized in organic and inorganic materials, already active in condition reporting campaigns and ordinary and extraordinary maintenance programs in the historical residences of Piedmont.[2]

Research on indicators of deterioration and on the definition of alteration phenomena and their visible effects on the works of art has represented, since the start of the EPICO project, a fundamental step in the programme.

The aim of the research fit the need emerging clearly in all the campaigns for the analysis of the state of preservation in a collection: to connect, in an objective, scientific and documentable manner, the alterations detected with the most correct, concomitant or independent, cause or causes.

Respecting the guidelines of preventive conservation, that never separates the evaluation of the conditions of the works of art from those of their "environment system," the research on alteration indicators and their causes followed a methodological approach, starting from the material of which the object is made, through its alterations, up to the evaluation of the relationship between the material itself and the environment in which the object is located, in this case a historical residence, today normally open to the public. To start from the analysis of the state of preservation of the works of art in their "environment system" allowed to reach the purpose both for on-site and bibliographic research phase: identify the possible cause-effect relationships of the

Old treatment (Conservation / Restoration treatment)
Visitors transit
Climate
Wrong manufacturing
Natural instability of the object (Manufacturing / Patina)
Water
Continuous and repeated housekeeping / Incorrect housekeeping
No housekeeping
Fire
Pest / mould
Light and UV
Handling / Transport / Accident
Display mode / Storage mode
Pollutants
Past use / Current use
Vibration
Criminals / Theft / Dissociation

Table 2
List of causes used in the EPICO method tests in 2017, before the last update.

alterations detected on the collections.

Among the numerous types of objects most present and widespread in the historical collections of the residences, the constituent materials considered most representative were selected, also as samples to be tested in the in situ sessions.

For each material the possible alterations were then listed. The choice to use the term "alteration" instead of "degradation" arises from the recommendations of the UNI NORMAL commissions[3] that indicate "the alteration is a modification of the material that does not necessarily imply a worsening of its characteristics in terms of conservation," while the term "degradation" means a modification which "always implies a deterioration." Therefore, the study on the indicators was based on the visual analysis of the surface of the works of art searching "visible alterations," without the presumption of defining the alteration as a process of deterioration in progress.

Based on the need to have a list of alterations easily identifiable by the simple visual observation of the objects, an initial list was drawn up, including a glossary with a description of the items (table 1 – drafted in 2016 by the team of Versailles).

To obtain a list of the causes to be linked to the conditions of the object under test, the team of conservators-restorers of the CCR la Venaria Reale, with the support of the Scientific Laboratories, started a campaign of bibliographic research to deepen the knowledge of the

Visible alteration indicator (specific term)	Description of visible alteration: what we see on the object	Generic alteration cause (main cause)	Generic alteration cause (secondary cause and\or aggravating cause)
Dust cementation	Alteration caused by the addition of substances (deposition of dust, dirt or other impurities) which may cause the surface appearance of the work to change	Lack of housekeeping (of the rooms / of the collections)	Climate

Specific damage factor	Bibliographical source	Diagnosis
Incorrect RH: RH> 65% The chemical process of dust cementation can be quite rapid at high relative humidity (80%) such that the cements may form in less than a day	Helen Lloyd, Caroline Bendix, Peter Brimblecombe, David Thickett, 'Dust In Historic Libraries,' in *Museum Microclimates*, Contributions to the Copenhagen conference 19-23 November 2007, Edited by Tim Padfield and Karen Borchersen	Cementation tends to occur at high humidity and can be driven by biological, physical and chemical processes. Humidity cycles cause physical movement of fibrous material that allow dust to embed deeper into porous surfaces. At high humidity calcium ions can leach from dust particles, and re-deposit as microcrystalline calcite, which cements the dust particle to the substrate in much the same way as lime mortars recrystallise. This chemical process can be quite rapid at high relative humidity (80%) such that the cements may form in less than a day. At high humidity, dust adheres very effectively to organic materials such as cotton and silk. The cementation process increases dramatically at high RH values.

Table 3, 4
Example of research on damage factors and visible indicators.

cause / effect relationship (table 2). In total, around one hundred papers, conference proceedings and specialised websites were consulted.

The existing data in the scientific literature were collected in a system of tables, subdivided by materials and alterations, which forms the basis of the new assessment method of the EPICO programme.

Considering the large amount of data collected, only one example will be presented here, representative of the problems that normally arise in the fact-finding and conservative reporting campaigns of cultural heritage. The subjectivity of the scheduler is perhaps the main factor that can influence the condition report campaign. For all the alterations detected during the test, the evaluation of the causes will depend not only on the knowledge of the constitutive materials and the executive techniques of the artefact, knowledge directly observable from the appearance and the type of degradation, but also by the critical capacity to reconstruct the conservative history of the work of art itself (previous interventions, internal and external movements, permanence in storage, etc.) and to evaluate the conditions of the environments.

The example shown in table 3 refers to the textile covering of a stool dating back to the end of the 18th century belonging to the collections of the Stupinigi Hunting Palace: the silk fabric with application of embroidery shown an accumulation of exogenic material of grey colour, compact, hard, and of variable thickness, modifying the surface morphology and colours of embroidery. In the testing phase this alteration could be classified as accumulation of dirt caused by a lack of maintenance of the fabric, not subjected to planned cleaning operations in the past. The detailed study on the conservation history of the artefact, that it was possible to reconstruct only thanks to the interviews with the staff of the Piedmontese residence, has led us to consider a possible cause aggravating the alteration detected: in the reconstruction of the handling inside the Palace it emerged that the stool has been moved to a non-air-conditioned warehouse and that the packaging helped to create a microclimate with relative humidity values favourable to the process known and verified in the bibliography as "dust cementation" [Lloyd, 2007, p. 138] (table 4).

The intrinsic limitation of this approach to the study of artefacts in their exhibition context lies in the fact that the alterations are observed on the objects themselves. In the case of an ongoing degradation this means observing it when it is already potentially dangerous for the work of art. We have the list of alterations and the list of related causes, the next step is to identify sample materials to be inserted in the same environment in order to evaluate the "aggressiveness" of the environment itself. These materials must interact with the environment in the same way that the constituent materials in order to highlight the cause of alteration present in it, but in a quickly manner and maximising the effect of the cause. It is important to be able to highlight the causes of alteration before their effect is visible, but above all before it can cause damage to objects. Furthermore, these materials must be able to emphasise in particular those causes that produce alterations not immediately highlighted only by the visual inspection carried out by the conservator-restorer.

Conclusions

Taking into account the complex work of observation of collections on site and of critical analysis of the possible causes that in the "environment system" of a historical residence contribute to an alteration of the materials, it is important to clarify here some considerations. A fundamental assumption for the research on the indicators of alteration was the knowledge of the materials: the phenomena of alteration of the state of conservation of the various artefacts can be correctly identified, defined and critically linked to the causes only starting from the constitutive material and from the executive technique of the works of art under test.

In work on site the professional figures in charge of the tests must submit the collected data to a critical check, through a system of relations between the artefact, the environment system and the conservative history of the work of art in its context. Purpose of this check is to limit the errors introduced by the subjectivity of the evaluation in the cause / effect relationships of the alteration.

The work done so far should not be considered finished, but rather is being continued with the elaboration of data collected during the test.

Finally, based on the experience gained over the years, we have understood how the visitor, here indicated as one of the possible causes related with some alterations, can be invested with a different role in the system of preventive conservation: it is an element to be taken into account for the management of anthropic risks but also it represents the "raison d'être" of the Residences open to the public.

Endnotes

[1] Excerpt from document "Objectifs du programme de recherche EPICO – 2014-2017," Palace of Versailles' staff, 2015.

[2] Paolo Luciani (wooden furniture), Marco Demmelbauer (metals, ceramic, glass), Valeria Arena (paper), Ilaria Negri (painting on canvas and on wood), Roberta Genta (tapestries, textiles).

[3] UNI 11182 - April 2006 - ICS 01.020; 91.100.15; Cultural Heritage – Natural and artificial stone – Description of the alteration – Terminology and definition.

Bibliography

This bibliography is to be considered as an extract of the totality of the scientific literature consulted by the working group.

METALS/MIRROR/GLASS

Alloteau F., Lehuédé P., Majérus O., Biron I., Dervanian A., Charpentier T., Caurant D., 'New Insight into Atmospheric Alteration of Alkali-Lime Silicate Glasses,' in *Corrosion Science,* vol. 122, 2017, pp. 12-25.

Brill R.H., 'Crizzling – A Problem in Glass Conservation,' in *Conservation in Archaeology and the Applied Arts*, Stockholm Congress, 1975, pp. 121-134.

Chen Z. Y., Liang D., Ma G., Frankel G. S., Allen H. C. and Kelly R. G., 'Influence of UV Irradiation and Ozone on Atmospheric Corrosion of Bare Silver,' in *Corrosion Engineering, Science and Technology*, vol. 45, 2010, pp. 169-180.

Costa V., Dubus M., 'Impact of the Environmental Conditions on the Conservation of Metal Artifacts: an Evaluation Using Electrochemical Techniques,' in *Contribution to the Copehnaghen Conference Museum Microclimates*, 19-23 November 2007, pp. 63-65. http://www.conservationphysics.org/mm/costa/costa.pdf (accessed on 22 November 2018).

Duran A., Herrera L.K., Jiménez de Haro M.C., Pérez-Rodríguez J.L. and Justo A., 'Study of Degradation Processes of Metals Used in Some Artworks from the Cultural Heritage of Andalusia,' in *Revista de Metalurgia,* 45 (4), 2009, p. 277-286.

Qiu P., Leygraf C., 'Initial Oxidation of Brass Induced by Humidified Air,' in *Applied Surface Science*, 258, 2011, p. 1235-1241.

Hadsund P., 'The Tin-Mercury Mirror: its Manufacturing Technique and Deterioration Processes,' in *Studies in Conservation*, vol. 38, issue 1, 1993.

Herrera Quintero L.K., 2009. *Physico-Chemical Research of Cultural Heritage Materials Using Microanalytical Methods*, Tesis Doctoral, Consejo Superior de Investigaciones Científicas Universidad de Sevilla.

Huang L., *Atmospheric Corrosion of Ag and Cu with Ozone, UV and NaCl, Dissertation, Materials Science and Engineering*, The Ohio State University, 2013.

Kilinççeker G., Taze N., Galip H., Yazici B., 'The Effect of Sulfur Dioxide on Iron, Copper and Brass,' in *Anti-Corrosion Methods and Materials*, vol. 58, 2011, pp. 4-12.

Knotkova D., Kreislova K., *Atmospheric Corrosion and Conservation of Copper and Bronze*, in *Transactions on State of the Art in Science and Engineering*, vol. 28, 2007, pp. 107-142.

Koob S. P., 'Crizzling Glasses: Problems and Solutions,' in *Glass Technology: European Journal of Glass Science and Technology*, Part A, 53(5), 2012, pp. 225-227.

Kunicki-Goldfinger J., 'Preventive Conservation Strategy for Glass Collections. Identification of Glass Objects Susceptible to Crizzling,' in *The Conservation of Cultural Heritage for Sustainable Development*, 2005, p. 301-304.

Lin H., 'Atmospheric Corrosion of Ag and Cu with Ozone, UV and NaCl,' in *Dissertation, Materials Science and Engineering*, The Ohio State University, 2013.

Oudbashi O., *Corrosion Risk Assessment Approach in Archaeological Bronze Collections: From Burial to Long-Term Preservation Environments*, Icom-CC Metal 2016, New Delhi, India, 2016.

Papadopoulos N., Drosou C.A., 'Influence of Weather Conditions on Glass Properties,' in *Journal of the University of Chemical Technology and Metallurgy*, 47, 4, 2012, pp. 429-439.

Payne de Chavez K., 'Historic Mercury Amalgam Mirrors: History,

Safety and Preservation,' in *Art Conservator a Publication of Williamstown Art Conservation Center*, vol. 5, n. 1, Spring 2010. http://www.williamstownart.org/techbulletins/images/WACC%20Historic%20Mercury%20Mirrors.pdf (accessed on 22 November 2018).
Qiu P. and Leygraf C., 'Initial Oxidation of Brass Induced by Humidified Air' in *Applied Surface Science* 258, pp. 1235-1241.
Römich H., Böhm T., 'Deterioration of Glass By Atmospheric Attack,' in *Climatic and Air Pollution Effects on Materials and Equipment*, publication n. 2, 1999, pp. 187-202.
Ryan J. L., McPhail D. S., Rogers P. S., Oakley V. L., 'Glass Deterioration in the museum environment: A Study of the Mechanisms of Decay using Secondary Ion Mass Spectrometry,' in *ICOM-CC 11th Triennial Meeting*, 1-6 September 1996, Edinburgh.
Samie F., *HNO3-Induced Atmospheric Corrosion of Copper, Zinc and Carbon* Steel, Doctoral Thesis, KTH, School of Chemical Science and Engineering (CHE), Kemi, Stockholm, 2006.
Svedung O. A., Johansson L.-G., Vannerberg N.-G., 'Corrosion of Gold-Coated Contact- Materials Exposed to Humid Atmospheres Containing Low Concentrations of SO_2 and NO_2,' in *IEEE Transactions on Components, Hybrids, and Manufacturing Technology* 6 (3), 1983, pp. 349-355.
Valdez Salas B., Schorr Wiener M., Lopez Badilla G., Carrillo Beltran M., Zlatev R., Stoycheva M., Juan de Dios Ocampo Diaz, Vargas Osuna L., Terrazas Gaynor J., *H2S Pollution and its Effect on Corrosion of Electronic Components*, Air Quality – New Perspective, 2012, pp. 263-286.
Walters H. V., Adams P. B, 'Effects of Humidity on the Weathering of Glass,' in *Journal of Non-Crystalline Solids* 19, 1975, pp.183-199.

CANVAS PAINTINGS/PAINTED WOOD/ FURNITURE/LACQUER

Bratasz L., Kozlowski R., Kozlowska A., Rivers S., 'Conservation of the Mazarin Chest: Structural Response of Japanese Lacquer to Variations in Relative Humidity,' in *ICOM-CC 15th Triennial Meeting*, 22-26 September 2008, New Delhi, India, Conference Preprints, vol. II, 2008, pp. 933-940.
Bratasz Ł., Rachwał B., Lasyk Ł., Łukomski M., Kozłowski R., *Fatigue Fracture of Painted Wood due to Repeated Humidity Variations. Institute of Catalysis and Surface Chemistry Polish Academy of Sciences*, 2010. https://www.researchgate.net/publication/263061432_Fatigue_Damage_of_the_Gesso_Layer_in_Panel_Paintings_Subjected_to_Changing_Climate_Conditions.
Cristoferi E., *Gli avori, problemi di restauro*, Nardini Editore, Florence, 1992.
Dardes K., Rothe A. (ed.), *The Structural Conservation of Panel Paintings: Proceedings of a Symposium at the J. Paul Getty Museum*, 24-28 April 1995. Getty Conservation Institute, Los Angeles, 1998. http://hdl.handle.net/10020/gci_pubs/panelpaintings.
Kirby J., 'Fading and Colour Change of Prussian Blue: Occurrences and Early Reports,' in *National Gallery Technical Bulletin*, vol. 14, 1993, pp. 62-71. http://www.nationalgallery.org.uk/technical-bulletin/kirby1993 (accessed on 22 November 2018).
Knut N., *Il restauro dei dipinti*, Ullmann, Cologne, 2003, pp. 335-338.
Krzemień L., Łukomski M., Bratasz Ł., Mecklenburg M., Kozłowski R., 'Mechanism of Craquelure Pattern Formation on Panel Paintings,' in *Studies in Conservation* 61, 2016, pp. 324-330.
Ligterink F. G., Di Pietro G., 'Canvas Paintings on Cold Walls: Relative Humidity Differences Near the Stretcher,' in *Contribution to the Copehnaghen Conference Museum Microclimates*, 19-23 November 2007. https://natmus.dk/fileadmin/user_upload/natmus/bevaringsafdelingen/billeder/M_M/Museum_Microclimate/Contributions_to_the_conference/ligterink_abstract.pdf (accessed on 22 November 2018).
Liotta G., *Gli insetti e i danni del legno, Problemi di restauro*, Nardini Editore, Florence, 1991.
Mecklenburg M. F., 'Some Mechanical and Physical Properties of Gilding Gesso,' in Bigelow D. *et al.* (ed.), *Gilded Wood*, Sound View Press, Madison (Conn), 1991, pp. 163-170.
Mecklenburg M. F., Tumosa C., 'Mechanical Behavior of Paintings Subjected to Changes in Temperature and Relative Humidity,' in Mecklenburg M. F. (ed.), *Art in Transit*, National Gallery of Art, Washington, 1991, pp. 173-216.
Mecklenburg M. F., Tumosa C. S. and Erhardt D., 'Structural Response of Painted Wood Surfaces to Changes in Ambient Relative Humidity,' in Dorge V. and Howlett F. C. (ed.), *Painted Wood: History and Conservation*, The Getty Conservation Institute, Los Angeles, 1998, pp. 464-483.
Mecklenburg M. F., *Determining the Accettable Ranges of Relative Humidity and Temperature in Museum Galleries*, part 1, Structural Response to Relative Humidity, Smithsonian Conservation Institute, 2007.
Mecklenburg M. F., 'Microclimate and Moisture Induce Damage on Paintings,' in *Contribution to the Copehnaghen Conference Museum Microclimates*, 19-23 November 2007.
Mecklenburg M. F., *Meccanismi di cedimento nei dipinti su tela: approcci per lo sviluppo di protocolli di consolidamento*, Il Prato, Florence, 2008.
Michalski S., 'Crack Mechanisms in Gilding,' in Bigelow D. *et al.* (ed.), in *Gilded Wood*, Madison (CT), Sound View Press, 1991a, pp. 171-181.
Michalski S., 'Paintings – their Response to Temperature, Relative Humidity, Shock and Vibration,' in Mecklenburg M. F. (ed.), *Art and Transit*, National Gallery of Art, Washington, 1991b, pp. 223-248.
Oldstad T. M., Haugen A., 'Warm Feet and Cold Art: is This the Solution? Polychrome Wooden Ecclesiastical Art-Climate and Dimensional Changes,' in *Contribution to the Copehnaghen Conference Museum Microclimates*, 19-23 November 2007. http://www.conservationphysics.org/mm/olstad/olstad.pdf (accessed on 22 November 2018).
Rivers S. and Umney N., *Conservation of Furniture*, Butterworth-Heinemann, Oxford, 2003.
Rivers S., Pretzel B., Faulkner R. (ed.), *East Asian Lacquer: Conservation, Science and Material Culture*, Archetype Books, London, 2011.
Roche A., *Comportement mécanique des peintures sur toile. Dégradation et prévention*, CNRS éditions, Paris, 2003.
Saunders D., Kirby J., 'Light-Induced Colour Changes in Red and Yellow Lake Pigments,' in *National Gallery Technical Bulletin*, vol. 15, pp. 79-97. http://www.nationalgallery.org.uk/technical-bulletin/saunders_kirby1994 (22 November 2018).
Saunders D., Kirby J., 'The Effect of Relative Humidity on Artists' Pigments,' in *National Gallery Technical Bulletin*, vol. 25, 2004, pp. 62-72. http://www.nationalgallery.org.uk/technical-bulletin/saunders_kirby2004 (accessed on 22 November 2018).
Schellmann N., 'Observations on the Causes of Flaking in East Asian Lacquer Structures,' in *Conservation Journal* 56 (Autumn 2008). http://www.vam.ac.uk/content/journals/conservation-journal/issue-56/observations-on-the-causes-of-flaking-in-east-asian-lacquer-structures/ (accessed on 22 November 2018).
Schellmann N., *Delamination and Flaking of East Asian Export Lacquer Coatings on Wood Substrates*, Archetype Books, London, 2011. https://www.researchgate.net/publication/275657145_Delamination_and_flaking_of_East_Asian_export_lacquer_coatings_on_wood_substrates (accessed on 22 November 2018).
Spring M., Higgitt C., Saunders D., 'Investigation of Pigment-Medium Interaction Processes in Oil Paint Containing Degraded Smalt,'

in *National Gallery Technical Bulletin*, vol. 26, 2005. https://www.nationalgallery.org.uk/technical-bulletin/spring_higgitt_saunders2005 (accessed on 22 November 2018).

PAPER/TEXTILE

Brimblecombe P. *et al.*, 'The Cementation of Coarse Dust to Indoor Surfaces,' in *Journal of Cultural Heritage*, 10, 2009, pp. 410-414.

Calvini P., Gorassini A., 'The Degrading Action of Iron and Copper on Paper: a FTIR-Deconvolution Analysis,' in *Restaurator*, vol. 23, n. 4, 2002, pp. 205-221.

Caneva G., Nugari M.P., Salvatori O. (ed.), *La biologia vegetale per i beni culturali, vol. 1, Biodeterioramento e Conservazione*, Nardini Editore, Florence, 2005.

Chiappini, *Insetti e restauro: legno, carta, tessuti, pellame e altri materiali*, Edagricole, 2001.

Choi S., 'Foxing on Paper: a Literature Review,' in *Journal of the American Institute for Conservation,* vol. 46, n. 2, 2007, pp. 137-152.

Dignard C., Mason J., Strang T., 'La lutte préventive contre les insectes et les petits animaux,' in *ICC, Conservation préventive dans les musées. Manuel d'accompagnement*, 1995, pp. 35-46.

Federato D., *Studio del comportamento chimico-fisico di tessuti in ambiente museale*, Master thesis, Master course in Chemical Sciences for Conservation and Restoration, Università Ca' Foscari di Venezia, academic year 2012-2013.

Figueira F., Fernandes A., Ferreira A., 'Discolouration and Opacity in Paper from Contact with Air and Pollution: Characterization and Proposal for a Reversing Treatment,' in *Works of Art on Paper, Books, Documents and Photographs: Techniques and Conservation*, Contributions to the Baltimore congress, 2-6 September 2002, pp. 65-68.

Flieder F., Capderou C., *Sauvegarde des collections du Patrimoine, La lutte contre les détériorations biologiques*, Cnrs editions, 2000.

Guild S., Macdonald M., *Prévention des moisissures et récupération des collections. Lignes directrices pour les collections du patrimoine*, technical bulletin n. 26, Ottawa, Institut canadien de conservation, 2004.

Lennard F. *et al.*, 'Strain Monitoring of Tapestries: Results of a Three-year Research Project,' in *ICOM-CC 16th Triennial Conference*, 19-23 September 2011, Lisbon.

L'étoffe d'une exposition : une approche pluridisciplinaire, Symposium 97, organised by Institut canadien de conservation and North American Textile Conservation Conference, Ottawa, Canada, 22-25 September 1997.

Lloyd H., Bendix C., Brmblecombe P., Thickett D., 'Dust in Historic Libraries et Libraries and archives in Historic Buildings,' in *Museum Microclimates. Contributions to the Copenhagen Conference,* 19-23 November 2007, National Museum of Denmark, 2007, pp. 135-151.

Manfredi M., Bearman G., France F., 'Quantitative Multispectral Imaging for the Detection of Parchment Ageing Caused by Light: a Comparison with Atr-Ftir, Gc-Ms and Tga analyses,' in *International Journal of Conservation Science*, vol. 6, n. 1, 2015, pp. 3-14.

Martuscelli E., *Degradazione delle fibre naturali e dei tessuti antichi. Aspetti chimici, molecolari, strutturali e fenomenologici*, pp. 103-183.

Monitoring of damage to historic tapestries. http://www.hrp.org.uk/conservation/conservation-projects/conservation-at-hampton-court-palace/monitoring-of-damage-to-historic-tapestries/#gs.=rwAlow.

Parchas M. D., *Comment faire face aux risques biologiques?,* direction des Archives de France, Paris, 2008.

Strang T. J. K., Dawson J. E., *Le contrôle des moisissures dans les musées*, technical bulletin n. 12, Ottawa, Institut canadien de conservation, 1991.

Van der Doe E., *Archives Damage Atlas. A Tool for Assessing Damage*, Metamorfoze, 2010.

Whitmore P. M., *Paper Ageing and the Influence of Water in Paper and Water: a Guide for Conservators*, 2011, pp. 238-240.

Worobiec A., 'A Seasonal Study of Atmospheric Conditions Influenced by the Intensive Tourist Flow in the Royal Museum of Wawel Castle in Cracow, Poland' in *Microchemical Journal,* 90, 2008, pp. 99-106.

Wyeth P., Janaway R. (ed.), *Scientific Analysis of Ancient and Historic Textiles: Informing Preservation, Display and Interpretation,* in *AHRB Research Centre for Textile Conservation and Textile Studies, First Annual Conference, 13-15 July 2004,* Textile Conservation Centre, Winchester Campus, University of Southampton, UK, 2005.

General Bibliography

Conservation of Cultural Property. Specifications for Temperature and Relative Humidity to Limit Climate-Induced Mechanical Damage in Organic Hygroscopic Materials, BS EN 15757, 2010.

Brimblecombe P., Grossi C. M., *The Identification of Dust in Historic Houses.* https://www.nationaltrust.org.uk/documents/the-identification-of-dust-in-historic-houses.pdf.

Child R. E., 'Insect Damage as a Function of Climate,' in *Contribution to the Copehnaghen Conference Museum Microclimates*, 19-23 November 2007.

Dust in Historic Houses. http://www.nationaltrust.org.uk/features/dust-in-historic-houses.

Loyd H., Brimblecombe P., Grossi C. M., 'Low-Technology Dust Monitoring for Historic Collections,' in *Journal of the Institute of Conservation,* vol. 34, n. 1, pp. 104-114.

Martens M., *Climate Risk Assessment in Museums: Degradation Risks Determined from Temperature and Relative Humidity Data*, phd thesis, Université d'Eindhoven, 2012. https://pure.tue.nl/ws/files/3542048/729797.pdf.

Michalski S., 'Damage to Museum Objects by Visible Radiation (Light) and Ultraviolet Radiation (Uv),' in *Lighting in Museums, Galleries and Historic Houses,* The Museums Association, London, 1987, pp. 3-16.

Michalski S., 'Paintings – Their Response to Temperature, Relative Humidity, Shock, and Vibration,' in *Works of Art in Transit*, M.F. Mecklenburg (ed.), National Gallery of Art, Washington, 1991, pp. 223-248.

Michalski S., 'Relative Humidity: a Discussion of Correct/Incorrect Values,' in *ICOM-CC 10th Triennial Meeting Preprints,* Washington, DC, USA, 22-27 August 1993, J. Bridgland (ed.), pp. 624-629, London, James & James, 1993.

Michalski S., 'The Power of History in the Analysis of Collection Risks from Climate Fluctuations and Light,' in *ICOM-CC 17th Triennial Conference Preprints, Melbourne, 15-19 September 2014*, J. Bridgland (ed.), art. 1506, 8 pp., International Council of Museums, Paris, 2014.

NORMA UNI 10586/1997, *Documentazione. Condizioni climatiche per ambienti di conservazione di documenti grafici e caratteristiche degli alloggiamenti*, Bresciani, Milan.

NORMA UNI 10829/1999, *Beni di interesse storico e artistico - Condizioni ambientali di conservazione – Misurazione ed analisi,* Bresciani, Milan.

NORMA UNI 10969/2002, *Beni culturali – Principi generali per la scelta e il controllo del microclima per la conservazione dei beni culturali in ambienti interni*, Bresciani, Milan.

Padfield T., Borchersen K. (ed.), *Museum Microclimates. Contributions to the conference in Copenhagen, 19-23 November 2007,* The National Museum of Denmark, Copenhagen, 2007.

Watt J., Tidblad J., Kucera V., Hamilton R., *The Effects of Air Pollution on Cultural Heritage*, Springer, 2008.

The EPICO Assessment Method: a Tool for Prioritising Preventive Conservation Actions in Historic Houses

Danilo Forleo
In charge of preventive conservation and head of the EPICO programme, National Museum of the Palace of Versailles and Trianon
danilo.forleo@chateauversailles.fr

Nadia Francaviglia
Preventive conservation advisor,
research associate for EPICO programme
nadia.francaviglia@gmail.com

Abstract
After analysing the existing evaluation methods, having tested them in situ and verified their effectiveness of implementation on the collections and decorations of three historic houses open to the public, we have identified and understood their strengths and weaknesses, in order to put in place the four main steps that can now summarise the EPICO evaluation method:

1. Prior zoning: the room has been treated as a basic cell, a common characteristic to all houses. We have defined criteria that enable us to identify homogenous classes of rooms and to select the representative areas of the palace that will be evaluated.
2. The collections and the decorations' condition report: by object and constituent material, the most significant damage are identified and, for each degradation, the evaluator must indicate their *seriousness* and their *range* (from 1 to 4), as well as the *generic cause* that may have generated the degradation that he is observing on the object.
3. Data processing: among the most interesting results of the data processing is that the EPICO method enables to calculate the importance of the cause index (IC), where each cause is related to the seriousness of the generated degradations.
4. The interpretation of the results and recommendations for the implementation of conservation actions: the treatment provides a classification of active causes and risks that help the collections manager prioritise the actions for preventive conservation.

The process of setting up the preventive conservation plan in a historic house has four phases: assessment, diagnosis, recommendations, action plan.

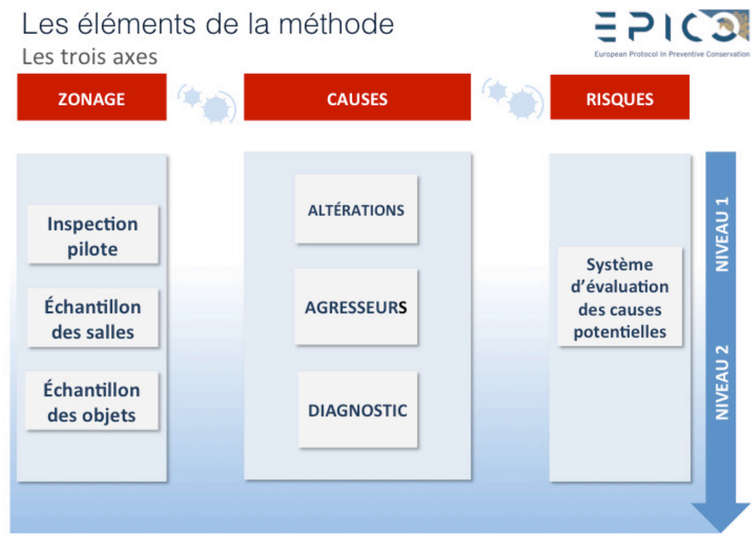
The EPICO method focuses in particular on the first two stages.

The objectives of the EPICO programme, already described elsewhere [Forleo *et al.*, 2017] respond to the founding principle of conservation assessment: "know to act and re-establish" [Guillemard, 2014].

Is it certain that climate rather than lighting is the most important damage factor inside our house? Experience shows us that the analysis of the climatic curves cannot suffice.

We do not wish to lead to recommendations by the only analysis of the conservation conditions, our ultimate goal is to make the objects "speak."

Fig. 1
Synthetic diagram of the active causes assessment method from the EPICO programme [Forleo, Francaviglia].



Only the analysis of hundreds of symptoms (the visible effects of the degradations on the collections) related to the causes at the source, can follow up to a good diagnosis.

The Method's Three Axis

The evaluation method tested within the framework of the EPICO programme consists of 3 axis that correspond to three distinct moments of the assessment (fig.1):

1. The zoning of the house: this step is fundamental if we must evaluate a large house with more than 500 displayed objects in the rooms; following an in situ pilot inspection and a brief collection of information on the configuration of the rooms and the history of the object's conservation, their typology, etc. we can identify the sample of rooms and objects that will be statistically representative of the conservation conditions of our house [Forleo, Francaviglia, 2018].

2. Cause evaluation: following specific steps, we start the evaluation of the active causes by recording the observable degradations on the objects and the analysis of conservation conditions. Following this process, we can then identify the plausible causes of the damage to establish our diagnosis.

3. Risk evaluation: we finish our diagnosis by evaluating potential damage causes, namely the aggressors for which it is not possible to observe the effects at the time of the report because they haven't manifested themselves yet.

We have concentrated more our research on the statistical zoning system and the evaluation of active causes (approach 1 and 2), since the risk assessment methods have already been developed in other contexts [Waller 2003; Brokerhof 2005; Xavier-Rowe 2011; Michalski 2016].

The Two Levels of the Evaluation
For these three approaches of the method, the evaluator can choose between two levels of complexity for its application according to the available time, the expertise of the team of evaluators, the degree of precision expected for the diagnosis. We called these two levels "initial assessment" and "comprehensive assessment."

Implementation Tools
This method, which is intended to be simple and transferable, must be able to be applied independently of the available database management tools. Ideally with paper or Excel® spreadsheets, widely available, or in the best case, with the computerised system of collections management. In the case of the Palace of Versailles, the collections management system (TMS® – The Museum System) is very efficient and flexible, which has allowed us to make it evolve so as to integrate the elements from our evaluation method.

Pilot Inspection
The application of the method requires data collection before starting the evaluation of the collections per se.

A significant part of this prior data collection concerns the rooms: the room is indeed our base unit, as a fundamental cell in the "historic house" system.

During the research, we realised that the criteria concerning natural risks (climate, light, etc.) would not be exhaustive enough to describe the conservation conditions of the «house» system. We have therefore chosen criteria that concern the architectural envelope and the site's operating procedures that statistically contain all the potential causes that may manifest themselves in a house:

– room orientation;
– human impact: coefficient calculated *by room* that takes into account three variables: the number of visitors per year, the floor area and the number of opening days per year according to peak times (low and high season). If we don't have the figures concerning peak times during the different seasons, we can also calculate it more globally [Forleo, Francaviglia, 2018];
– museography (presentation of *apartment* type collections, where all the typologies of the objects are also represented, or *gallery* type, when a typology of an object takes precedence over others);
– activities excluding visits (shootings, receptions).

These criteria help us classify the rooms so as to define the representative sample of the house's conservation conditions or the conditions of a particular zone. A sampling of the objects is also possible on the basis of a pivotal criterion: **the history of the conservation of collections**. Particularly it is about knowing the dates of the last moves and restorations, which allows the classification of the objects into three categories:

– unrestored, exhibited for 5 years or more;
– recently moved (less than 3 years);
– recently restored (5 to 10 years).

The objective is to relate the observed degradations at the time of the collections conditions report with the exhibition conditions in the room where the objects are displayed.

The preliminary collection of this data implies information research work within the institution, it is fundamental to implement a preventive conservation strategy based on the specificities of the place. It seems important to note that this is significant teamwork because it requires the involvement of several services and professionals within the institution (documentation, collections management, computer database management).

Prior Zoning

For a small house, the Petit Trianon for example, with less than 1,000 objects on display, it is possible to make a complete survey of the collection but we must also take into account larger residencies such as the Palace of Versailles with more than 1,000 rooms open to the public and more or less 17,000 displayed objects.

We have tested several sampling methods (random or clustered) and given the heterogeneity of the collections and the analysed locations, the cluster method proves to be the most efficient. The studies conducted by Bianca Fossà and Marta Giommi [Giommi, 2009], which are the subject of a paper in this publication (see *infra*) were a starting point for our reflection.

The combination of certain criteria (museography, orientation, etc.) lead to as many clusters from which the rooms are sampled.

After the draw, it would be ideal to survey all the objects in each of the sample's rooms. If after this first sampling, the amount of objects is still too important and the team is not able to take care of the collection, it is possible to proceed to a double sampling and to draw the objects to assess on the basis of the three criteria describing the history and the typology of the collections.

Data Record Form for the Condition Report

For the condition report, we use the same form model implemented during method testing and then developed for our assessment system.

The first part of the identification of the object, in the case of the collections of the Palace of Versailles, can be easily extracted from the management of the collections computer database, TMS®. It gives us information on the inventory number, the typology as well as the description of the object and its constituent materials.

TYPE OF DAMAGE: ABRASION / WEAR / SCRATCH / FRAYING

DEFINITION

Abrasion: wear through rubbing due to poor treatment or handling which leaves marks on the surface

Scratch: loss of material, slender cut on the surface due to a mechanical movement

Wear: deterioration of the surface as a result of use or repeated or extended rubbing

Source: Glossaire visuel du Centre de Conservation du Québec

INDEX OF GRAVITY

1. SUPERFICIAL ABRASION / SCRATCH

4. DEEP ABRASION / SCRATCH, NOTICEABLE UPON TOUCHING

INDEX OF EXTENT

1. Localised damage **less than 10%** of the surface	**2.** Damage covers **10% < x < 25%** of the surface	**3.** Damage covers **25% < X < 50%** of the surface	**4.** Damage covers **more than 50%** of the surface

Fig. 2
Visual glossary developed during in situ tests in 2016.

Table 1
Example of a generic cause term, a specific cause and an associated diagnosis.

GENERIC CAUSE	SPECIFIC CAUSE	DIAGNOSIS
• Inadequate maintenance	• Abrasive / wet cloths • Inadequate micro-suction tools • Care product (shining, washing, polishing)	• Unsuitable maintenance protocol (material or frequency) • Lack of training / awareness of the staff
• Dust accumulation – repeated maintenance	• Over-frequency	• Inadequate management of visitor flow (airlock, changing rooms, regulation of the number of visitors, etc.) • Inadequate exposure mode (lack of protection, tulle…)
• Handling / transport accident	• Handling • Transport • Accident • Accidental blows from visitors or museum staff • Friction due to the repeated passage of visitors	• Excessive frequency of movement of works (policy, institutional events) • Non-compliance with handling and transport protocols (inappropriate procedures, packaging) • Lack of training / awareness of the staff • Inadequate management of visitor flow (airlock, changing rooms, regulation of the number of visitors, etc.)
• Use according to function	• Handling of doors and windows	• Absence of a protocol for the use of works (copies or non-heritage objects)

On the other hand, the second part that must be filled in is dedicated to the condition report of the objects, which is the heart of the assessment: where it is possible to choose among a list of 18 generic degradation indicators.

For each degradation, the most probable cause is identified among a list of 14 generic causes.

For the initial assessment, the alterations are listed for each material as well as the plausible causes and the corresponding diagnosis.

The exhaustive assessment provides the evaluation of the alteration on a scale from 1 to 4 through two criteria, severity and extent. This system is fundamental for then calculating the importance of the causes attributed to each damage. For each generic cause, a specific cause can be indicated and therefore a plausible diagnosis, based on the available information.

Visual Glossary of Damage

The list of damage indicators and the terms of generic causes has been the subject of a long research.

It was indeed very important to ensure that the alteration terms used during the test phase are understood in the same way by the entire team of evaluators, unambiguously.

Once the list had been settled on 18 generic damage indicators, we wrote a definition for each of them (when it was not available in literature).

We offered a range of 4 levels of severity and extent illustrated by images.

This document, put in place by the Versailles team was then entrusted to the team of conservators from the Venaria Conservation Centre (CCR) and provided support for the research on specific damage indicators (see *infra*) (fig. 2).

The involvement of CCR teams on terminology standardising work on heritage damage has represented a significant asset in this research.

The visual glossary created as part of the second phase of the EPICO programme is an essential support for the evaluation team.

Glossary of Damage Causes and the Diagnosis

The same as for the damage terms, we have written a glossary of the damage causes that provides:

– a definition for each generic cause;
– a predefined list of specific causes, which represents the detail of each generic cause;
– a predefined list of correspondent diagnosis.

These lists are selectable during the condition report and in situ data collection. They are then subject to specific data processing, detailed as follows.

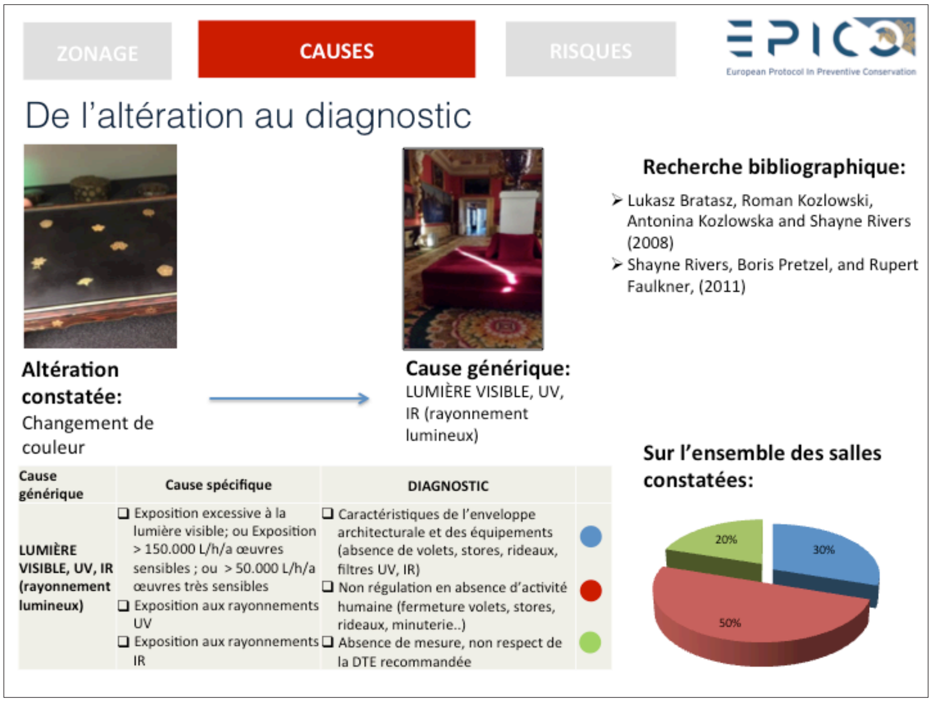


Fig. 3
Example of diagnosis on a given cause (light and UV).

From Damage to Diagnosis

Take lacquerware for example, which is very sensitive to exposure to light. If on an initial level we can simply indicate light as a generic cause, an exhaustive evaluation can also guide us towards the identification of the specific cause and to a diagnosis that allows us to better support our recommendations, therefore, our priorities for action.

In the specific case of light exposure originating from the windows, the knowledge of the practice of opening and closing the shutters as well as the number of days open to the public can help us calculate the total exposure doses (DTE) and understand if these practices need to evolve or not, in order to slow down the discoloration process.

Knowing that the list of degradations, causes and the diagnosis are pre-established and that the same diagnosis can be proposed for several causes, we can obtain simple reports for a room, a zone or a house.

In the proposed example, a simple practice change and appropriate training of the agents in charge of closing the curtains and shutters can quickly stop the detected active cause (fig. 3).

Calculation Method

For each reported active cause, we can evaluate its impact on the collection. The goal is to have a ranking of all the causes from the most important to the least important in order to prioritise our investments on the causes that have a major impact on our house.

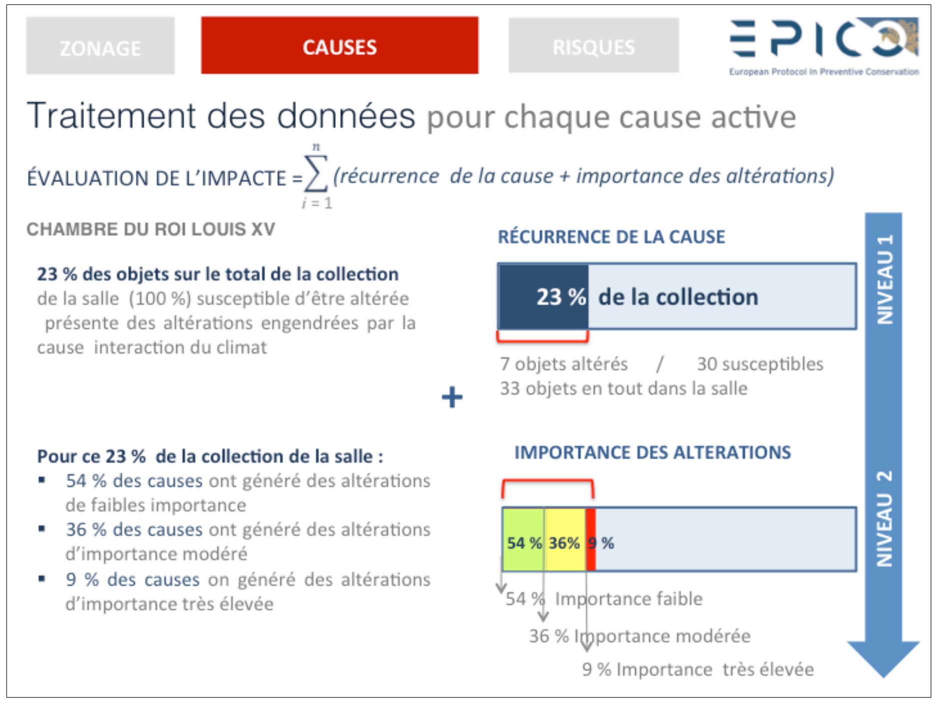


Fig. 4
Method for calculating the frequency and impact of the active causes on a room or a given area [Forleo, Francaviglia].

The evaluation of the impact of the cause follows a simple equation = recurrence of the cause + importance of the generated degradations of this same cause.

Recurrence is easily evaluable. The collection and processing of data can be done during the initial evaluation (our first level of expertise and time required for the evaluation). This gives us the number or % of objects in the collection affected by a given cause (fig. 4).

Here is an example: in King Louis XV's bedroom in Versailles, a certain number of objects are likely to be deteriorated by inadequate climatic conditions (for example organic materials and metals). Of this group of objects, 23% actually exhibit degradations by the climate cause. It is essentially a quantitative information.

In the most advanced level of evaluation, we can also have qualitative information. For this same cause (the climate), we can know the importance of the degradations engendered on the collection.
Using the same example as King Louis XV's bedroom, if we consider that 23% of the "sensitive" collection of the room is affected by climate effects:

– 54% of the time the climate cause generated minor degradations;
– 36% of the time the climate cause generated degradations of moderate importance;
– 9% of the time the climate cause generated degradations of very high importance.

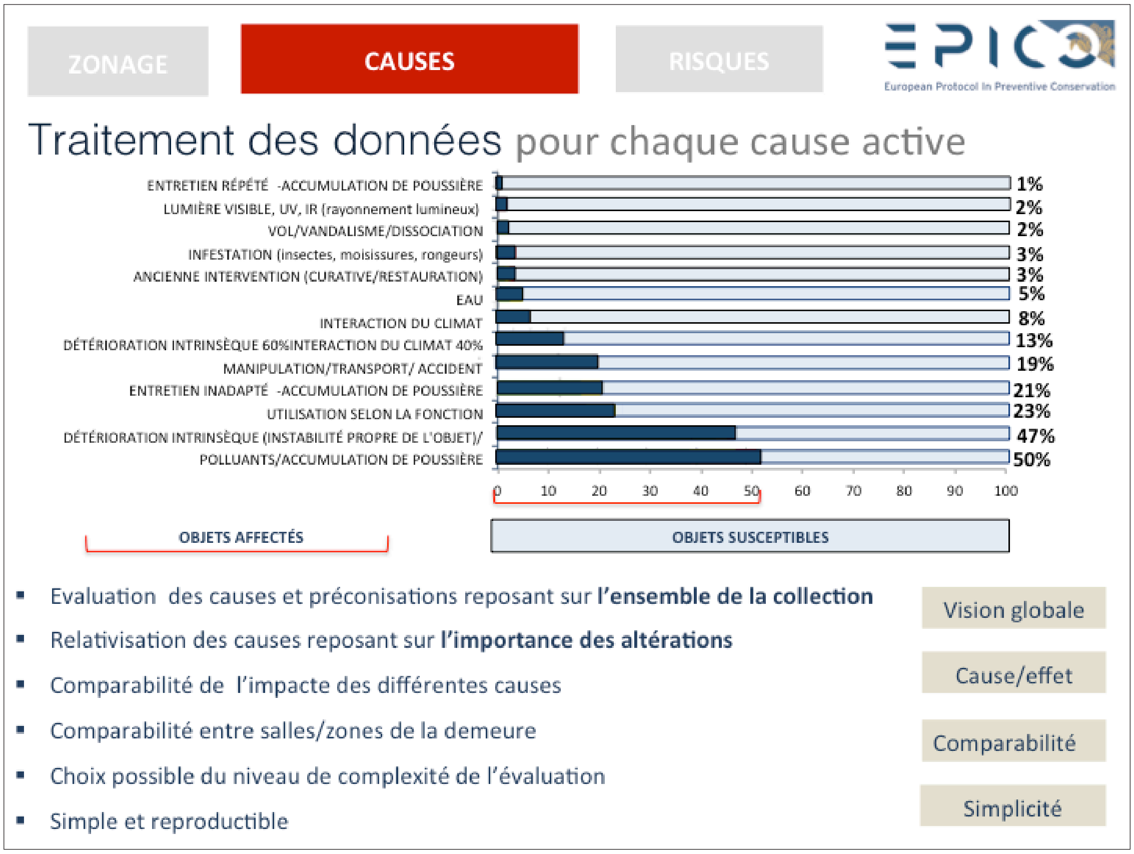


Fig. 5
Results presented in graph form of a group of active causes.

Data Treatment

Calculating the recurrence of a cause for the room's objects or the house gives essential information. It is based on the basic principles of preventive conservation that requires us to look at the entire collection and not at each object individually. The results of our assessment and the recommendations are corroborated by the mass of collected data – the interpretation errors are thus minimised: the importance of each cause is the result of the sum of the number of objects affected by the same cause.

In the most advanced level of the evaluation, calculating the importance of the damage is also useful. This allows us to estimate the cost/benefit of treating one cause over another when writing the recommendations.

For example, the *inadequate maintenance* cause may have been frequently diagnosed but it generates minor degradations. In addition, by training agents during a week it can be easily treated at a very low cost.

On the other hand, *dust accumulation* and the presence of *pollutants,* also observed recurrently, generate very important degradations. These causes are due to a large influx of visitors, therefore, to the policy of opening rooms to the public. Their treatment requires long-term thinking and involving the site's administrators at the highest hierarchical level.

The calculation system of the causes allows us to compare their impact on the rooms/zones of the house on a same scale and it can be applied by simple means (fig. 5).

Risks

We have developed the method more in direction of zoning and cause evaluation. Risk evaluation methods already exist today and have been widely tested and used in a wide variety of contexts [Karsten, Michalski, 2012].

The simplest method, which can best relate to our cause evaluation, is the calculation method of the RISK SCORE tested by the English Heritage, which takes into account the probability that the risk will manifest itself, the number of objects potentially affected and the consequent loss of value (see infra).

As in the English Heritage method, the list of damage factors is the same for the assessment of causes and risks.

Contrary to the approach proposed by our English colleagues, in our system an aggressor that has already been identified as an active cause will not be analysed as a risk.

The risk evaluation concerns only the aggressors whose effect on the collections is not yet visible at the time of the report.

The risk evaluation only concerns the rooms from the previously identified statistical sample.

Results

Repeating the proposed scheme with two possible levels of applications:

– zoning and the pilot inspection are common to both levels, as they are necessary, particularly in the case of a house whose size and number of displayed objects doesn't allow the team to carry out a complete survey.

– Following the data collection carried out with the forms we presented, the evaluator is able to propose, for the first level of assessment, a classification of damage and generic causes by number of affected objects and a classification of plausible causes.

For the most advanced level, "the exhaustive assessment," a cause classification with IMPACT, represents the result of the combination of the quantitative side given by the recurrence of each cause and the qualitative side of the importance of the engendered degradation. As in the case of level 1, a classification of the diagnosis can be made as well as a classification of specific causes.

The risk evaluation does not differ from level 1 to level 2.

Conclusions

We want to limit our modelling system in the classification of cause and risk diagnosis.

It is preferable to leave the following step of interpretation and drafting of recommendations to the evaluator's skills and experience that is necessary, according to the specificities of the house in question, to estimate the cost/benefit of the cause treatment or the degradation risk compared to another.

Nevertheless, assessment is still, in our opinion, the fundamental step for the drafting of the recommendations and the preventive conservation plan.

Bibliography

Association des Restaurateurs d'Art et d'Archéologie de Formation Universitaire, *Constats, diagnostics, évaluations : la conservation préventive en action*, X[th] days-debates organised by the Master of preventive conservation from the University of Paris 1 – under the direction of Denis Guillemard, Paris, June 14 and 15, 2006, published in *Conservation-Restauration des Biens Culturels*, Cahier technique n° 15, ARAAFU, Paris, 2007.

Brokerhof A., 'Risk Assessment of Museum Amstelkring: Application to a Historic Building and its Collections and the Consequences for Preservation Management,' in ICOM-CC Committee for Conservation, *14th Triennial Meeting: Preprints*, The Hague, 12-16 September 2005, James & James, London, 2005, pp. 590-596.

Forleo D., Francaviglia N., 'Conservation Assessment of Historic House Collections: Testing Different Statistical Methods,' in *Studies in Conservation: Turin Special Issue*, actes du colloque international IIC, September 10-14, 2018, Turin.

Forleo D., Francaviglia N., De Blasi S., Pawlak A., 'Méthodes d'évaluation de conservation des collections dans les demeures historiques,' in *"Cronache 7," La Venaria Reale,* Conservation and Restauration Centre, Sagep Publisher, Genoa, 2017.

Forleo D., Francaviglia N., Wansart N., 'Les méthodes d'évaluation des collections: étude comparative et test en vue de leur application aux collections exposées des demeures historiques et châteaux-musées – Programme de recherche EPICO,' in *International Symposium "Les nouvelles rencontres de la conservation préventive,"* Association AprèvU, 8-9 June 2017, Archives Nationale, Pierrefitte-sur-Seine, 2017.

Giommi M., 'Indagine sulla conservazione con metodo statistico,' in Prisco G., (under the direction of), *Filologia dei materiali e trasmissione al futuro. Indagine e schedatura dei dipinti murali del Museo Archeologico di Napoli*, Gangemi, Rome, 2009, pp.119-131.

Guillemard D., *Évaluation de conservation: déterminer les risques et les causes de dégradation pouvant entraîner une perte d'intégrité et de valeur d'un site culturel*, support during the Master in Preventive Conservation, University Paris 1 Panthéon-Sorbonne, Paris, unpublished, 2014.

Karsten I., Mishalski S., Case M., 'Balancing the Preservation needs of Historic House Museums and their Collections Through Risk Management,' in ICOM-DEMHIST, *The Artefact, its Context and Their Narrative: Multidisciplinary Conservation in Historic House Museums*, The Getty Research Institute, Los Angeles, November, 6-9 2012, ICOM-CC, Paris, 2012. Available on: http://www.icom-cc.org/ul/cms/fck-uploaded/documents/DEMHIST%20_%20ICOM-CC%20Joint%20Interim%20Meeting%20 2012/10-Karsten-DEMHIST_ICOMCC-LA_2012.pdf.

Waller R., *Cultural Property Risk Analysis Model, Development and Applications at the Canadian Museum of Nature,* PhD Thesis in the Discipline of Conservation, Göteborg University Institute of Conservation, Acta Universitatis Goteburgensis, Göteborg, 2003.

Xavier-Rowe A., Fry C., 'Heritage Collections at Risk: English Heritage Collections Risk and Condition Audit,' in ICOM-CC, *16th Triennial Conference,* 19-23 September 2011, Lisbon, International Council of Museums, Lisbon, 2011. Available on: http://www.english-heritage.org.uk/content/learn/conservation/2543455/2543024/Heritage_Collections_at_Risk.pdf.

02

From Assessment to Planning: Managing Preventive Conservation in Historic Houses

Following a comparative approach of the application of assessment methodologies to real-life collections management situations, the conference's second approach aims to share experiences with international historical houses and palace museums, thanks to the contribution of speakers involved in the front line of the management of well-known houses as much for their complexity as for their beauty, historical and social interest.

The authors are asked to describe the tools and the methods used to analyse and understand the conservation priorities within their institution, giving an overview of the actions undertaken and the results obtained, but also the difficulties encountered and the challenges ahead. This is done with exchange and sharing in mind.

Major institutions such as the Vatican museums and the Palace of Versailles, that benefit from teams dedicated to preventive conservation and risk factor assessment of the collections, to institutions such as the Neuschwanstein Palace in Bavaria and the House of Rui Barbosa in Rio de Janeiro, where very specific issues related to the environment had to be studied with a pragmatic approach in order to implement a sustainable and effective conservation plan.

The maintenance of the collections and the corrective actions undertaken following the conservation state assessment are also broached, with the aim of highlighting the tangible aspect of the work of the teams directly involved in daily preventive conservation.

Five roundtables aim to connect heritage professionals around the most recurrent topics in preventive conservation of historic houses. Architects, researchers, restorers, conservators are led to share their *modus operandi* in the roundtables dedicated to the architectural envelope and the management of houses in private estates. Scientists, collection managers and preventive conservation specialists, have also been able to discuss the themes of maintenance, light and climate in historic buildings, finding common points despite the different approaches introduced in these countries.

Themes

1. The practical application of assessment methods in ordinary collection management.
2. The importance of the method in the assessment process and the drafting of recommendations, particularly for institutions with few human and financial resources.
3. Roundtables: identification and programming of risk prevention activities related to maintenance, climate, light, work in historic houses.

SESSION 3

Chairman
Béatrice Sarrazin
General curator of cultural heritage,
Palace of Versailles

Speakers
Bart Ankersmit
Thalia Bajon-Bouzid
Élisabeth Caude
Vittoria Cimino
Bianca Fossà
Marco Maggi
Tina Naumović
Claudia Suely Rodrigues de Carvalho

The White room in Heeswijk Castle.

Evaluating Collections: a Flexible Methodology

Abstract

SOS Collections® is a method for documenting, assessing and managing museum cultural heritage, the elements of a complex system which is the collection. This method allows to know and assess in parallel and in a very reasonable time frame, the nature, the conservation state and the vulnerability of each collection, even if very vast and belonging to one or several museums, while ensuring the possibility to compare the obtained results, always in relation to the specific environmental conditions of exposure or storage.

The time required to define a conservation strategy is significantly reduced thanks to the use of a single form system applicable to all types of collections, as well as the possibility of carrying out the study by using statistical sampling, customised software, textual and digital data, and image processing. Data comparison (constituent materials, types of damage and extent, types of treatments and time required, vulnerability and risk level) is based on the location of the collection and on the entirety of each museum's cultural heritage. This makes it possible to define and plan a strategy based on a real scale of identified priorities and the necessary financial and professional resources.

A Manual containing a description of the methodology and the tools needed for its application makes the use of the software easier for conservation professionals. The method, because of its flexibility, will be used by the ISCR for the finalisation of the system for the *Risk Map of Italian Cultural Heritage*.

Bianca Fossà
Conservator, ISCR-Istituto Superiore per la Conservazione e il Restauro
bianca.fossa@beniculturali.it
http://www.iscr.beniculturali.it/

Marta Giommi
Conservator
marta.giommi@inwind.it

Keywords

Preventive conservation, museum collections, conservation plan, assessment, preservation conditions.

The need to develop a methodology and tools to conduct a survey on the conservation of collections from one or more museums, sometimes with very different type of collections and in a short time, was born in Italy in the mid-1980s. This came from the experience of working in major national Italian museums, for the purpose of defining a conservation plan on the basis of identified priorities.

The ideas and practices now known as *preventive conservation* were then in their early stages, but the Italian museums, for different reasons and except for a few isolated cases [Urbani, 1976], suffered a tangible delay in practicing conservation in museum collections. This happened despite the birth in 1987 of the *Risk Map of Italian Cultural Heritage:* a national project based on the principle that knowing the risks allows for all conservation activity planning to be done according to objective priorities. First an anthropogenic and natural phenomena database had to be created, which would help define maps of the entire Italian territory measuring its "dangerousness," and secondly cultural heritage – monument or collection object – were defined on the basis of its conservation condition, in other words, its "vulnerability." In this system, the "risk" of loss of cultural heritage is a function of these two indicators [Castelli, 1997].

In spite of the scientifically innovative nature of this project, we wondered about the necessary amount of time needed for its realisation and the application possibilities within museum collections: the challenge then was to find methodological and computer tools that could speed up the knowing preliminary investigation phase of collections in one or more museums, the assessment phase, and the data processing phase, thus enabling the definition and the application of a conservation plan and the protection of the collections.

But how to know the state and the needs of collections as vast and heterogeneous, when it is impossible to compile each cultural heritage's conservation form while assessing them so as to identify their needs and priorities? A bibliographical search showed us that a large number of foreign professionals were asking themselves the same questions and describing their experiences and approaches. The general assessment scheme now seems to be defined around three typologies: the *Conservation Assessment*, the *Collections Condition Survey* and the *Curatorial Assessment* [Berrett, 1994; Michalski, 1992; MWHCA, 1992; Vallas, 1995; Waller, 1994; Wolf, 1993].

Almost at the same time, we consulted Carl Drott and Suzanne Keene's publications: statistics, that were used for demographic surveys, could be adapted to museum *populations*, i.e. collections [Drott, 1969; Keene, 1991].

Drott's approach, created to assess the state of the collections of Californian university libraries, used what statistics calls *Random Sampling*: the sample to be inspected is representative of the studied set, which is identified randomly from a list of items with their location.

In the case where lists of objects and their locations aren't available, the *Cluster Sampling* must be used: here the sample to be studied is identified by the object's geographical location. Therefore it is usable, especially in the storage rooms of major museums so that an assessment in a reasonable amount of time is made, on a limited number of objects representative of each collection either in reference to constituent materials or the state of the objects. It must nevertheless be emphasised that the use of statistics is a possibility: if time and means are sufficient, the inspection of all the collection will be privileged.

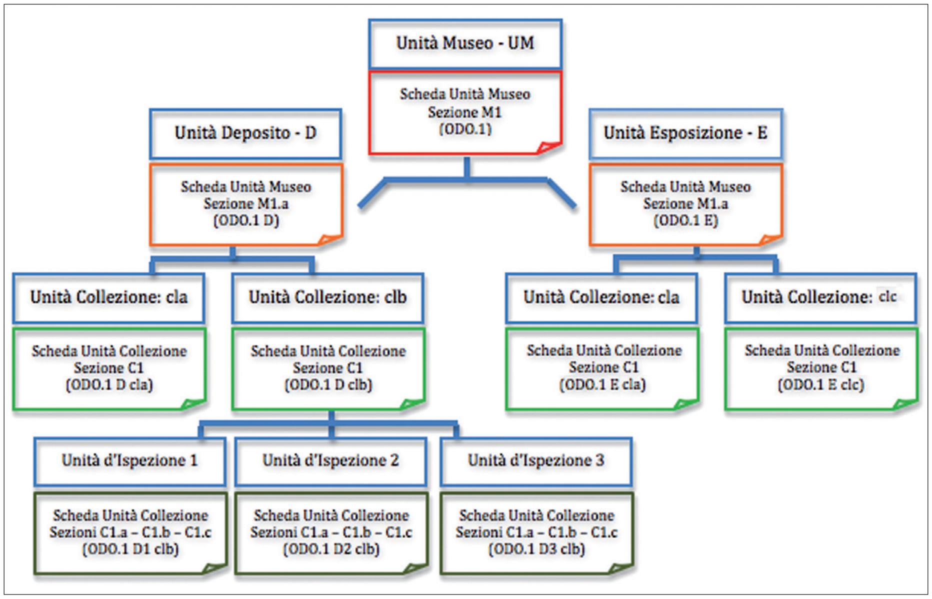


Fig. 1
Example of a diagram of the application of the *SOS Collections®* methodology in a museum with 3 types of collections, where the "clb" collection that is stored in 3 rooms/Storage Inspection Units [Fossà, Giommi].

From the beginning, it was obvious that there was a vast quantity of data to be collected and its processing for interpretation would have been too complicated to manage: thanks to computer science, whose costs had become more and more accessible, and thanks to the collaboration of a computer scientist[1] we developed a custom software that has become an application of the software FileMaker Pro® [Fossà and Truglio,1997; Fossà and Giommi, 2013].

The difficulties related to the creation of text and digital data archives, as well as graphics and photographic documentation, their consultation, treatment, presentation and processing of the data where not a problem anymore and almost became a game: we just needed to define a set of form templates for the collection and processing of digital data.

It was while realising numerous tests in the storage rooms of Villa Giulia in Rome that *SOS collections®* was developed: a methodology and a software [Fossà, 1995] that allow the survey of conservation conditions of the places and state of the collections so as to identify the risks, the types and the intervention treatment times for planning according to the identified priorities. The system provides the possibility to compare the results of data processing for each collection and each museum, as well as assessment data over time.

The methodological organisation adopted to carry out the assessment (fig. 1) needs a first phase of collecting general information on the museum. Called "Museum Unit," the building is considered as a large box placed in a defined geographical environment and characterised by the type of building and the management model.

Then the "Storage" or "Exhibition room" units are assessed: the number of rooms, their location in the building, the surfaces and the volumes

Fig. 2
A form of variable parameters defined for an art collection and the predefined macro-categories [Fossà, Giommi].

C1 – COLLEZIONE: Raccolta dati – Identificazione e parametri

Nome Museo: xxxx **Sigla:** ODO **Ispezione n.:** 1 **Data:** xxxx
Nome Collezione: Collezione Soliano b **Sigla:** clb **Operatori:** xxxx

MANUFATTI/MATERIALI COSTITUTIVI		TIPOLOGIE DI DANNO	
DTE	Dipinto su tela	**S1**	Danni strutturali maggiori
VET	Vetro, vetro dipinto	**S2**	Danni strutturali minori
MET	Metallo: lega di rame	**SU**	Danni strutturali di superficie
CUO	Cuoio	**AL**	Alterazioni
CER	Ceramica	**CF**	Degrado chimico/fisico del materiale
DMS	Dipinto murale staccato	**BI**	Danni di origine biologica
TES	Tessuto	**II**	Intervento inadeguato
LEG	Legno	**DI**	Depositi/incrostazioni

LIVELLO DI RISCHIO		TIPI DI INTERVENTO	
A	MOLTO BASSO. Stato di conservazione buono e stabile.	**1**	MANUTENZIONE ORDINARIA: spolveratura; imballaggio/supporto
B	BASSO. Manufatto danneggiato ma in condizioni di stabilità; necessita di un intervento curativo nel lungo termine.	**2**	MANUTENZIONE STRAORDINARIA: spolveratura; imballaggio/supporto; nuova collocazione
C	ALTO. Manufatto danneggiato con degrado probabilmente in atto; necessita di un intervento curativo nel medio termine.	**3**	INTERVENTO CONSERVATIVO/PRONTO INTERVENTO: spolveratura; adesione/protezione; imballaggio/supporto; nuova collocazione
D	MOLTO ALTO. Stato di conservazione inadeguato; degrado attivo; necessita di un intervento curativo nel breve termine.	**4**	INTERVENTO DI RESTAURO

they offer, the environmental and conservative observed conditions, the exhibited and stored collection types.

In order to know each space's conservation conditions, the data concerning climate and light is collected. Other information will also be needed in order to describe and evaluate structures (building material, access, building security), infrastructures (climate control systems,

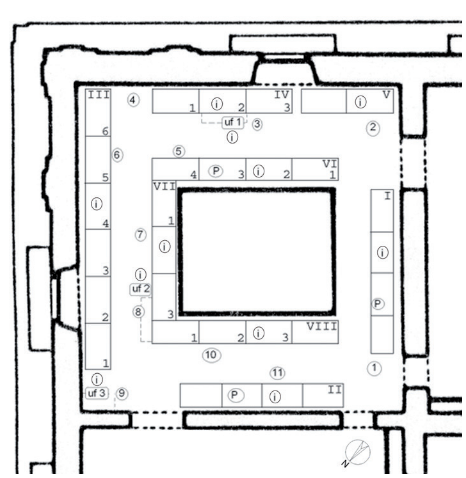


Fig. 3
Plan of a storage room with the location of storage furniture and the places where the pilot inspection was conducted and where the statistical sample of the collections was inspected (i) [Giommi].

1.c Raccolta dati: OGGETTI

ODO.1 D1.2 clb

Museo xxxxx **Isp. n°** 1 **Deposito n°** 1 **sala n°** 2 **Collezione** Collezione Soliano b

Data xxxxx **Operatore** xxxxx **Totale n. oggetti** 21

	COLLOCAZIONE		OGGETTO																			
	Identific.	Ogg. n.	Tipo	N° Inv.	Materiali		V	Larg dm	Prof dm	Alt dm	Tipi di Danno S1	S2	SU	AL	CF	BI	II	DI	LR	TI	Tempi m	Note
1	UF1	3	dipinto su tela	01	DTE	olio su tela		32	8	8	60	60	40	50	40	10		99	D	4	2880	
2	NC16	10	mattonella	917	CER	maiolica		0,5	0,5	2,5		10							A	1	30	
3	NC16	0	custodia	920	CUO	cuoio, tessuto		3,9	1	2,5	10	30	20	30	20	40		20	B	4	6000	
4	NC16	0	calzatura	923	LEG	legno, tessuto		3,2	1,5	1,6	30	50	50	40	40	40		99	D	4	1620	
5	UF22	10	dipinto murale	953	DMS	intonaco, velatino	x	8,6	1,4	8,9	10	40	70				90	30	D	4	1920	
6	UF22	0	dipinto murale	956	DMS	intonaco, velatino	x	11,4	1,4	9,4	50	50	50				90	30	D	4	1920	
7	UF22	0	dipinto murale	959	DMS	intonaco, velatino	x	20	1,4	14	50	50	50				90	30	D	4	1920	
8	UF24	2	paliotto	964	CUO	cuoio impresso		20,6	0,5	13	40	40	50	80	50	50		70	C	4	2880	
9	UF27	1	arazzo	975	TES	tessuto, legno	x	6,2	0,7	7,1		20	30		70			70	D	4	9600	

Fig. 4
Example of an art museum's object data collection form [Fossà, Giommi].

smoke detection, alarms, typologies and storage conditions or exhibition furniture, equipment such as ladders, trolleys, etc.) as well as the norms and procedures put in place.

In the case of a museum with very heterogeneous collections, for example, archaeological collections, costumes, armours, paintings and sculptures, they are studied as different and comparable sets: each collection forms the "Collection Unit."

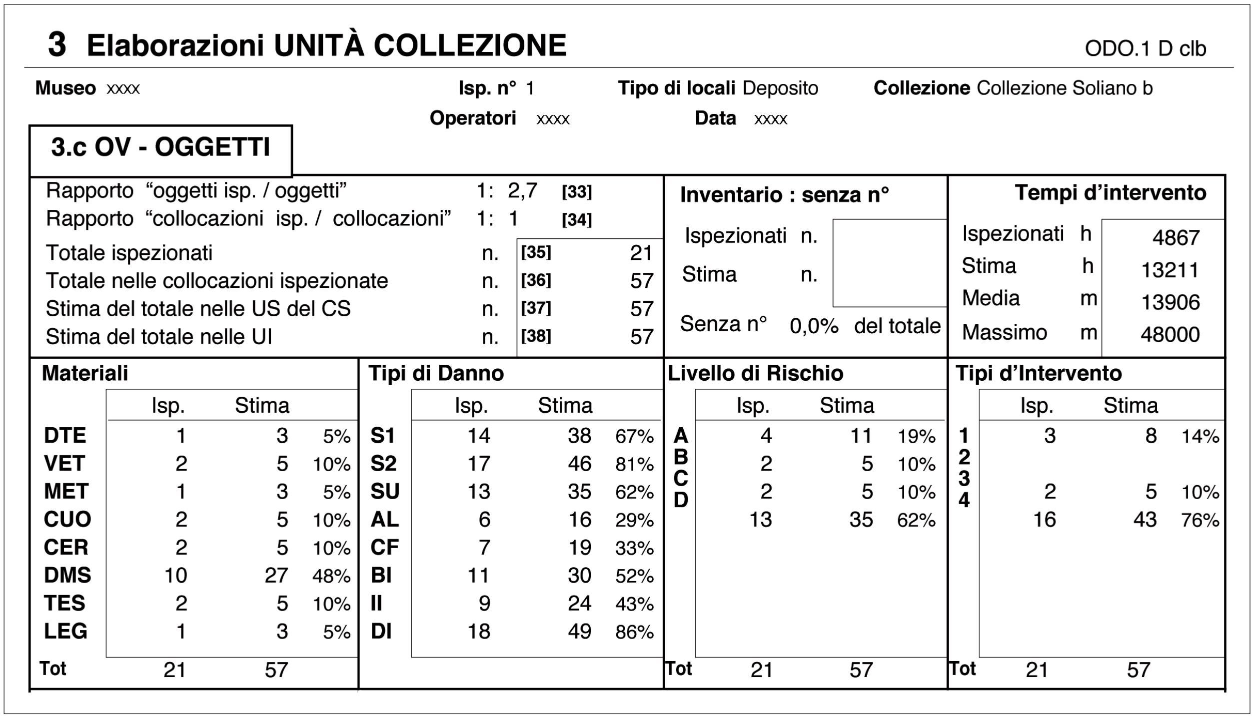
In order to carry out a detailed inspection of the premises, of the storage furniture and the collection sample, the collection will be studied in each room where it is kept: the set is named "Inspection Unit: Room – Storage elements – Objects."

The scheme just described will be applied starting from a first phase of the survey, the "pilot inspection," the assessment's most delicate phase, which can require up to 20% of the survey's total time. At the museum level, we will define the "survey profile" by deciding if we start in the storage space or in the exhibition hall.

For each collection, we will also define the statistical profile and the variable parameters. If the profile is well identified, for a collection of tens of thousands of objects, only a thousand objects will need to be inspected to obtain reliable results of +/-5%.

The survey will be lead by conservators specialised in the typologies of materials and the inspected collections: their capacity to recognise an alteration and to understand its causes will be fundamental, as well as defining risk levels, the types of interventions that are needed and the time required for their completion.

For each Collection Unit we will define variable parameters: up to a maximum of 8 classes of material constituting the cultural heritage and the 4 types of direct interventions to achieve, whereas the alterations, grouped into 8 categories and the risk, classified according to 4 levels, are



3 Elaborazioni UNITÀ COLLEZIONE

ODO.1 D clb

Museo xxxx **Isp. n°** 1 **Tipo di locali** Deposito **Collezione** Collezione Soliano b

Operatori xxxx **Data** xxxx

3.c OV - OGGETTI

Rapporto "oggetti isp. / oggetti"	1: 2,7	[33]	
Rapporto "collocazioni isp. / collocazioni"	1: 1	[34]	
Totale ispezionati	n.	[35]	21
Totale nelle collocazioni ispezionate	n.	[36]	57
Stima del totale nelle US del CS	n.	[37]	57
Stima del totale nelle UI	n.	[38]	57

Inventario : senza n°

Ispezionati	n.	
Stima	n.	
Senza n°	0,0%	del totale

Tempi d'intervento

Ispezionati	h	4867
Stima	h	13211
Media	m	13906
Massimo	m	48000

Materiali

	Isp.	Stima	
DTE	1	3	5%
VET	2	5	10%
MET	1	3	5%
CUO	2	5	10%
CER	2	5	10%
DMS	10	27	48%
TES	2	5	10%
LEG	1	3	5%
Tot	21	57	

Tipi di Danno

	Isp.	Stima	
S1	14	38	67%
S2	17	46	81%
SU	13	35	62%
AL	6	16	29%
CF	7	19	33%
BI	11	30	52%
II	9	24	43%
DI	18	49	86%

Livello di Rischio

	Isp.	Stima	
A	4	11	19%
B	2	5	10%
C	2	5	10%
D	13	35	62%
Tot	21	57	

Tipi d'Intervento

	Isp.	Stima	
1	3	8	14%
2			
3	2	5	10%
4	16	43	76%
Tot	21	57	

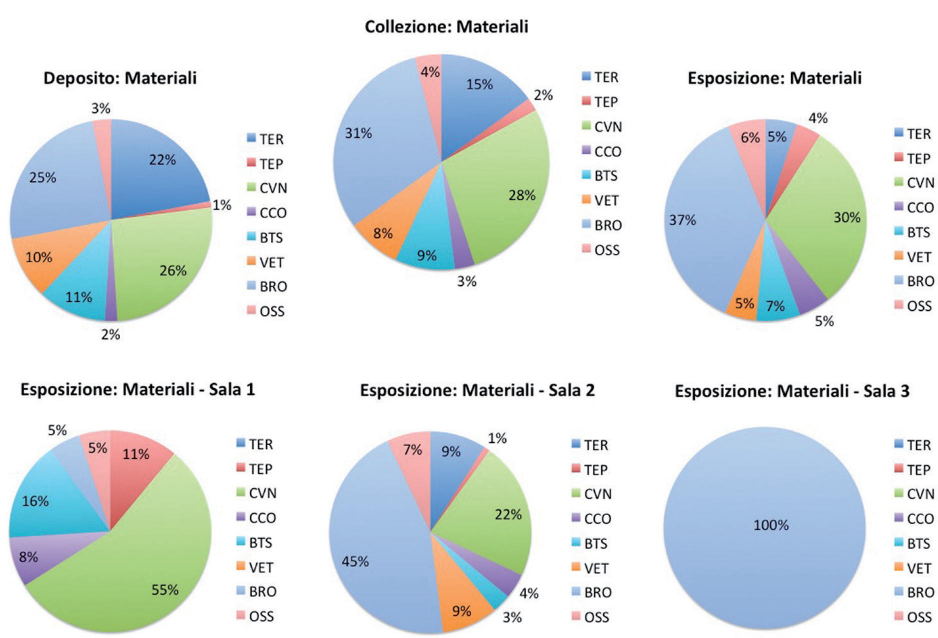
Fig. 5
Part of a Collection Unit processing with information about the objects [Fossà, Giommi].

Fig. 6
Collection's material classes, partially stored and partially exhibited and their distribution in each of the 3 exhibition halls [Fossà, Giommi].

predefined macro categories (fig. 2).

For all the parameters an even number of choices have been established in order to limit the risk of always falling on the intermediate answer and to have results on an average value that would not have been probative.

The actual survey starts with the collection of data from the rooms and the collections according to the identified profiles and with the creation of



M2 - Elaborazioni - Riepilogo per collezioni

Museo xxxx

Locali esistenti e Stima dei locali necessari

Nome Collezione	Sigla	N. Sale	Superfici m² Esistenti	Superfici m² Necessari UI	Superfici m² Rapporto	Superfici m² Necessari UC	Volumi m³ Esistenti	Volumi m³ Necessari UI	Volumi m³ Rapporto	Volumi m³ Necessari UC
Collezione Soliano a	cla	1	34	9	378%	9	120	32	378%	32
Collezione Soliano b	clb	1	38	24	157%	24	133	84	157%	84
Collezione Soliano c	clc	1	125	77	162%	77	626	232	270%	232
Collezione Soliano d	cld	1	40	37	105%	37	138	112	123%	112
Transetto e	cle	3	18	52	34%	52	62	156	40%	156
Collezione Soliano f	clf	1	31	30	104%	30	108	103	104%	103
Transetto g	clg	1	111	145	76%	145	387	436	89%	436
	TOTALI	9	396	375	106%	396	1573	1156	136%	375

Stima delle Unità di Stoccaggio necessarie

Nome Collezione	Sigla	Superfici m² Orizzontali Presenti	Necessari	Rapporto	UC	Superfici m² Verticali Presenti	Necessari	Rapporto	UC	Volumi m³ Orizzontali Presenti	Necessari	Rapporto	UC	Volumi m³ Verticali Presenti	Necessari	Rapporto	UC
Collezione Soliano a	cla	0	3	0%	3	155	63	246%	63	0	2	0%	2	63	9	703%	9
Collezione Soliano b	clb	0	11	0%	11	0	84	0%	84	0	8	0%	8	0	12	0%	12
Collezione Soliano c	clc	77	130	54%	130	0	2	0%	2	104	56	169%	56	0	0	0%	0
Collezione Soliano d	cld	0	61	0%	61	0	32	0%	32	0	26	0%	26	0	4	0%	4
Transetto e	cle	0	43	0%	44	0	140	0%	141	0	31	0%	34	0	15	0%	17
Collezione Soliano f	clf	0	71	0%	91	0	0	-	0	0	44	0%	56	0	0	-	0
Transetto g	clg	0	73	0%	73	0	20	0%	20	0	105	0%	105	0	11	0%	11
	TOTALI	77	393	9%	412	155	340	14%	341	104	271	10%	286	63	51	29%	53

Fig. 7
The existing and necessary surfaces and volumes of rooms and storage furniture for a museum's 6 different collections [Fossà, Giommi].

an archive of graphics and photographic documents (fig. 3) to ensure the correct interpretation and evaluation of text and digital data.

In all the sheets, the data concerning a room, a type of storage furniture or an object are collected on a line (fig. 4).

Once completed the observation campaign, the software will process the data, and the study of the results will allow us to write a final report, which will be able to contain:

– the documentation archive (digital, graphics, photographic and textual documentation);
– the development of digital data;
– a description of the collections;
– an audit of the identification of the risks related to the conservation conditions and the associated priorities;
– the museum's conservation plan;
– the estimation of financial means and the necessary human resources.

To give an example of the rendering obtained on the basis of acquired information, figure 5 shows a part of the Collection Unit Processing Form with the objects information, and the same model is followed by the Museum Form, the Storage/Exhibition Halls Forms and each Inspection Unit Processing Forms.

All the numbers are always also expressed in percentages of the total: the total number of objects (an estimated number, if we used statistics),

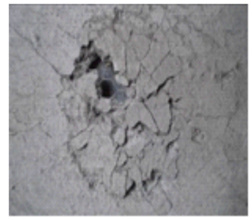
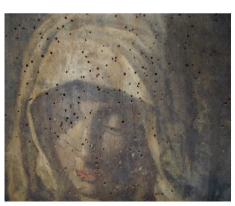
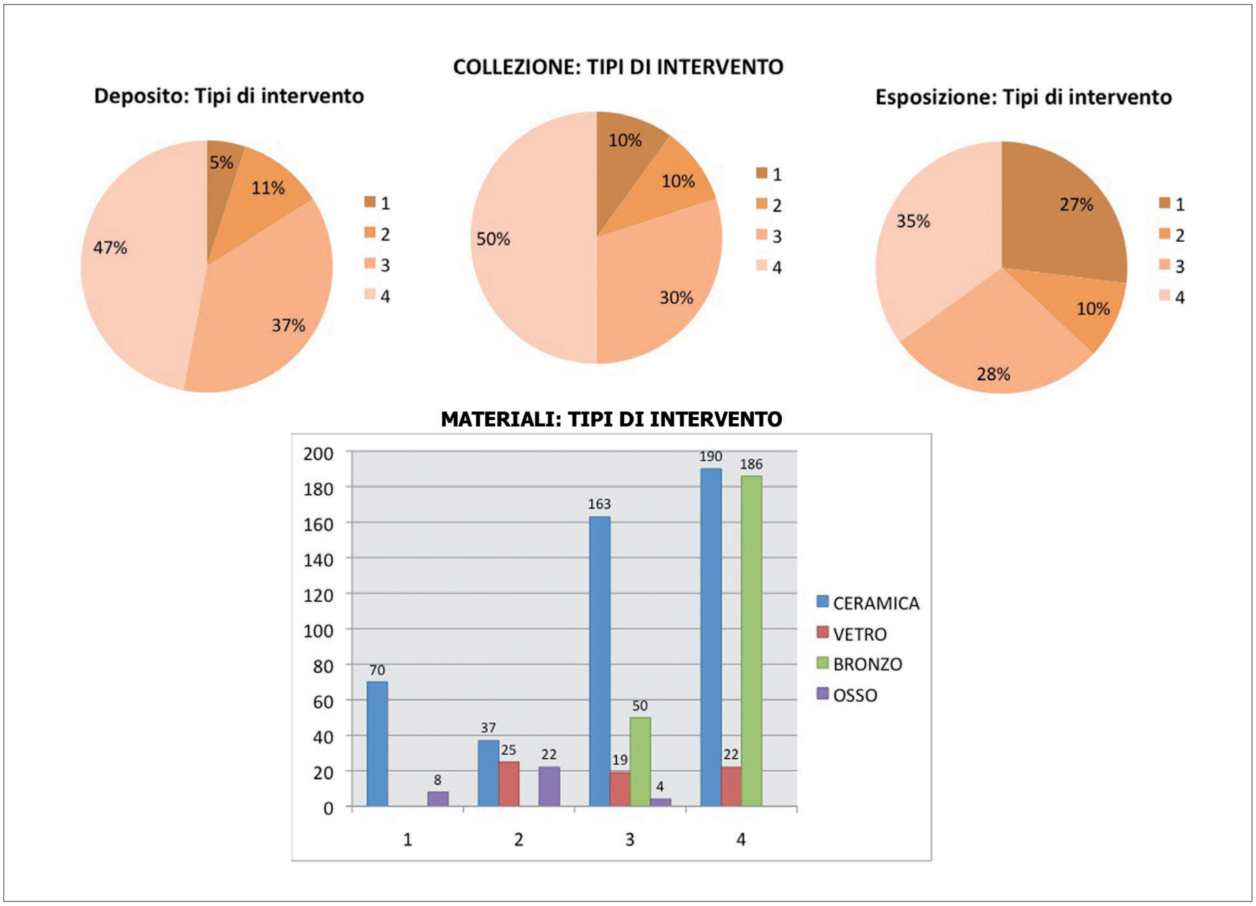
TIPI DI DANNO	CLASSI DI MANUFATTI /MATERIALI COSTITUTIVI			
42% Danni strutturali	**Ceramica**	**Dipinto murale**	**Legno**	**Materiale lapideo**
				
28% Depositi	**Ceramica**	**Dipinto murale**	**Dipinto su tela**	**Materiale lapideo**
				
12% Degrado chimico/fisico	**Metallo**	**Tessuto**	**Carta**	**Materiale lapideo**
				
10% Danno biologico	**Dipinto su tavola**	**Carta**	**Cuoio**	**Scultura lignea**
				
8% Interventi inadeguati	**Ceramica**	**Legno**	**Dipinto su tavola**	Legno
				

Fig. 8
Table summarising the main types of observed alterations on each collection's material class with photographs taken during the report [Di Napoli, Rivaroli, Talone].



of items without an inventory number, of material class, type of damage, risk level, type of interventions and intervention time.

In the report it is useful to integrate graphics and photos: figure 6 shows an example of circular diagrams created for the Collection, the Storage, the Exhibition and also for each exhibition room because of the distribution of material classes where very heterogeneous.

The volume data will be very useful for the evaluation of the storage rooms and in particular in case of remodelling the storage space: the software calculates the volumes, the horizontal and vertical surfaces, as well as the objects' real clutter at the moment of the observation, but also the volumes and the horizontal or vertical surfaces needed to store in an ideal way the collections [Walston and Bertram, 1992] in terms of space, but also in terms of storage furniture (fig. 7).

This data is processed with respect to each class of material, allowing to plan in detail a reorganisation of the collections based also on the objects' constituent materials and the associated conservation requirements [Pearce, 1990].

The alterations identified on the objects are recorded in 8 macro categories that can be used for all the materials: the goal isn't to document the alterations of a single object but to be able to assess the degradation

Fig. 9
Graphics of the types of interventions for a collection, for the objects in the storage room and for the exhibition collections and with respect to each class of materials [Fossà, Giommi].

risk. For each object, it is possible to indicate the percentage of the affected area by each type of alteration, and these 8 categories are sufficient for making an exhaustive report. The creation of tables with the images of observed alterations on the inspected objects (fig. 8) proves very useful for monitoring the evolution of the degradations over time.

The level of risk for each object is marked by the assessor on the basis of observed damages and observed conservation conditions. During the pilot inspection, especially if several evaluators are involved, it is therefore very important to define in which conditions each of the 4 levels will be marked for each material class, taking into account that each level is linked to the speed of the risk of degradation over time.

The recommendations concerning the treatments to be carried out will identify for how many objects of each material class are needed for the 4 different established treatments typologies: this information is obviously very important for planning operations over time (fig. 9).

Finally, the estimation of the times associated with the recommended interventions, expressed in hours and minutes, will allow us to define the executive projects (fig. 10).

In one of the museums where this method was used, we estimated the time required to perform this type of evaluation, compared to the time needed to fill up a "classical" Conservation sheet for each object.[2] A campaign report with this "classical" form would have required two years of work for one evaluator, while with *SOS Collections®* thanks to the statistical method, the same evaluation required one month's work. If the campaign was conducted on all of the museum's objects, it would have taken four months with this method.

Once the description of the collections has been completed, the information gathered from all the forms is compared: the audit phase is the most delicate because it is necessary to identify the existing relationships between the observed alterations, the risk levels marked for the objects and the observed conservation conditions. All this information will be fundamental to define the conservation plan and convince the recipients of the report of its validity.

The conservation plan will indicate the priorities and the treatment typologies, the possibilities (or not) to realise them in parallel, the human resources necessary for their realisation, etc., but also the norms and the procedures to be followed after intervention in the different contexts of exploitation of the collections, in order to reduce the present risks by ensuring their conservation for the future generations.

Over the years, the methodology has been taught to university students studying to be conservators in France and in Italy and in the framework of international projects; it has also been used for degree dissertations [Giommi and Sgarzi, 2003; Di Napoli, Rivaroli and Talone, 2011] and by professionals working in archeological and fine art museums [Fossà *et al.,* 2006; Giommi, 2009].

MATERIALI		DTE	VET	MET	CUO	CER	DMS	TES	LEG	Totali	
Oggetti	n.	3	5	3	5	5	27	5	3	57	
Spazi necessari											
Sup	m2	6,9	0,1	0,0	0,4	0,1	82,4	4,1	0,1		
Vol	m3	5,6	0,0	0,0	0,4	0,0	11,6	1,7	0,0		
Alt media	dm	8,0	1,9	1,8	7,8	2,2	12,3	6,3	1,6		
Sup media	dm2	256,0	1,5	1,4	7,1	2,0	303,5	74,9	4,8		
Vol medio	dm3	2048,0	2,9	2,5	71,8	3,8	427,8	306,1	7,7		
Ogg Oriz	n.	3	5	3	5	5		3	3	27	
Sup	m2	6,9	0,1	0,0	0,4	0,1		2,9	0,1		
Vol	m3	5,6	0,0	0,0	0,4	0,0		1,6	0,0		
Alt media	dm	8,0	1,9	1,8	7,8	2,2		5,5	1,6		
Sup media	dm2	256,0	1,5	1,4	7,1	2,0		105,7	4,8		
Ogg Vert	n.						27	3		30	
Sup	m2						82,4	1,2			
Vol	m3						11,6	0,1			
Alt media	dm						12,3	7,1			
Sup media	dm2						303,5	44,0			
Tipi di Danno											
	S1	3			5	3	24		3		
	S2	3	3		5	5	24	3	3		
	SU	3	3		5	3	16	3	3		
	AL	3			5		5		3		
	CF	3		3	5		3	3	3	**Tempi d'Intervento**	
	BI	3			5		19		3		
	II						24			Totale h	Media min.
	DI	3	5	3	5	3	24	3	3		
Livello di Rischio											
	A		3 50%			5 100%		3 50%		47	258
	B		3 50%		3 50%					293	3240
	C			3 100%	3 50%					1411	15600
	D	3 100%					27 100%	3 50%	3 100%	11460	19486
Tipi d'Intervento											
	1		3 50%			3 50%		3 50%		3	23
	2										
	3		3 50%			3 50%				65	720
	4	3 100%		3 100%	5 100%		27 100%	3 50%	3 100%	13143	18158
Tempi d'Intervento											
Totale	h	1303	23	109	1574	45	8990	435	733		
Media	m	28800	255	2400	17400	495	19872	4805	16200		

Fig. 10
Part of a Collection Unit processing form where the times associated with the 4 recommended interventions are developed in relation to material classes, risk levels and typologies of intervention [Fossà, Giommi].

A manual describing the methodology and the software's instructions now allows professionals to have a good command of it. The methodology will be integrated to the *Risk Map's System,* where the object's risk will be calculated by an already existent algorithm [Fossà and Giommi, 2011].

In conclusion, "*SOS Collection*® was conceived with a systemic approach, wishing to relate the state of the collections and the storage or exhibition spaces conservation conditions. The method was developed for the sake of user flexibility, measurability, and data comparability, keeping the evaluation on schedule and in the different examined spaces and the adaptability to computer tools other than File Maker Pro. Data interpretation allows a prioritisation of preventive conservation or curative actions with the necessary resource estimation for their implementation" [Forleo, 2017, p. 43].

Notes

[1] We thank Mr. Maurizio Truglio who has gratuitously created a custom software and all the updates we asked to test the methodology in different contexts.

[2] We refer to the form that conservators use to document conservation treatments and, if many models exist, most of them have several pages and their compilation can even take several days.

Bibliography

Berrett K., 'Conservation Surveys: Ethical Issues and Standards,' in *Journal of the American Institute for Conservation (JAIC)* 33 (2), pp. 193-198, 1994.

Castelli G. (under the leadership of), *La Carta del Rischio del patrimonio culturale*, Ministero per i Beni Culturali e Ambientali, Ufficio Centrale per i beni archeologici, architettonici, artistici e storici, Istituto Centrale per il Restauro, Rome, 1997.

Di Napoli M., Rivaroli L., Talone R. *et al.*, 'I depositi del Museo dell'Opera di Orvieto: studio conservativo e proposte di allestimento. La Scheda Collezione come soluzione delle problematiche correlate allo studio ed alla salvaguardia di collezioni cospicue di beni culturali,' in *Atti del Convegno Lo Stato dell'Arte, IX Congresso Nazionale IGIIC*, Cosenza, Italy, 13-15 October 2011, Nardini, Florence, 2011, pp. 247-255.

Drott C. M., 'Random Sampling: a Tool for Library Research,' in *College and Research Libraries,* 30, mars 1969, pp. 119-125.

Forleo D., Francaviglia N., Wansart N., 'L'évaluation des collections,' in Forleo D. (ed.), *Cronache 7 – Méthodes d'évaluation de conservation des collections dans les demeures historiques,* Sagep Editori, Genoa, 2017, p. 43.

Fossà B., *Une stratégie préventive pour la conservation des collections en réserves. Une expérience dans le musée archéologique national de la Villa Giulia à Rome*, mémoire de maîtrise dirigé par Denis Guillemard, Université Paris I-Panthéon-Sorbonne, MST en Conservation-restauration des biens culturels, not published, 1995.

Fossà B., Truglio M., 'SOS collections®: un programme personnalisé au service de la conservation préventive,' in *Informatique & conservation restauration du patrimoine culturel, 8es journées d'études de la SFIIC*, Chalon-sur-Saône, 23-24 October 1997, SFIIC, Champs-sur-Marne, 1997, pp. 61-69.

Fossà B., Giani E., Giommi M. *et al.*, 'Studio conservativo delle armi e armature Odescalchi: nuove metodologie per la schedatura di una collezione,' in *Bollettino d'Arte*, fascicle 137-138, 2006, pp. 115-142.

Fossà B., Giommi M., *SOS Collections®: metodo e strumenti per la schedatura conservativa, la valutazione e la gestione delle collezioni museali. Manuale d'uso.* 1-2, ISCR, Rome, unpublished, 2011.

Fossà B., Giommi M., 'SOS Collections®: metodo e strumenti per la gestione conservativa delle collezioni museali,' in *Bulletin ICR – Nuova Serie (27)*, 2013, pp. 36-49.

Giommi M., Sgarzi S., *La conservazione in ambito museale: nuove proposte per il sistema di schedatura delle collezioni e degli ambienti. I depositi del Museo Nazionale di Palazzo Venezia: la collezione Odescalchi di armi e armature*, mémoire de maîtrise dirigé par Bianca Fossà, Ministero per i Beni e le Attività Culturali, Scuola di Alta Formazione e Studio dell'Istituto Centrale per il Restauro di Roma, unpublished, 2003.

Giommi M., 'Indagine conservativa sulla collezione con metodo statistico,' in Prisco G. (ed.), *Filologia dei materiali e trasmissione al futuro. Indagini e schedatura dei dipinti murali del Museo Archeologico Nazionale di Napoli*, Gangemi Editore, Rome, 2009, pp. 119-131.

Keene S., 'Audits of Care: a Framework for Collections Conditions Surveys,' in *Storage-Preprints for UKIC Conference, Restoration 91, October 1991*, UKIC, London, pp. 6-16, 1991.

Michalski S., *A Systematic Approach to the Conservation (Care) of Museum Collections*, Canadian Conservation Institute, Ottawa, 1992.

Ministry of Welfare Health and Cultural Affairs, *Delta Plan for the Preservation of Cultural Heritage in the Netherlands. Final Report*, International Workshop, 21-23 October 1992, Restoration RAI, Ministry of Welfare Health and Cultural Affairs, Amsterdam, 1992.

Pearce S. M., 'Approaches to Storage,' in *Archaeological Curatorship*, Leicester University Press, London/New York, 1990, pp. 88-102.

Urbani G. (ed.), *Piano pilota per la conservazione programmata dei beni culturali dell'Umbria. Progetto esecutivo*, Istituto Centrale per il Restauro, Rome, 1976.

Vallas P., 'Maîtrise de l'état des collections et définition des besoins,' in Oddos J. P. (ed.), *La conservation. Principes et réalités.*, Editions du Cercle de la Librairie, Paris, 1995, pp. 57-74.

Waller R., 'Conservation Risk Assessment: a Strategy for Managing Resources for Preventive Conservation,' in Roy A., *Preventive Conservation. Practice, Theory and Research*, Preprints of the Contributions to the Ottawa Congress, 12-16 September 1994, International Institute for Conservation of Historic and Artistic Works, London, 1994, pp. 12-16.

Walston S., Bertram B., 'Estimating Space for the Storage of Ethnographic Collections,' in *ARAAFU, La conservation préventive, Actes du 3e colloque sur la Conservation-Restauration des Biens Culturels. Recherches et Techniques Actuelles, 8-10 October 1992*, Association des Restaurateurs d'Art et d'Archéologie de Formation Universitaire, Paris, 1992, pp. 137-144.

Wolf S. J., 'Conservation Assessments and Long-Range Planning,' in Rose C. L., Williams S. L., Gisbert J. (ed.), *Simposio internacional y primer congreso mundial sobre preservacion y conservacion de colecciones de historia natural, 3*, 10-15 May 1993, Ministerio de Cultura, Madrid, pp. 289-307.

A Museum at Risk: Managing Indoor Climate Risks in Heeswijk Castle

Abstract

Managing the indoor climate in an historic house context is a complex issue: the stakes are high, many components are of high cultural value; often the collection, interior and building form an ensemble; and the process to determine the optimal control strategy is time consuming. Developing options to reduce indoor climate risks is not a daily task for many historic house managers. Especially large refurbishments or restorations probably take place only once in their lifetime.

The decision making process with its nine supports will help even the inexperienced heritage manager in structuring the process and reaching a realistic and affordable climate control option. This presentation will explain the process and illustrate the typical working methods and outcomes by describing the case study of 16th century Castle Heeswijk. This small museum, with its important collection was fully climatised in 1996. Between 2009 and 2013 the museum had no cooling capacity (dehumidification) and between 2014 and 2016 humidification was unstable.

Bart Ankersmit
Senior Scientist,
Cultural Heritage Agency of the Netherlands
b.ankersmit@cultureelerfgoed.nl

Marc Stappers
Physicist, specialist in building physics, Cultural Heritage Agency of the Netherlands
m.stappers@cultureelerfgoed.nl

In the southern province Brabant of the Netherlands, Heeswijk Castle is one of the most wonderful enlisted buildings to visit. The almost thousand years old castle has a rich history related to the lords of Heeswijk-Dinther and the last owners, the barons Van den Bogaerde van Terbrugge, who had ties with the Royal Family.

In the 18th century, Europe was caught in the grip of a long period of unrest. Powerful monarchies contested their legacies. The southern part of Brabant was in Spanish and Austrian Habsburg hands, the northern part was occupied by the Dutch Republic. During this period, Heeswijk Castle was neglected by its owners. In 1826 the castle was restored and made into the family's residence again. Throughout the years the family collected a large number of objects. A bizarre will stated in 1895 that the great-grandson of the baron was not allowed to inhabit the castle until his 80th birthday in 1963. The heirs, living outside the castle, put the famous museum collection on sale in 1897 and 1903. 75% Of the total collection became scattered around the world. Whatever was not sold remained in the castle until today.

In 1997 the last baroness died and a foundation took over the care

a

b

c

Fig. 1a-c
Overview (a), the Chinese room (b) and the White room (c) in Heeswijk Castle.

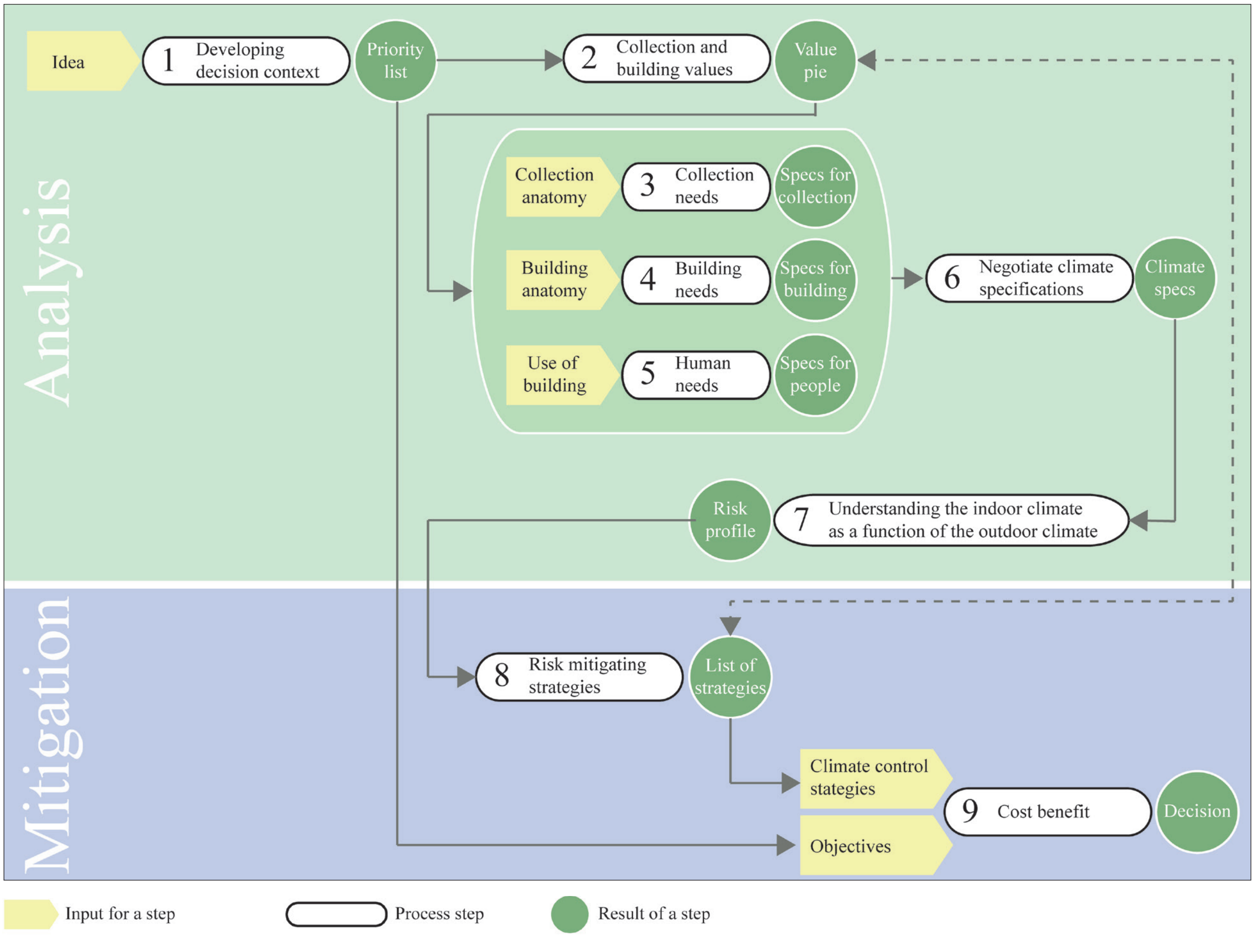
of the castle. The garden and buildings were restored, the castle was opened as a museum. A restaurant and café completed the new function of this historic building. Nowadays the castle is visited by about 30.000 people annually. Next to the museum visits, the castle is rented out for weddings and other cultural activities.

The main building of the castle has several so-called museum spaces. These are seen as the most valuable rooms in the castle and contain many important moveable objects of high cultural value. In figure 1 an aerial overview of the castle and two museum rooms are presented. In figure 5 the museum rooms are indicated by a colour in the floor plan of the first and second floor.

Challenges and Approach
The director of Heeswijk Castle asked the Cultural Heritage Agency to analyse the challenges the museum faces today in relation to climatisation, the most important being:

– an imbalance of income and expenses due to high energy costs;
– users of the castle that indicate they feel uncomfortable;

Fig. 2
The nine steps of the decision making model to manage indoor climate risks.



– unacceptable damage to the collection that assumingly is caused by an incorrect indoor climate.

Following the nine steps as presented in the publication *Managing Indoor Climate Risks in Museums* [Ankersmit and Stappers, 2017] the situation was analysed and ideas were developed to address the challenges presented by the director.

Step 1: towards a balanced decision. The decision context and decision process is explored. The individual goals of the heritage institute and the stakeholders involved are expressed and attributes assigned. A selection is made of the objectives that have most impact on the outcome of the decision.

Step 2: valuing heritage assets. The significance of the building and the movable collection are made explicit. Altogether, the values and significance provide the framework within which options for modifying the building and/or the environment around the objects are considered and evaluated.

Step 3: assessing the climate risks to the moveable collection. Based on sensitivity categories and an examination of the current condition of the collection, the climatic needs for the collection are defined.

Step 4: building needs. Those parts of the building that are considered valuable and susceptible to certain climate conditions are identified and the climatic needs for these parts are specified. Special attention was paid to wood paneling and wall papers found throughout the castle.

Step 5: assessing human comfort needs. The climatic requirements for the human occupants are defined for each climate zone.

Step 6: understanding the indoor climate. The building envelope properties and the layout and functioning of the climate control systems are evaluated.

Step 7: defining climate specifications. Based on the outcomes of Step 1-5 the climate specifications for the climate zones within the building are developed.

Step 8: mitigating strategies. Different strategies to achieve the climatic conditions specified in Step 7 are developed.

Step 9: weighing alternatives. A multi criteria analysis is used to evaluate how each mitigating strategy helps achieving the ambitions developed in Step 1.

Results

Step 1: *What is Important?*

In a brainstorming session with the museum stakeholders the general objectives of the museum were developed and discussed in detail. Here the current challenges encountered in managing this property play an important role. The main objectives to which final options about the control of the climate have to be weighed against are, in random order:

– preservation of cultural value: the castle is seen as an historically grown so-called interior-ensemble consisting of moveable and immoveable objects. The total value of the castle is much more than the sum of the cultural value of the individual parts;
– Increase income and/or reduce expenditure. The high energy consumption (gas and electricity) of the museum plays an important role;
– provide access to cultural values to a wide audience, not only museum visitors but also people who come to the castle for specific events that generate income.

Step 2: *Values*

Using the valuation method *Assessing Museum Collections, Collection Valuation in Six Steps* developed by the Cultural Heritage Agency of the Netherlands [RCE, 2014] it was established that the most important cultural values of Heeswijk Castle and its interiors are the historic and artistic values of this historically grown ensemble. The cultural value of the building and the collection considered together is bigger than the sum of its parts. Changes to either of them may result in an even larger loss to the ensemble. Thus modifications to optimise the climate will often (if not always) result in a relatively large loss of experience, authenticity and/or historic value.

The museum rooms, colour coded in figure 5, in the castle are the most important rooms and contain the most significant moveable objects. Typical treasures, that were not sold in the auctions of 1897 and 1903, are:

– the fully decorated Chinese room with original wall paper, furniture, silk curtains, Venetian glass lamp and painted ceiling (see also fig. 1);
– the Salon with important portrait paintings;
– the White room, with a unique asbestos floor (see also fig. 1);
– the Tin room uniquely decorated with wooden panelling and a large set of tin objects;
– the room were the last owner died with its unique gilt leather wall hangings.

Step 3 and 4: *Collection Preservation*

The collection shows climate related damages. Old photographs were compared to current condition to investigate when the damage was formed. It proved impossible to establish a proper time line, since the damage observed today was already present in the historic photos. The climate, as was maintained in the past 20 years, has not increased the risk of mechanical damage. However, the condition of the Chinese wallpaper in the Chinese room, was a concern. The paper is brittle and very susceptible to mechanical damage due to impact, shock or vibrations. Fortunately, entrance to the room is very limited, only staff enters to clean the room.

Since climate control was introduced in the museum in 1996, the staff has been continuously busy programming, reading and calibrating data loggers. The relative humidity and temperature were measured in different rooms in 2008, 2009, 2010, 2014, 2015 and 2016. Unfortunately these data show gaps and analysis is further complicated by the varying time interval between data points being 1 or 2 hours. Nevertheless, available data has been combined into different data sets. In figure 2 some of these different sets are presented.

To assess the risk of chemically unstable materials, climate data can be plotted in a psychrometric chart with the lines of equal life times (the coloured lines in the top right graph in figure 3). During summer, with temperatures up to 25-27°C, lifetime of chemically unstable materials is reduced by a factor 2 as indicated by the orange line. In winter time however, the lifetime is doubled (15°C<T<17.5°C). The risk of mould was assessed by plotting the measured climate data in the so-called isopleth system and assess the likelihood of germination on a substrate on which spores can germinate easily resembling common used building materials. All the data fall well below the lowest limit for germination (LIM) to occur. The risk of mechanical damage was assessed by using the model developed for wooden sculptures (fig. 3, lower left corner). The lines presented between the risk of mechanical damage is zero, outside the lines permanent deformation can occur. The lower red line is the line below which damage, such as cracking will occur.

Although several wooden objects show cracks and other deformations, from the climate risk assessment and object survey it can be concluded that the collection is currently not at risk for biological and mechanical degradation. The risk of chemical degradation varies over the year; while in winter the lifetime of chemically unstable materials is doubled this benefit is reduced by higher temperatures in summer, when the lifetime is reduced.

Step 5: *Comfort for Staff and Visitors*

Since its opening in 2003 the museum attracts an ever growing number of visitors, around 19.000 in 2013 and 2014 to 27.000 in 2017. According to the staff, the comfort of collection is always seen as more important than the comfort for visitors, but how comfortable they are is never really investigated. Using the model developed by van der Linden (2006) allows plotting the measured indoor temperatures as a function of available outdoor temperatures (KNMI, the national weather institute) which shows comfort levels. The coloured lines indicate the

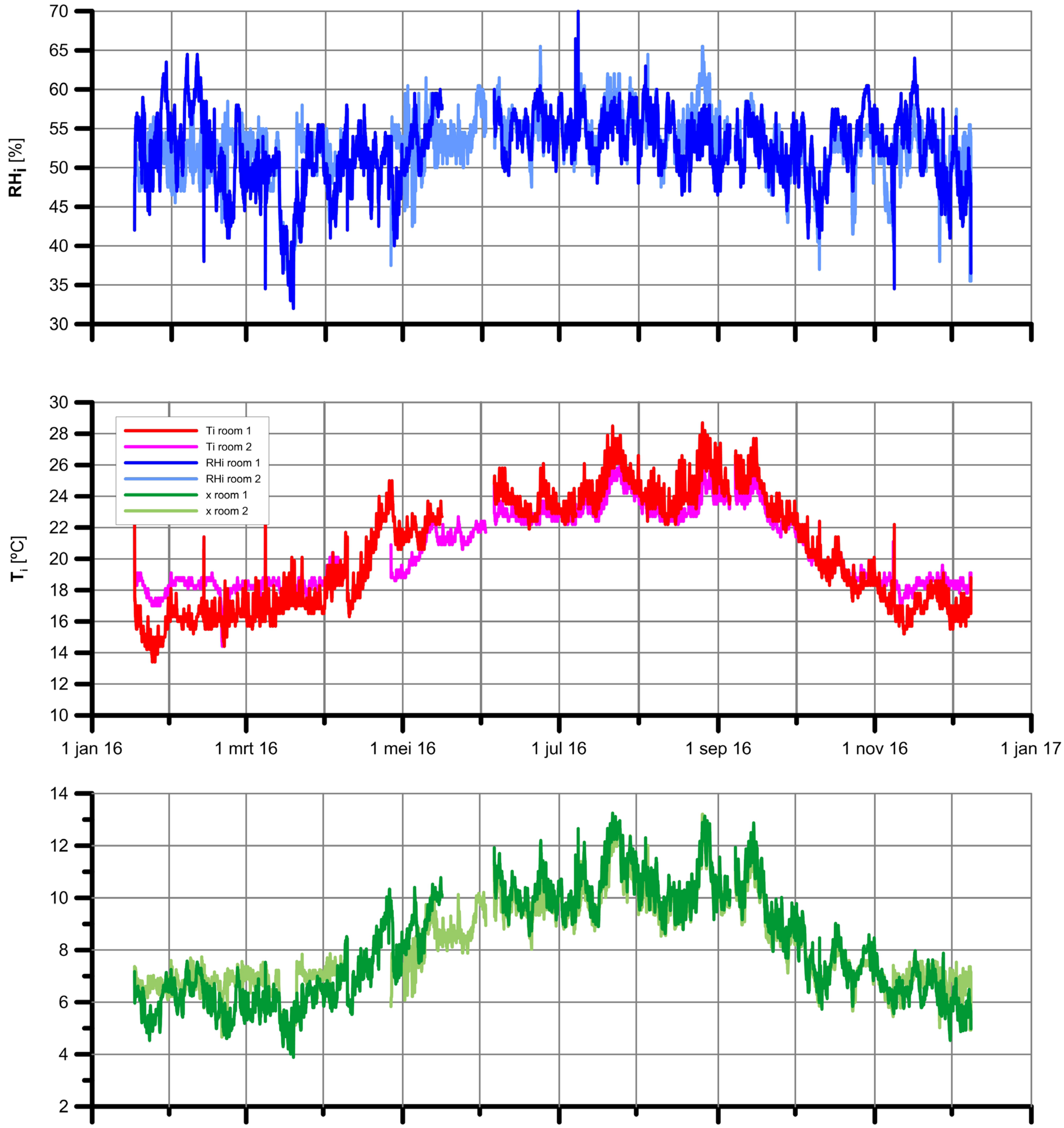
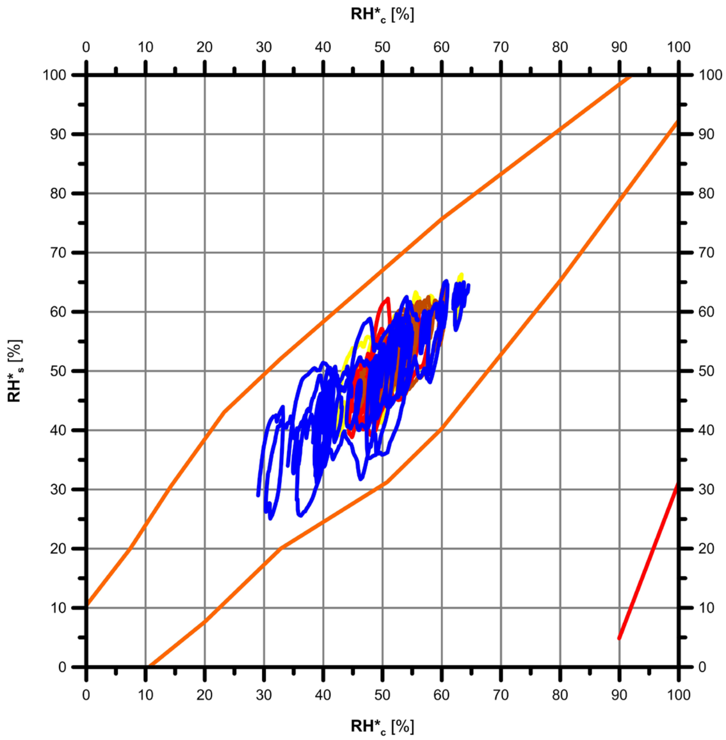
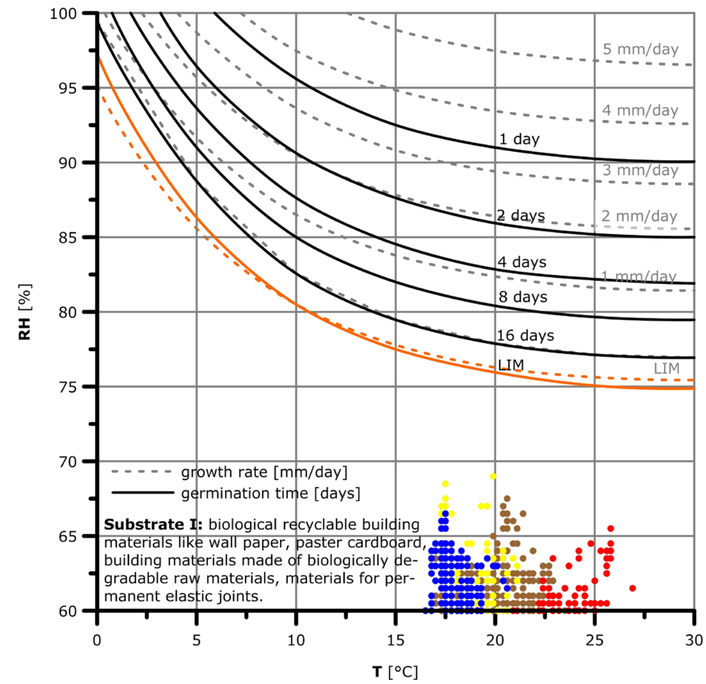
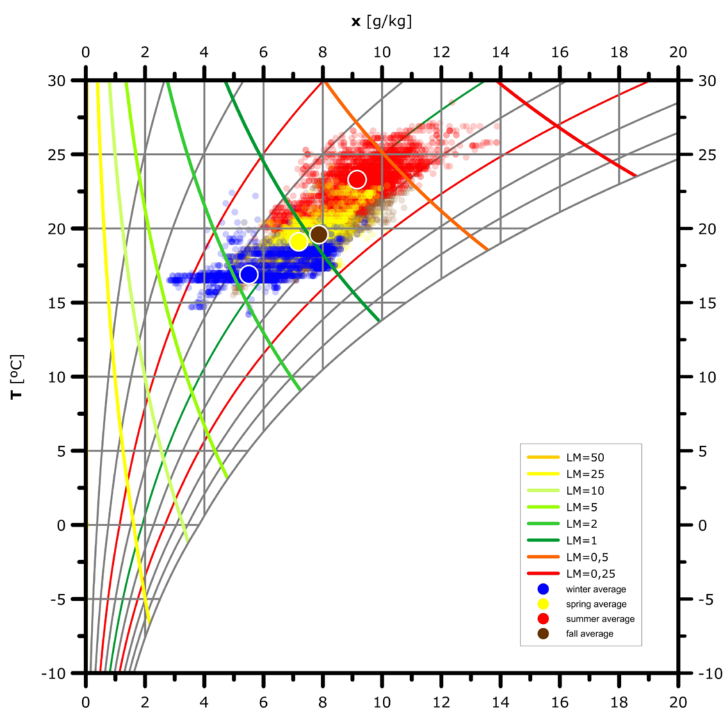


Fig. 3
On the left the temperature, relative and specific humidity plots of 2016 of the Tin room (1) and White room (2) are presented. On the right the three plots show the climate risks for chemical degradation (top right), mould (middle right) and mechanical degradation (bottom right) using the climate measured in the Salon between 2009 and 2016. For this analysis the climate risk model developed by M. Martens (2012) was used.







percentage of people comfortable. The green lines show for example the comfort of 90% of all people, who are comfortable if the specific in- and outdoor temperature falls between the lines. In figure 4 the climate data collected in the Salon are presented.

It can be readily seen that winter and summer is too cold for most people and spring and fall sometimes provide indoor temperatures within the 80% acceptance level. As indicated by the challenges the staff is concerned with comfort for visitors but also indicated that collection preservation is more important than human comfort. A balance need to be found between human comfort and the risk of chemical degradation. Which rooms allow a slightly higher winter and/or summer temperature, with subsequent slightly lower lifetimes of chemically unstable materials? The chemical stability of paintings and furniture in the Salon for example would allow such an adaptation. But for the books and prints in the

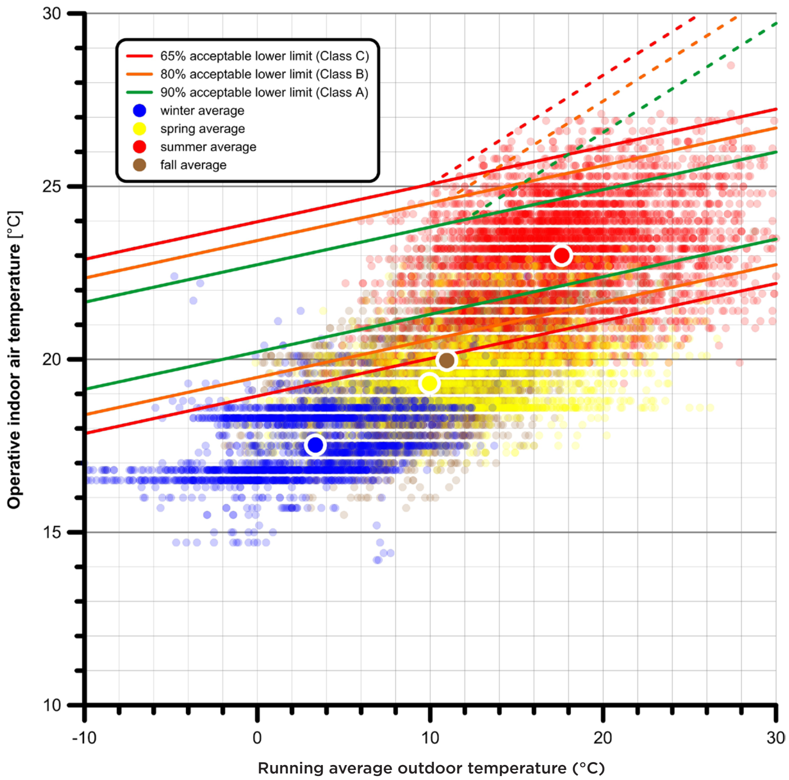


Fig. 4
Collected indoor temperatures measured in 2009, 2010, 2013, 2014, 2015 and 2016 in the Salon as a function of outdoor temperatures. The comfort limits for an "alpha" building in which the user has limited control over the indoor temperature by e.g. opening windows, is presented using the so-called Adaptive Thermal Model, extracted from Van der Linden et al [2006].

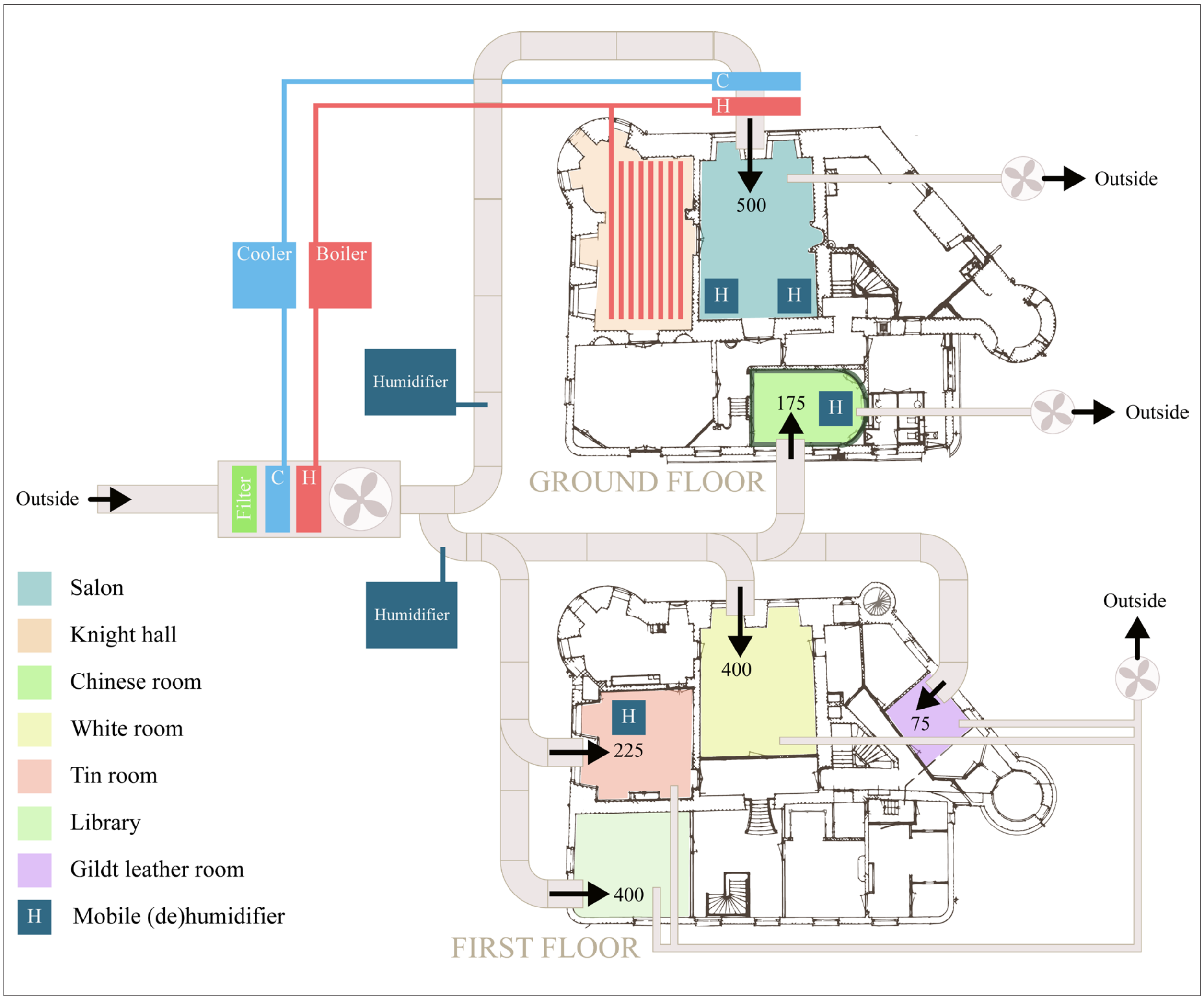
Fig. 5
Climate control of Heeswijk Castle in 2017. The museum rooms are indicated by a colour. Outside air is brought to a specific temperature by a system with cooling, resulting in dehumidification and heating capacity. The air is subsequently split into 2 main air flows that are both humidified by a steam humidifier. The first air flow is again cooled or heated and delivered into the Salon (500 m³/h). The second flow is used to supply different rooms with controlled air: the Chinese room on the ground floor (175 m³/h) and into 4 rooms on the second floor. All rooms in which conditioned air is delivered take this air out by 3 fans. There is no recirculation.

library it might be an unacceptable risk.

Step 6: *Understanding the Indoor Climate*

Heeswijk Castle is a monolith building constructed of massive brick walls that provides for large thermal mass. This would help to reduce large temperature swings. On the other hand large single glazing systems in wooden frames accumulate thermal energy in summer and transmit heat to the outdoor in winter increasing temperature gradients. Although generally most historic buildings are quite leaky and have large air exchange rates, making it difficult to maintain the indoor air at a certain temperature and relative humidity.

Gas and electricity were introduced into the main building in the early 1990s. Shortly after, in 1996, a small climate control system was installed to control both the relative humidity and temperature in part of the castle. In 1999 also the other so-called museum rooms in the older part of the main building became air conditioned. In 2009 the first malfunctioning of the climate system occurred, when the cooling completely failed. This situation lasted until 2013 when one of the two original unites was replaced. Since then cooling and thereby dehumidification functioned at 50% of its original capacity. In 2011 the control software was updated. The second malfunction of the climate control system occurred in 2014. The humidification became highly unreliable. This situation lasted for two years. In response two steam humidifiers were installed (see fig. 5). To further stabilise the relative humidity,



mobile (de)humidifiers were placed in different rooms throughout the castle. The Chinese room was climatically separated from the rest by a glass pane in the door frame. It is expected to be the room with the lowest infiltration rate. The situation in 2017 is schematically depicted in figure 5.

Generally the climate shows seasonal as well as short term fluctuations of both temperature and relative humidity (see also fig. 2). The rooms on the ground floor are heated in winter, while the rooms on the first floor are not and remain relatively cool.

When comparing e.g. the indoor climate in 2009 with 2016 in the Salon, it can be noticed that 2009 shows a seasonal fluctuation of the relative humidity of approximately 15%, while 2016 shows a relative humidity between 50% and 65% year round. This is most likely due to a malfunctioning of the cooling in that time. A summary of the climate of the two most controlled rooms, i.e. Salon and Chinese room is

	2008		2009		2010		2013		2014		2015		2016	
	T	HR	T	HR	T	HR	T	HR	T	HR	T	HR	T	HR
Salon			19.7 (2.7)	50.9 (7.1)	20.8 (2.9)	50.4 (6.0)	19.5 (2.6)	58.0 (3.1)	20.8 (2.1)	55.7 (4.3)	20.2 (1.8)	54.8 (4.9)	20.7 (2.1)	55.7 (6.0)
Chinese Room	20.4 (2.4)	50.4 (4.8)	20.2 (3.8)	50.0 (6.2)	18.9 (2.8)	51.3 (5.6)	18.9 (2.8)	51.3 (5.6)	20.7 (2.1)	53.8 (2.7)	20.2 (2.2)	50.8 (4,7)	20.8 (2.4)	51.7 (4.7)
			No cooling / No dehumidification						Unreliable humidification					

Table 1
The yearly average temperature and relative humidity in the Salon and the Chinese room. The standard deviation is given in between brackets.

provided in table 1.

From the data above it can be seen that the temperature distribution in both rooms is quite similar, the relative humidity in the Salon is somewhat higher with slightly larger variations than found in the Chinese room. The climate in the other rooms shows similar variations. All in all it can be concluded that the chosen strategy in which every hour about 1775 m^3 air is transported into the museum rooms does not provide a tightly controlled relative humidity or temperature and that the largest sudden fluctuations the objects in the museum rooms are exposed to, are generated by the installation. There is no significant effect of the malfunctioning cooling (2009-2013) on the indoor climate, except a notable higher annual relative humidity in the Salon in 2013. Similarly the unreliable humidification does not show e.g. a larger stand deviation of the relative humidity data.

Transporting, heating and cooling air is energy consuming. Gas is used for heating. Electricity is mainly used by the fans for the transport of air. Cooling and steam humidification will also require electricity. When the gas usage over the past seven years is evaluated it can be readily seen that independent of the month, it has been more than doubled over the past 7 years, with subsequent increase of costs. Analysis of the electricity consumption is problematic, because incomplete data are only available for 2011-2016 and it is not clear what the contribution of the climate control components in the overall data is. A general trend can be observed in these data: a decrease of electricity consumption of approximately 20-30% for most building components between 2011 and 2014. 2015 and 2016 show an increase back to the original consumption of 2011. This decrease can probably be explained by the absence of cooling capacity, the increase after 2014 by the implementation of the two steam humidifiers.

It seems that the climate control strategy has a very limited effect on the indoor climate but consumes a significant amount of energy. A first attempt could be the decrease the air exchange rate by renovate or draught proofing the windows. Maybe some floors can be thermally upgraded. Unfortunately improving the buildings performance will change or decrease the cultural and aesthetical values of the building. A second option is to investigate the effect of individual components of the climate control system on the indoor climate will help to develop ways to further optimise the situation. A likely strategy would be to try to limit the dependency of the indoor climate on technology. One could think of running the system at a lower frequency, or even a shut down during the night. At the moment most doors remain open to create a large internal volume that allows for air to be freely distributed and mixed in the building. The effect of opening, or closing, some doors on the climate in that zone can be studied, with a goal to reduce ventilation per zone.

Conclusions

In order to analyse the challenges of Heeswijk Castle, step 1 to 6 were followed. The last 3 steps; Steps 7 (climate specifications), Step 8 (mitigating options) and Step 9 (cost benefit) were not addressed since they fall outside the scope of this study.

New climate specifications that fit the building and the organisation and ways to maintain these can be developed based on the findings of this study. Are the objects at risk in this climate?

Over the past years the climate in the museum rooms has never been the (strict) museum climate that was originally intended by those involved at the decision making at the time. Although the original programme of requirements has not been found, it is believed that the specifications for relative humidity and temperature will have been very similar to those found in museums that were renovated in these days: 48%-53% [Jütte, 1994]. Using the concept of proofed relative humidity fluctuation it is possible to specify future indoor climate conditions by analysing the historic climate. This is done by calculating the median (50th percentile) and the standard deviation of the relative humidity data set. The (maximum) acceptable future fluctuation is defined as the standard deviation of all historic relative humidity data [CEN, 2010].

The allowable bandwidth would increase significantly without increasing the risk of mechanical damage to the moveable objects. If a lower relative humidity (and temperature) is excepted in winter, this would greatly reduce the risk of condensation on and/or in the building envelope. Using the historic climate data presented in table 1 for the Salon and the Chinese room helps in choosing the year with the largest standard deviation. 2009 showed the largest standard deviations for both rooms: 51%±7% (Salon) and 50%±6% (Chinese room). If these specifications would be used to develop an alternative climate strategy they become so-called performance targets and they should be

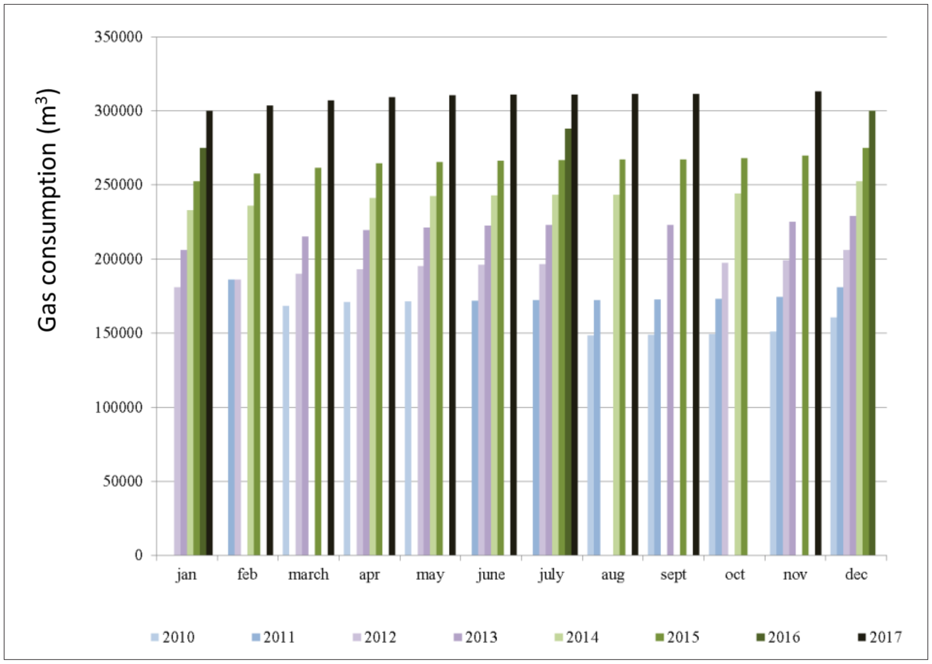


Fig. 6
Monthly gas consumption of Heeswijk Castle between 2010 and 2017.

re-written into: 44%-58% and 44%-56%, allowing the climate to freely swing between these boundary conditions. Knowing that these two different descriptions have a huge impact on energy consumption. In his doctoral study Kramer showed that Class AA as a range (45–55%) saved 50% of energy compared to the case of one set point (50±5% RH) [Kramer *et al.*, 2016].

The second question to address is if the climate system can be optimised with two objectives in mind: a better control of the indoor climate and a lower energy consumption.

Especially the mall functioning of the cooling system in 2009 and humidification in 2014 and the notion that the climate did not change drastically (see table 1), which is substantiated by the observations of the museum staff that the indoor climate did not change drastically, indicates that the overall impact of the climatised air on the indoor climate is probably limited. Further research is required to evaluate the effectiveness of the climate system by temporary shutdown of (parts) of the system and/or change the use of mobile (de)humidifiers. These adaptations would be aimed at reducing the dependency on machines and thereby reducing energy consumption and energy and maintenance costs. The effect of the climate strategy components, ie cooling, heating etc. should be better understood. It is expected that the mobile devices have very limited effect on the relative humidity in open spaces. The effect of closing doors by looking at air exchange rates is an option, especially if it will make the use of mobile devices more effective. In order to understand the effect of any intervention on the indoor climate, proper measurements should done. For Heeswijk Castle it is recommended to start with a proper measurement plan. No extra manpower or budget is required to generate data that have similar interval times and start at the same time, but analysis of such data is significantly less time consuming.

Notes

[1] This study was done with the help of Antje Verstraten, Renate Oosterloo and Vera Tolstoj, three students who study Historic Interiors at the University of Amsterdam. The staff of the Castle; Luc van Eekhout, Elly Verkuijlen and Hein van de Greef have been very helpful and hospitable. The access to their information was essential. We are grateful to the volunteer who also designed the climate system Ad van de Akker who explained to us the layout.

Bibliography

Ankersmit B., Stappers M. H. L., *Managing Indoor Climate Risks in Museums*, N. Luxford (ed.), Springer, 2017.

Ankersmit B., Stappers M. H. L., 'Guideline in Jeopardy: Observations on the Application of the ASHRAE Chapter on Climate Control in Museums,' in *Preprints of the IIC conference in Turin 2018*, accepted for publication, 2018.

Bahg J., *Passieve conservering; klimaat en licht*, Centraal Laboratorium voor Onderzoek van Voorwerpen van Kunst en Wetenschap, 1994.

CEN, *Conservation of Cultural Property – Specifications for Temperature and Relative Humidity to Limit Climate-Induced Damage in Organic Hygroscopic Materials*, European Standard EN 15757, 2010.

KNMI, outdoor climate data available at: http://projects.knmi.nl/klimatologie/daggegevens/selectie.cgi.

Kramer R. P., Schellen H. L. and Van Schijndel A. W. M, 'Impact of ASHRAE's Museum Climate Classes on Energy Consumption and Indoor Climate Fluctuations: Full-Scale Measurements in Museum Hermitage Amsterdam,' in *Energy & Buildings* 130: 286-294, 2016.

Linden A. C. *et al.*, 'Adaptive Temperature Limits: A New Guideline in The Netherlands,' in *Energy Build* 38: 8-1, 2006.

Martens M. H. J., *Climate Risk Assessment in Museums: Degradation Risks Determined from Temperature and Relative Humidity Data*, Dissertation, Technical University Eindhoven, 2012. Available at: https://pure.tue.nl/ws/files/3542048/729797.pdf.

RCE, *Assessing Museum Collections, Collection Valuation in Six Step,* Versloot A. (ed.) Cultural Heritage Agency, Amersfoort, 2014.

Preventive Conservation in the Vatican Museums

Abstract

The Vatican Museums conservation strategy has its roots in the ancient tradition of protection exercised by the popes, as it does in the practice of heritage preservation, which anticipates the very concept of the museum itself. Today conservation requires synergy and periodical application, scientifically tested protocols, the commitment of properly trained professionals, result checking and funding certainty.

The need to conserve at best the immense heritage as well as dealing effectively with the problems of anthropic pressure has led the Vatican Museums to create an office with the specific task of drawing up preventive conservation strategies and planned maintenance plans not only intended for collections, but also for equipments and settings. The model of integrated conservation in use for some years now in the Vatican Museums supports the climatic monitoring of the exhibition, work and storage spaces, the daily routine of interventions such as dusting and periodic monitoring of the conservation state of collections, as well as the timely repair for minor damage.

Vittoria Cimino
Head of the Conservator's Office, Vatican Museums
conservatore.musei@scv.va

Marco Maggi
Assistant of the Conservator's Office, Vatican Museums
conservatore.musei@scv.va

Keywords

Conservation, prevention, programmed maintenance, monitoring, dusting, documentation, decorations' repair, marble floors' reinstatement.

In 1543 Pope Paolo III Farnese established the figure of "preventive conservation officer." With a famous *motu proprio,* he assigned the role of *Mundator* to Francesco Amadori, Michelangelo's assistant, and tasked him with the well-paid task of providing for the periodic, widespread dusting of the paintings of the Sistine Chapel.[1]

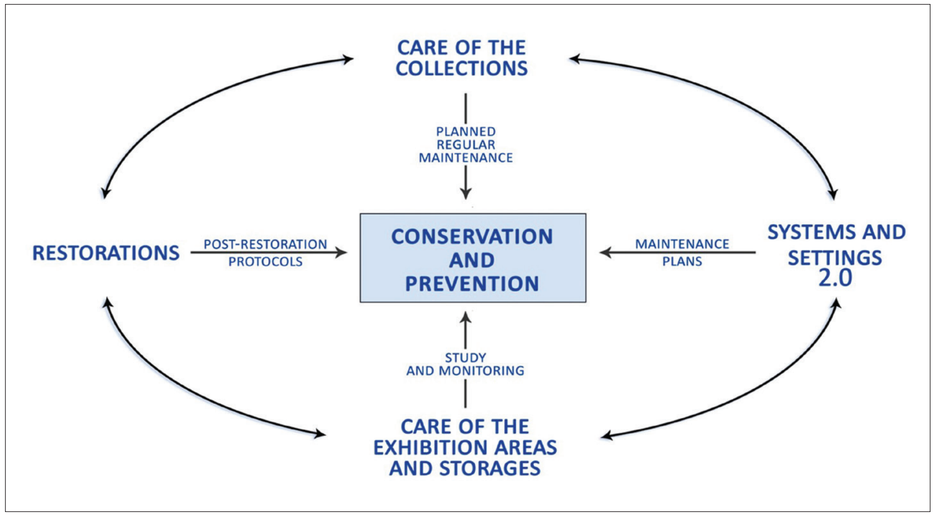
The "Last Judgement" had been finished for a little over a year but already the Pope understood the importance of prevention.

Since then, history has run its course, and the pendulum of consideration has repeatedly fluctuated between "maintenance" and "restoration" from 1970 to today, perhaps inclining more towards the latter since the results are spectacular and very effective for communication purposes.

[Urbani, 1973; Urbani, 1976; Urbani, 2000; Zanardi, 2009].

Mass tourism in the recent years and increasing cultural consumption have lead us to reevaluate old practices of care and maintenance, as

Fig. 1
The "circular path" of the global, integrated and sustainable conservation model. (© Governatorato SCV – Direzione dei Musei)



they are more sustainable and effective for the prevention of both damages and wear to cultural heritage [De Guichen, 2005].

The Preventive Conservation Office of the Vatican Museums was created in 2008, together with the new *Regolamento della Direzione dei Musei*.[2]

The preventive conservation officer, in concert with the management, the departments and the laboratories, analyses the Museum's various activities and carries out studies aimed at solving specific problems: permanent or temporary exhibition methods, display cases protection, handling and transportation of artworks on loan, conservation in storage areas, disinfestation protocols and treatments, environmental control and monitoring critical issues, preliminary studies and post-conservation protocols, visitor flows.

The Preventive Conservation Office has the task of adopting the ICOM *Code of Ethics* [ICOM, 2004], the documents and guidelines that guide the processes of adaptation and development of museums [MIBACT, 2001], developing strategies and measures aimed at lowering the risk threshold and raising the quality level of the historical-artistic and archaeological heritage entrusted to the care and protection of the Vatican Museums. Outside the Museums, the Office is called to carry out its activity in all the places of representation or worship where the Holy See, in the exercise of its functions of protection, requires it, both inside and outside the State.

Comparable in terms of size and number of visitors to the major museums in the world, the Vatican Museums are a system of museums not conceived as a container of works of art but as the result of additions and the integration of parts of the Apostolic Palace which had religious, housing and representation functions. In addition to the collections, exhibited in a multitude of courtyards, rooms, galleries and narrow passages, it is the rooms themselves, the chapels, the “secret” apartments, the galleries with famous frescoes, that are objects of interest and visit.

A continuous exhibition that unfolds over seven kilometres of precious rooms, displays thousands of works and welcomes more than six million visitors each year.

The need to preserve such an immense, but fragile, heritage, has led the Vatican Museums during the last ten years to experiment and subsequently adopt a *global, integrated and sustainable model of conservation* [Cimino, 2017], where coexists and effectively interacts all of the possible indirect protection protocols, the exhibitions’ environment care, the settings, the systems and the restoration work (fig. 1).

Exhibition and storage area care starts with an in-depth knowledge of them as well as understanding that artworks are not isolated systems but are, on the contrary, strictly related to their immediate environment’s influence.

Levels and variations must be measured over time, in order to understand or quantify the impact of natural or artificial environmental factors.

The Preventive Conservation Office carries out the thermo-hygrometric monitoring activity directly, without entrusting the service to third parties. By creating and managing a widespread detection network, the Office is able to receive and assess all the information recorded in a very short time.

The objectives are to:

– maintain existing air conditioning and treatment equipments at their best possible efficiency;
– ensure practical assistance to all the museum’s departments, by reporting “in real time” risk situations for the cultural heritage pieces or by drawing attention to specific environmental problems;
– assure the necessary maintenance operations or repairs of the equipments;
– provide advice and study material useful for drafting preventive conservation and conservation/post-restoration programmes, in new projects regarding structures, systems, and settings.

Thermo-hygrometric **monitoring**, together with the **control of light radiation and pollutants**, are performed by qualified personnel, using certified procedures and specific, periodically calibrated, equipment.[3] The environmental monitoring system consists of a network of more than 100 sensors, located in the exhibition areas (rooms and galleries), conservation laboratories, libraries, and storage areas: anywhere where there are collections made of sensitive materials or situations to be investigated.[4]

The Vatican Museums have 13 Departments, 7 Conservation Laboratories, a Scientific Research Laboratory, numerous offices, and services. The monitoring data is processed in graphical diagrams and accompanied by explanatory comments and suggestions, it is then sent each month to the department's curators and to the heads of the laboratories and offices involved.

The Museums' Directorate only receives a written report summarising the data which includes brief explanations and suggestions for improvements. This allows the directorate to have a comprehensive vision of the general situation as well as being aware of the details.

The Storage Areas

The Vatican Museums have more than forty storage rooms distributed around various buildings. Some of them are technological environments, equipped with efficient humidity concentration control and air-conditioning devices at pre-set levels. Others are served by Air Handling Units (AHU), which ensure the content values even at very short intervals, others still need specific technical adjustments. There are also those (which house archaeological antiquities) that have kept the ancient name of *Magazzini* and that technology has not breached yet. In this case, the conservative precautions are mainly aimed at not disturbing or losing their magnificent, "historical" environment with needless innovations.

Whatever the storage area, waiting for a general review that may give it more dignity, more space, and more resources, the Vatican Museums have introduced a **periodical maintenance plan for storage areas** in order to ensure that all of them are thoroughly cleaned and reorganised twice a year. That is our philosophy: the best way to preserve cultural heritage is to know it, use it and maintain it.

Periodical maintenance is preliminary and becomes the opportunity for organising special reorganising operations, always advantageous, and targeted cycles of dusting and control of the stored collections.

The aim of creating an "integrated system" capable of slowing down the deterioration processes, natural or induced, requires regular control protocols and structured environmental monitoring programmes. For that reason, besides "exceptional" cases, such as the Sistine Chapel's new air conditioning and lighting systems, a selected team of professionals is charged with dusting and checking cultural heritage, then repairing minor damages when needed.

The Directorate of the Vatican Museums' new philosophy relies on a close synergy between scientific and administrative areas, which provides for the necessary economic resources amounting to 0.3% of the

Fig. 2
The Sistine Chapel, crowded as usual. (© Governatorato SCV – Direzione dei Musei)

annual revenues.

Periodical Maintenance Plans for Collections and Precious Rooms
In 2010, in order to ensure appropriate levels of conservation, decorum and enjoyment of the exhibited collections, while containing the possible damages due to pollution and wear resulting from the Vatican Museums high number of visitors (fig. 2), the first **plan for the periodical maintenance of movable collections** was implemented.

It consists in the coordinated, planned and repeated execution of dusting, checking and documentation of the thousands of objects throughout the entire exhibition, objects from all ages, origins, and materials [Paolucci, 2009; Paolucci, 2012].

It was a small revolution that entrusted to external restorers (highly-qualified professionals), brought together under a single manager,[5] the strategic activity of care and control of the collections that the conservation laboratories, involved in many other operations and services, would not have been able to guarantee. The principle was: not to have a sporadic maintenance, but a regular, meticulous, continuous review of the totality of the Vatican museums' cultural heritage that bestows an equal dignity to a masterpiece, the nearby fragment of a sarcophagus or a secondary piece.

The aim was to be able to ensure basic attention to all the collections in their exhibition environment. As well as maintaining the methodological correctness of the operation, the excellence of the results, the traceability of the work carried out and the archiving of the information gathered over time.

The quality objectives expected by the Directorate of the Vatican Museums are achieved through the organisation of programmes that take into account the needs of the curators while relying on the conservation and scientific research laboratories' technical supervision, which is under the coordination of the Preventive Conservation Office.

The restorers work five days a week during six consecutive hours, according to an agreed protocol that includes work methods, operations, compliance with handling criteria and tools, use of personal protective equipment, equipment and machinery.

The digital archiving program of the controls' results, represents a qualification point for the entire project. It is available online by all the interested departments, including both administrative and management departments. This allows the conservation laboratories to view the emerging conservation problems and then decide whether to act immediately or subsequently as part of a global program. The Preventive Conservation Office consults the data and then sends periodic reports to the Directorate, this maintaining it constantly informed of the activities carried out.

Encouraged by the good results, in 2015, the Vatican Museums began the **integrated maintenance plan**, which is also enriched by the **maintenance of valuable decorations and floors**, that are the parts of the museum most easily subject to physical wear and to small acts of vandalism, which are a result of the strong anthropic pressure.

In this way, it is possible to ensure a coordinated intervention on the cultural heritage works and their surrounding environment, avoiding episodic or disconnected operations.

Daily Practice

The group consists of 10 professionals: 6 restorers, 2 decorators, a marble worker and a coordinator. They work from Monday to Friday, from 1 pm to 6 pm.

The **six restorers** are responsible for the periodical maintenance of cultural heritage pieces exhibited in galleries, rooms or stored in storage areas: they are charged with **dusting** and **checking the conservation**

Fig. 3
Periodic maintenance of the Chiaramonti Gallery. (© Governatorato SCV – Direzione dei Musei)

Fig. 4
Periodic maintenance of the decorations in the Round Room of the Pio-Clementino Museum. (© Governatorato SCV – Direzione dei Musei)

state of the cultural heritage pieces (fig. 3).

The necessary equipment consists of a set of soft brushes (from the "Japanese" ones made of goat hair for the most delicate surfaces, to those made of natural bristles in different shapes and sizes), antistatic and microfibre cloths, sponges of various types, vacuum cleaners with high-efficiency filters, ladders and aerial work platforms, window cleaning detergents, gloves, extension cords and lamps, cameras for documenting critical situations and filling in the conservation forms.

As an example, every month the conservators vacuum about 5.4 kg of dust, use 90 antistatic cloths and consume an unspecified quantity of different types of brushes.

When there is no possibility of working in a closed museum sector, bollards define a restricted workspace, in order to guarantee the safety of the objects and the visitors. As for the display cases, it is necessary to take a picture of them before maintenance, in order to document the exact position of the cultural heritage pieces in order to reproduce the exact position of the pieces.

In addition to removing atmospheric particulate matter and other weakly coherent deposits from the sculptures, paintings on canvas and panels, ceramics, metal artefacts, objects made of etherogeneus materials, from ethnographical collections, papal carriages and automobiles, the restorers check the conservation state of the collections and record the data in a **specifically developed database**.

The two decorators, following the technical indications provided by the Painting Conservation Laboratory and the Scientific Research Laboratory, are responsible for all the decorations "at human height" on the walls and repairing the minor damages caused by natural degradation phenomena and anthropic pressure (fig. 4).

These interventions are aimed at solving problems related to detachments, decohesion of the paint film, alterations due to salt efflorescence but mainly abrasions and scratches produced by shocks, rubbing and wear.

In the Vatican Museums, the pictorial techniques are those of fresco, lime secco and tempera. The reintegration technique is chosen on the basis of its affinity with the original materials: watercolours, lime milk, and powder pigments, industrial tempera colours.

In the case of plaster loss, the decorators use lime putty and marble dust and then finish with a well-evened layer of plaster prepared to receive the colours.

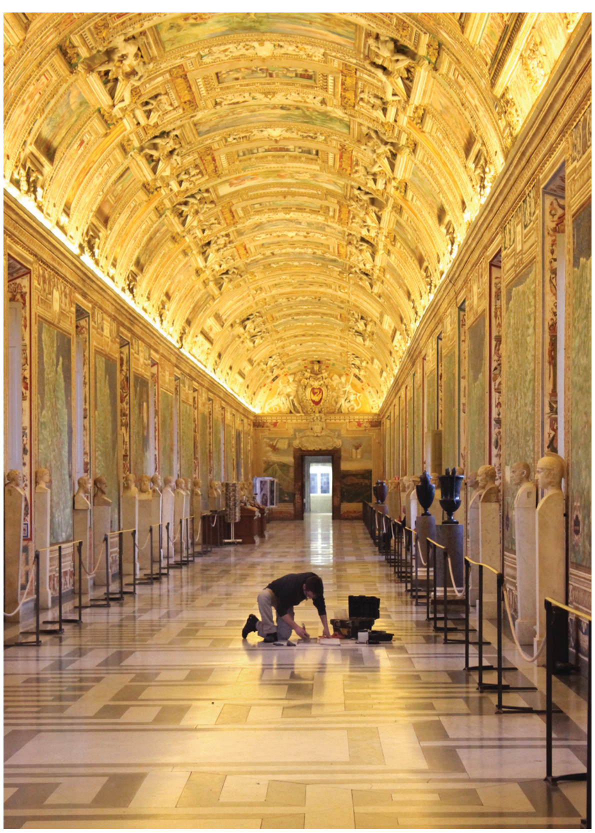
The **marble worker** is responsible for the repair of different surfaces – such as marble floors and inlays, mosaics – throughout the Vatican Museums' entire exhibition (fig. 5).

The operational programme consists of:

– urgent repairs;

– the review and documentation of the conservation state of the floorings.

Fig. 5
Marble floor repair inside the Gallery of Maps.
(© Governatorato SCV – Direzione dei Musei)



After three years, it is possible to define a typology of the most common problems:

– lack of pieces in the marble inlays;

– loss of adhesion, due to decohesion of the mortar screed or degradation of floor adhesives, both original and related to previous maintenance works;

– broken marble pieces on inadequate bedding layers;

– old and inappropriate reintegrations.

The Digital *Database*: an Essential Tool for an Effective Maintenance

The best practices for cultural heritage conservation are: environmental control, checking and documenting the conservation state of the collections and regular maintenance.

Moreover, it is essential that all these measures be complemented with a systematic recording of these activities in a digital database.

The **Museum Maintenance Programme** is actually more than a filing system: it is easy to use and manage a "genuine dialogue" with the Vatican Museums' collections.

Fig. 6
The Gallery of Tapestries, crowded as usual.
(© Governatorato SCV – Direzione dei Musei)

This constantly updated database is consultable on the Museums' intranet. It contains all the recorded maintenance activities since 2010 – 5.000 working days – and gives access to images and charts, produces statistics and develops working strategies based on requests and alerts.

An Indicative Example: Tapestry Maintenance

Conservation practices have always existed and with them, the awareness that heritage maintenance is a necessary condition for its own survival.

Today – compared to the past – a better technical and scientific training of the operators, the motivation of conservation experts together with the new possibilities offered by information technology applied to diagnostics and documentation, constitute a great opportunity to overcome the limits of an episodic and disconnected approach.

By comparing all the information gathered from the dusting activity, it is possible to define the application of intervention protocols and increasingly adequate behavioural styles.

An indicative example is given by the approach to the dusting operations carried out on the tapestries of the Upper Galleries. An intervention that is absolutely necessary because the precious manufactures are exhibited without protective barriers in the corridor that leads to the Sistine Chapel, which is usually very crowded (fig. 6).

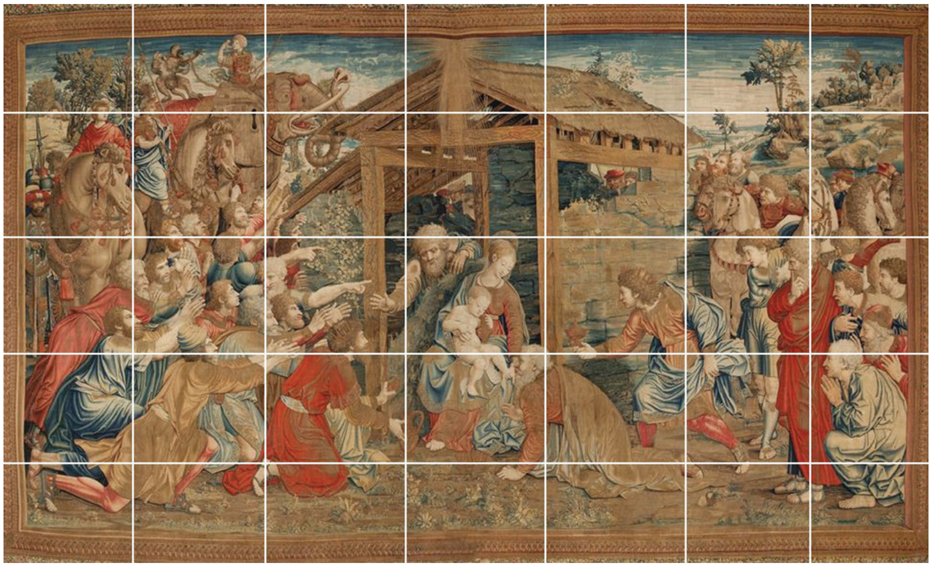
The protocol gives ample space to the inspection and recognition method for evaluating and documenting over time the quality of the particulate, the quantity that is present on the surfaces and, through microscopic analysis, for identifying in it the possible presence of original textile fibres (fig. 7).

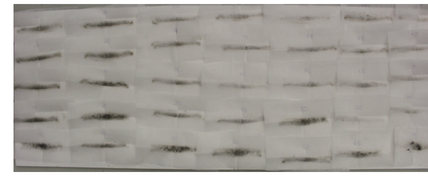
After ideally subdividing the surface of the tapestry into areas of 1 or 1.5 square meters, the intervention method requires the frontal aspiration of the artefact, indirectly, through the interposition of a filter on the nozzle of a low power vacuum cleaner, for about 10-15 minutes (fig. 8).

The analysis of the used filters, substituted and orderly collected (fig. 9-10), makes it possible to elaborate maps of particulate distribution (fig. 11), to establish correlations with previous campaigns and to advance hypotheses on the possible reasons for the accumulation of particulate matter (airflows coming from doors or windows, convective motions deriving from the air-conditioning system, visitors). In addition to this, also the verification of the inventory data and a punctual graphic and photographic documentation must be added as it preserves not only the memory of any "accidental" damage but of any other condition of interest such as incoherent or coherent deposits, undulations, and deformations,

Fig. 7
Periodic maintenance in the Gallery of Tapestries. (© Governatorato SCV – Direzione dei Musei)

Fig. 8
Intervention methodology: detail. (© Governatorato SCV – Direzione dei Musei)





Figg. 9-10
Virtual division of the tapestry surface into small areas. Detail of the filters before analysis. (© Governatorato SCV – Direzione dei Musei)

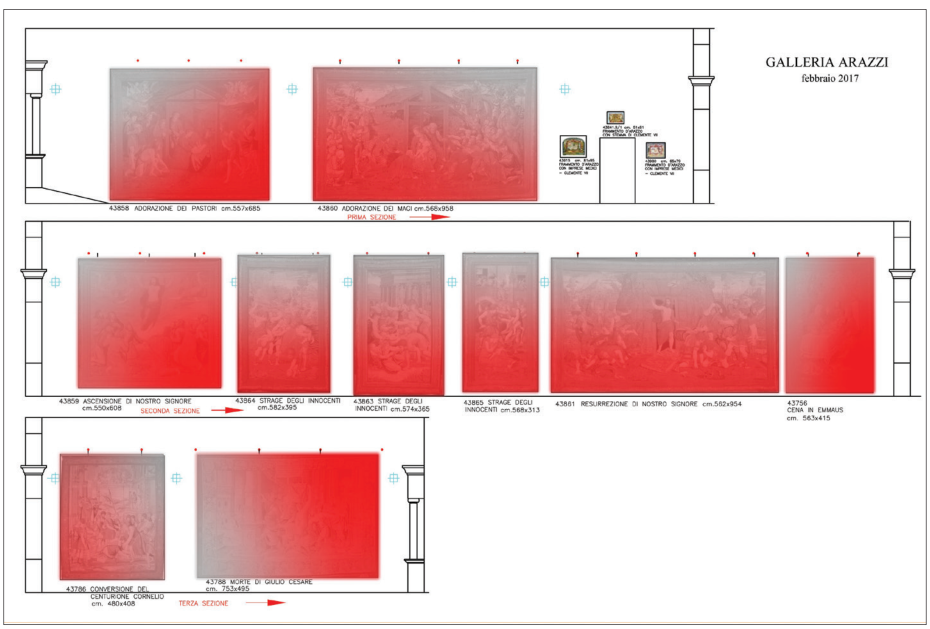


Fig. 11
General map of particulate matter distribution. (© Governatorato SCV – Direzione dei Musei)

unstitched supports, loose warps, localisation of worn out areas, lacunae, fading (fig. 12).

Thanks to the now substantial case studies, the Vatican Museums decided to carry out on the dusting of the tapestries once a year, and with the methodology above described and all the necessary precautions, considering such interval of time is sufficient for the good conservation of the artefacts and has an optimal cost-benefit ratio.

Conclusion

In 2008, the Vatican Museums established an Office for Preventive Conservation, which ensured the implementation of regular care and

Fig. 12
Conservation state documentation: detail of a weak area. (© Governatorato SCV – Direzione dei Musei)

maintenance operations dedicated to the conservation of huge heritage buildings, archaeological areas, historic interiors and movable artworks of every period, origin and material.

The new integrated and sustainable conservation model that is being successfully experimented is a multi-lane system where – alongside traditional restoration activity – the care of the exhibition areas, the prevention of risk conditions and programmed maintenance plans coexist and effectively interact. Attention and resources are directed to the constant and systematic review of the exhibited heritage pieces and to the prompt repair of the small damages caused by wear, as well as the effects of anthropic pressure. The aim is to preserve the collections while ensuring propriety and enjoyment.

Endnotes

[1] The periodic maintenance on the Sistine Chapel was flanked by that of the adjacent Pauline Chapel and Regal Room: the operations included removing any accumulations of dust and smoke from the walls, with the greatest possible care ("...*a pulveribus et aliis immunditiis prefatis mundare et a mundatis tenere omni cum diligentia*...") [*Motu proprio,* 1543].

[2] "The Conservator's Office, in agreement with the Directorate, the Departments and the Laboratories, develops and implements strategies aimed at ensuring the prevention of the risks of deterioration that may affect the works and monuments entrusted to the Directorate and the protocols necessary for the best conservation after restoration. 2) It analyses the environmental and structural factors that can generate risks for the conservation of the collections, including situations where the works are permanently or temporarily exhibited to the public, kept in storage areas or moved, indicating the necessary measures to achieve the optimal conditions for the conservation and exhibition. 3) It works with the competent Departments, encouraging technical support and specific indications in the choice of materials, exhibition structures, equipment, and systems in relation to the conservation of the collections and the monuments. 4) A conservator with a degree in scientific disciplines is assigned to the Office" [*Regolamento,* 2009].
The Conservator's Office of the Vatican Museums is actually the equivalent of the Preventive Conservation Departments established in other European museums.

[3] The Conservator's Office is entrusted to Vittoria Cimino, head and coordinator, assisted by Marco Maggi, first assistant, and Alessandro Barbaresi. The team has recently been reinforced with the help of an architect, Matteo Mucciante.

[4] This last mode allows to detect and communicate in real time any deviations of behaviour that are noteworthy, in order to carry out the necessary maintenance operations.
All the data are kept in the Office's database and processed into charts that allow the study of individual situations and their evolution over time.

[5] Since 2010 CROMA, a company composed of qualified conservators has always been awarded the tenders for the assignment of the service. cromasrl.2017@gmail.com.

Bibliography

Cimino V. (preface by Jatta B.), *The Conservation of the Vatican Museums. A Ten-year Project Completed*, Edizioni Musei Vaticani-Allemandi, Vatican City State-Turin, 2017.

De Guichen G., 'Conservazione preventiva: una nuova mentalità,' in *Gestione e cura delle collezioni*, Florence, 2005.

ICOM – International Council of Museums, *Code of Ethics for Museums*, revised by the 21st General Assembly of ICOM meeting in Seoul (Republic of Korea) on 8 October 2004.

MIBACT – Ministero per i Beni e le Attività Culturali, *Guidelines to the Scientific-Technical Criteria and Operational Standards of Museums*, Ministerial Decree, 10 May 2001.

Motu proprio 'Ad pulcherrimas picturas,' by Paolo III Farnese, 26 October 1543, Archivio Storico Vaticano (ASV): Arm. XXIX, t. 106, ff.175vv-176r.

Paolucci A., 'Diamoci una spolverata. Il direttore Paolucci spiega l'innovativo progetto di pulitura di 5mila sculture dei Musei Vaticani. Diventerà permanente: un esempio per i musei italiani,' in *Il Giornale dell'Arte* 290, 2009.

Paolucci A., 'Per restare esemplari. Programmi di conservazione preventiva e manutenzione dei Musei Vaticani,' in *L'Osservatore Romano*, 15 March 2012.

Regolamento della Direzione dei Musei, Vatican City, 24 September 2009.

Urbani G., *Problemi di Conservazione*, Bologna, 1973.

Urbani G. (ed.), *Piano pilota per la conservazione programmata dei beni culturali in Umbria, progetto esecutivo*, Ministero per i Beni e le Attività Culturali – Istituto Centrale del Restauro, Rome, 1976.

Urbani G. (edited by Zanardi B.), *Intorno al restauro*, Milan, 2000.

Zanardi B., *Il restauro, Giovanni Urbani e Cesare Brandi, due teorie a confronto*, Milan, 2009.

Maintenance of the Palace of Versailles' Collections: Present and Future Textile Collections, a Particular Example

Abstract

The National Museum of the Palace of Versailles and Trianon has entrusted for fifteen years a weekly dusting mission of its heritage textiles to a team of eight external contractors, all graduates of a master's degree in conservation. Seats and bed upholstery, tapestries, carpets are thus regularly treated. Besides the dusting, there is also a monitoring of the textiles that can take place thanks to this expert and frequent eye. In addition to the dusting of the work, each member of the team, having the competence and the necessary experience, is able to draft condition reports of the textiles, to establish a diagnosis, to inform the curators in charge of the collection of works that need a curative conservation treatment or restoration by drafting recommendations.

An organisation and a specific methodology have been put in place over the years in close consultation with the Conservation Department and in connection with the Palace Administration.

The use of silk crepeline or of nylon tulle on the seat upholstery to protect it from dust is just one of the examples of the various actions taken at the Palace.

Élisabeth Caude
General Curator of Cultural Heritage, General Manager of the Collections Mobilier et Objets d'art, Palace of Versailles
elisabeth.caude@chateauversailles.fr

Thalia Bajon-Bouzid
Conservator, Conservation-Restoration of Old and Modern textiles, Vrinat-Aguirre-Argenton-BajonBouzid-Dejean-Forestier-Mansouri-Strouk Consortium, Conservation ETC
thbajonbouzid@gmail.com

Keywords

Qualified restorers, textile, maintenance, protection, crepeline, tulle, staff awareness, micro-aspiration, preventive conservation, dust.

The fight against the dust in spaces, decors and works is a considerable issue to which the Conservation Department of the Palace of Versailles is confronted to in a more and more acute way: the difficulty is due to the surface of the spaces that need to be maintained, from the quantity to the fragility of the works, to their presentation which the most often is without display cases and sometimes still under plastic covers, the massive attendance of the site, especially on the route of the grand tour, the generalisation of big construction campaigns in the Palace in the context of the master plan and an increasing drier climate that favours the diffusion of the dust from the park.

The objectives are twofold: to ensure the preservation of the objects that the dust by clogging all the surfaces, damages on the long term because of its chemical agents, and to assure the visitor a presentation pleasing to the eye which testifies to a quality daily maintenance. But these two objectives are in themselves contradictory: the more frequent the micro-aspiration as to meet these two goals, the more one weakens the object by a too regular friction, even with a professional and controlled gesture.

The management of such a site thus implies to reconcile an extreme frequentation with patrimonial concerns, but this approach of taking into account the environment is, it must be confessed, relatively recent. Many actions have already been taken to manage, for example, the light so as to reconcile reception and circulation of the public, while reducing the light thus preserving fragile fabrics by maintaining a correct level of lighting. In order to proscribe natural light, solutions have been proposed such as the installation of blinds to filter it or even plain silk curtains which must be kept closed. As for the anti-UV filters on the outer window panes, they must be changed regularly.

The too frequent opening of the windows, during the summer period to avoid the discomforts due to the extreme attendance levels results in the important entry of dust (white sand surrounding the Palace), insects and even birds. The building works part of the Master Plan, whose first instalment on the south apartment have precisely for objective to mitigate these risks. However, it must be acknowledged that the various building works carried out in many parts of the Palace, as well as the maintenance of the buildings (electrical installations, heating) and the grounds are another important source of dust for the collections.

A Policy of an Organised Micro-Aspiration

Conscious of this double issue, the Palace quickly realised that the internal staff could not answer these objectives and that it had to entrust this maintenance and monitoring activities to textile restorers whose job would be the micro-aspiration mission. Even the tapestry workshop, absorbed by the upholstery and tapestry tasks, could not assume this role. The maintenance of heritage textiles at the Palace of Versailles began in 2000, at the initiative of Pierre Arizzoli-Clémentel, then director of the museum (1996-2009), to ensure the monitoring and maintenance of collections and to remove progressively the plastic covers that covered the textiles of the pieces of furniture. He wanted to entrust the dusting of the upholstered furniture to specialists able to adopt conservation gestures in regard to old or rewoven fabrics, thus relying on his many years of experience at the Museum of Fabrics of Lyon.

From the beginning, the principle is defined by entrusting the task to a restorer graduated from the Institut Français de Restauration des Œuvres d'Art, the current Institut National du Patrimoine, Department of Restorers, who is assisted by a trained upholsterer. Both intervene every Monday, the closing day at the Palace. Only the collections exhibited on the visitors' circuit are concerned, and only the works from the collections. Some spaces accessible to guided tours can be dusted after checking their use another weekday.

Evolution of the Intervention Framework Since 2000

Practised by a single restorer in 2000, the function is reinforced in 2002 by a second restorer, assisted by a colleague both of them graduated from the IFROA. They keep a weekly rhythm.

From 2006-2007, with the implementation of the new public procurement code, this work is subject to framework agreements whereas previously the interventions were done on an estimate.

An extended team of six qualified restorers wins the contract and forms a Consortium with an authorised representative. In 2009, when the first contract was renewed, the number of restorers was identical and became the Vrinat Consortium. In 2012, a seventh restorer joined the Consortium. The renewal of the contract in 2017 was composed of eight qualified restorers including an authorised representative, which is a privileged spokesperson for the public entity, responsible for technical and administrative relations with the Palace of Versailles. Its main intermediaries are the Fine Art Furniture conservators, notably the general manager and the agents of the Public Contracts Department and the agents of the Reception and Surveillance Department. She acts as a coordinator for the team and organises the implementation of the services. The team guarantees the presence of one to four restorers each Monday depending on the planned operations, except for public holiday Mondays.

The contributors' diploma is a strong requirement be it from the Institut National du Patrimoine and its Department of Restorers (formerly IFROA) or that of the Master of Conservation and Restoration of Cultural Heritage at the Paris I Panthéon-Sorbonne University.

The administrative form of the services has therefore evolved over time: from annual intervention quotes (2000-2006) to a fixed-price contract (May 2007-May 2009, August 2009-August 2012, and August 2012-August 2016, 2nd and 3rd contract, Vrinat Consortium). From March 2017, the fourth contract combines two formulas, a flat fee and an order form, in order to gain flexibility and meet the increased requirements of spaces to intervene.

Contracts have also evolved with the evolution of museography and the considerable increase in attendance. Micro-aspiration is not the only intervention. The task is also accompanied by monitoring and an alert role on the state of the textile collections, more generally an exchange mission in terms of preventive conservation. These aspects are materialised through contacts with the Conservation Department, a dialogue and the delivery of documents, appraisals and reports.

The geographical perimeter also varied for twenty years in accordance with, it must be admitted, the financial means allocated to contracts. From 2000 to 2006, the places concerned are the State and Private Apartments of the King and Queen, the Apartments of the Dauphin and the Dauphine, the Apartments of Mesdames, the Apartments of Mme de Pompadour, the Apartments of Napoleon at the Grand Trianon and the Apartments of Marie-Antoinette at the Petit Trianon.

During the following period, it was requested to monitor by level: on the ground floor, the Apartments of Mesdames, of the Dauphin, of the Dauphine, of the Queen and the Halls of the First Empire; on the first floor, the King and Queen's State Apartments, the King's Inner Apartment, the King and Queen's Inner Cabinets as well as the Battles Gallery on the second floor, the Queen's Private Cabinets and the Attics. The Crusades rooms are also included in this requested perimeter, seventeenth-century rooms as well as the Apartments of Madame de Pompadour, Madame Du Barry and Maurepas along with the Grand and Petit Trianon. Some latitude is left depending on the urgencies.

From 2009 to 2012, the perimeter is identical but increases with the works entered in the collections and the refurbishment of the Petit Trianon. The next round, for budgetary reasons, limits the perimeter to the spaces of the King's and Queens's Inner and Grand Apartments. The 2017 contract chooses to widen the perimeter and proposes a rotation on all the spaces open to visits – big circuits and conference visits –, to the Palace as well as the Trianons. The mandatory number of passes is predefined per space. But the finding of dust causes to decide additional passages.

In terms of intervention days, the work in 2003 required 48 days, in 2007-2009 it goes up to 102 days and drops down to 90 days during the following 2009-2012 period. The 2017 contract has 81 days on the flat-fee portion plus all the punctual interventions on order forms.

Characteristics of the Current Contract

In 2017 a new contract was awarded and the Vrinat Consortium with an additional restorer has, once again, won the tender, thus making it possible, thanks to its presence over several years, to have a vision of a long-term evolution. The aim of the 2017 contract is to take advantage of the previous appraisals and to include all the visitable areas according to a predefined rotation which enters into the flat-fee portion. This work plan makes it possible to ensure passages per year, ranging from 53 for some spaces of the State apartment to two or three for apartments accessible for guided tours. The Grand and the Petit Trianon are included in this process. In addition to this flat-fee portion, a part of the contract is placed under the purchase order regime to adapt to the needs. This modulation allows dealing with emergencies and excessive dust. Regular meetings between the Conservation Department and the Consortium help refine a strategy that benefits from the long-term experience and annual reports. These appraisals are now annual and no longer on contract and several documents accompany them – observation reports on the state of the collections and recommendations for preventive conservation: transmission of reports of textile tears, the beginning of an infestation or the renewal of poses of protective silk or tulle.

For the first time, the contract is tackling heavy micro-aspiration projects, including beds, imperials, bed curtains and draperies, on the basis

Figg. 1 to 3
Examples of furniture/textile elements present in the Palace's collections (© Vrinat Consortium).

of an annual intervention, which requires a complex implementation, due to constraints related to work at height. The restorers have their own scaffolding which they assemble and dismantle. Restitution textiles are also concerned. In addition, the training of assembly and scaffolding work followed by the conservators' Consortium, now allows them to dust the upper parts of the beds, the tapestries, the curtains and the wall hangings (fig. 9). Finally, due to the lack of other possible contributors, the velvet Louis-Philippe banquettes used by visitors are currently integrated.

Fig. 4
Detail of the Queen's imperial chamber while being dusted (© Vrinat Consortium).

Fig. 5
Tests for the protection of fragile fabrics with a crepeline or a tulle cover (© Vrinat Consortium).

Missions: Dusting, Textile Monitoring and Follow Up and Preventive Conservation

The team of restorers' mission for this contract of maintenance of the textile collections includes all of the Palace's rooms where the textiles are preserved. To which the Trianon-sous-Bois wing has been added. The corpus of textile elements to take into consideration is made up of bed quilts and bed curtains, fire screens and screens, armchair upholstery, chairs, sofas, folding seats as well as Savonnerie carpets and tapestries (figg. 1 to 3). These may be original fabrics but most textiles upholstering original furniture are antique reweaves or modern museum reconstitutions**.** The analysis of their aesthetic, heritage and financial value leads us to take them into account as if they were antic historical textiles.

A routine dusting of all the fabrics without prior observation of the conservation and dust state may cause damage. It seemed imperative to adapt not only the frequency of the passages but also the dusting equipment, depending on the different furniture textiles and their state of conservation: fashioned silks, velvets, wool carpets, tapestries… in volume, suspended, flat… (fig. 4). For this purpose, professional vacuum cleaners equipped with power VSD and HEPA filters (absolute filtration), as well as accessories adapted to each type of object, according to their state of degradation and their possible restorations are used. The nature of the dust, fine particles in suspension or long fibres conveyed by visitors, is also taken into account in the choice of dust collection equipment.

Since 2000, it has been possible to establish an ideal passage rhythm thanks to the team's experience, – if some spaces become quickly dusty, others are much less so. This variation depends on the attendance of public places, scheduled events in three different locations (exhibitions, building work, film shoots…). Dust also depends on airflows and more or less well respected preventive conservation measures (door and/or window closing, wearing overshoes when passing on carpets, keeping the public at bay, use

	Tulle de nylon	Crêpeline de soie
Protection contre la poussière	-	+
Protection contre les frottements	-	+
Discrétion	+	-
Résistance du materiau	+	-
Facilité d'époussetage	+	-

Fig. 6
Summary table of performed tests (© Vrinat Consortium).

Fig. 7
Footprints on the Mercure Salon platform (© Vrinat Consortium).

of the floor polisher…) (fig. 7). The delicateness of the textiles also determines the frequency of the passages. As an example, the most dusted areas are (unsurprisingly) the Hall of Mirrors, the Grand Couvert, the King's State Apartment… Conversely, other spaces are only covered by an annual passage like the Midi and North Attics which are little open to the public so less dusty, the same applies to interventions requiring scaffolding such as the imperial ones, the top of the bed curtains and tapestries.

The expertise and regular Consortium work with the exhibited textile collections made it possible to develop a council mission in preventive conservation. That is how any observations of deteriorations to a textile or poor storage conditions are gradually reported directly to the Conservation Department. Some installation advice may help to reduce the factors that favour the dust on works. Just by raising the tapestries to protect the bottom edges and protecting the edges of all the carpets with wooden structures, which are a kind of stand or an inclined plane that allows to raise the edge on the public side, thus limiting dust deposits during the passage of the broom, wax deposits and dissuading visitors or guides to set foot there is enough.

Another preventive action to limit the aggression of dust on very valuable textiles which are historical of great value or already badly damaged is the implementation of silk crepelines[1] on seat upholstery to protect them from the dust thus replacing the plastic films that were used until then at the Palace. The contract established in 2010 and once again awarded in June 2014 for a planned period until 2018 provides a framework for these

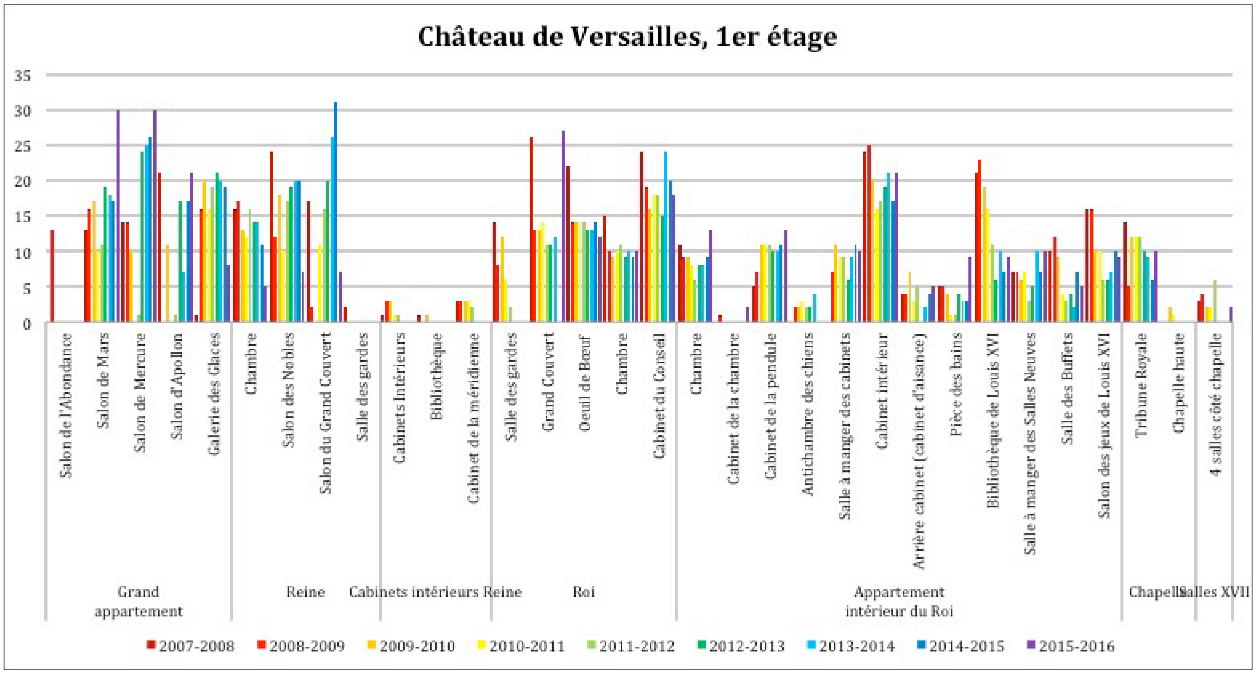


Fig. 8
Diagram showing the number of passages per space (© Vrinat Consortium).

interventions. The durability of the mission makes it possible to judge over several years the relevance of this treatment in the medium and the long term. Three months of tests were carried out in 2013 by placing a tulle[2] and a crepeline on folding seats in the Apollo salon, along the visitors' circuit (fig. 5). In conclusion, it has been determined that silk crepeline protects the textile from an important amount of dust, even if it covers it up more. It seems more appropriate for furniture dusted episodically. The tulle, on the other hand, lets in more dust, but is more discreet, especially for horizontal surfaces, and makes dusting easier. It is, therefore, more suitable in the case of furniture dusted regularly (fig. 6).

To combat insect and mite infestations, extensive dusting is recommended two or three times a year as is the monitoring of suspected pieces. Traps are laid against rodents. Advice is also given concerning the handling and movement of works because deteriorations are regularly found on the Palaces' textile works: snags, worn or torn tapestries and trimmings, footprints or stains on the carpets or on the upholstery. It sometimes happens that the conservators' Consortium is requested for dust removal before the closure or the reopening of certain spaces, particularly in connection with the works of the Master Plan.

It is desirable to train personnel in the handling of textiles, particularly large formats, with the systems facilitating the removal and hanging, among others, of tapestries and their packaging flat or rolled without forming folds or tensions... The staff must be aware of the heritage value of the textiles.

Since the creation of the first Consortium in 2007, the objective has been to establish a fluid communication with the Conservation Department and to promote a certain pragmatic efficiency. In previous contracts, plans were left for the different annotated spaces. These notes (conservation state of the textiles, dust state of a space...) were used to establish diagrams representing dusting frequencies of the different spaces during the years, the periods covering a contract... These graphs then helped to make the needs of the Palace more tangible and to draw up the specifications for the current contract (fig. 8). At the end of each contract and now at the end of the year, a report is given to the Conservation Department using the photographies of the objects for which the team has reported a conservation problem. For these textiles, a quick condition report is established, accompanied by recommendations for the improvement of their conservation conditions or restoration suggestions. These documents are used in the preparation of conservation management tools and budget requests. The most often they result in a restoration (Vrinat *et al.*, 2015, p. 99).

Fig. 9
The dusting of beds and imperials with scaffolding (© Vrinat Consortium).

Although it is not the only example in the Palace of collections affected by micro-aspiration campaigns – similar steps are being taken with regard to collections of sculptures or paintings – it is one of the most delicate to put into practice for many reasons. First of all, the specificity of the textile collections requires the expertise, the gesture and the eye of authorised restorers of the textile collections. Secondly, the increasing use of the Palace on Monday for new activities, be they patronage operations, school group visits that started two years ago, film shoots or, even more importantly, political or diplomatic events whose consequent drastic security measures exclude any cohabitation in terms of intervention and imposes on the conservators' consortium a great adaptability. It must also be careful to respect the balance between the work plan defined by the rotation and the additional passages started with purchase orders. All these aspects require a close dialogue with the Conservation Department on the occasion of the regular agenda. And these actions essential for the safeguard of the collections and the quality of their presentation result in a strong financial commitment from the Institution.

Since 2017 vigil rounds have been instituted, they are shared by the art technicians in the Palace's museum workshops and are made in the presence of the Curator general manager of the collections of Furniture and Art Objects. They are organised topographically and their appraisal makes it possible to identify the interventions that need planning in each workshop (cabinet making, gilding, tapestry) and their degree of emergency (small interventions to plan, urgent interventions or restorations).

Each round gives rise to topographic and summary documents (a form par room that records the observations made by each of the workshops and a summary of the actions by workshop and by priority). These documents are used partly to fuel the workshops' programming.

The commitment of the Conservation Department in the EPICO program will allow developing tangible actions, especially during the implementation phase of the program (EPICO II). The conservation assessments carried out with the EPICO method will make it possible to compare the importance of each damage cause – here dustiness – and to concentrate the resources on the priority factors within the framework of the general preventive conservation plan and in support of the scientific and cultural programming of the museum.

Paths of reflection must be opened to make more efficient the micro-aspiration site for textile restorers. The definition of intervention protocols for the companies in charge of the household of free circulation spaces is necessary. The call for volunteers and the gesture training of a few motivated Palace agents should be explored, together with a review of the material available to them.

It would be convenient for the Conservation Department to have a preventive conservation technician who could handle certain types of collections and in the case of textile collections, velvet benches and restored textiles of different heritage value.

In addition, the use of maintenance contracts by type of collections, entrusted to restorers specialised each in their field, must be generalised. In general, an increased awareness among reception and surveillance agents and firefighters of the criteria for conservation and manipulation of architectural elements (door, hardware, etc.) through training provided by the Conservation Department would allow putting the heritage preservation of the collections and their environment at the heart of everyone's concerns.

But it is also in the direction of the public that it is necessary to turn to, by encouraging it through educational actions to take measure of its responsibility regarding the collections it comes to admire: admittedly the public shows an interest in communications and reports devoted to the restoration of works and the construction works done in the museums' backstage, but it must realise that it too is a conservation actor for future generations.

Endnotes

[1] A sort of transparent silk veil.
[2] Nylon tulle.

Bibliography

Vrinat A. *et al.*, 'Conservation-Restauration de la parure brodée du lit dit 'de Louis XIV,' in P.-X. Hans, *Le salon de Mercure, chambre de parade du Roi*, Cesson-Sévigné, Artlys, 2015, pp. 99-103.

Preservation Policies for Historic House Museums Based on Prevention: the Brazilian Context

Claudia S. Rodrigues de Carvalho
Architect, DSc.,
Fundação Casa de Rui Barbosa, Brazil
crcarvalho@rb.gov.br
www.casaruibarbosa.gov.br/conservacaopreventiva

Abstract

The establishment of publicly accessible Historic House Museums requires preservation actions that do not only contemplate the building and its contents, but the relationship between them, thus ensuring that the maximum amount of information from the past will be passed onto the future generations. Once an historic house becomes a museum, the maintenance of its aspect notwithstanding, its function changes and its use is transformed. These changes pose a great challenge for the management of its daily life in what concerns the balance between preservation and access. Founded in 1930, the Casa de Rui Barbosa Museum is considered to be the first historic house museum in Brazil established and managed by the public sector. The joint preservation of the historic structure and its collections has been guided by a preventive conservation plan for more than a decade. This process includes inspection, diagnosis, monitoring and reviewing of preservation actions, in which the building, collection, gardens and systems are integrally linked. In this sense, formulating preservation policies must consider prioritise the mitigation of deterioration and damages to the building and the collection, at the same time ensure the enjoyment of the visiting public. With more than 300 historic house museums, Brazil is yet to turn the preventive approach to conservation into reality. This work explores the limits and possibilities of implementing a preventive conservation policy for Brazilian historic house museums based on accumulated experience by Preventive Conservation Plan of Casa de Rui Barbosa Museum in identifying risks that threaten the joint preservation of buildings and artefacts and in developing strategies for mitigating those risks.

Keywords

Casa de Rui Barbosa Museum, preservation policies, risk management, joint preservation.

Casa de Rui Barbosa Museum, in Rio de Janeiro, is considered the first historic house museum in Brazil, as it was opened to the public on August, 1st, 1930.

Built in 1850, the house is a national monument, and its last owner was Rui Barbosa, a prominent lawyer, writer and statesman in the late 19th century and beginning of the 20th century. Born in Salvador, on November 5th, 1849, Rui Barbosa travelled a lot in his early years, and lived in Buenos Aires, Paris and London. Owner of a remarkable intellectual ability, he graduated in Law in 1870. Rui Barbosa went into advocacy, journalism and politics, and was considered a man ahead of his time, which fell short of his civic virtues and talent. A freedom activist, he defended equality, ethics and culture.

He was the main author of the first Brazilian Republican Constitution. He ran for presidency twice, but did not succeed. The first of his campaigns for Presidency was called "Civilist," that being the first time there had been popular support for democracy in Brazil. After that, and until today, he is regarded as a popular hero. Rui Barbosa also took part of the Second Conference on Peace in Hague, in 1907, representing Brazil as Ambassador Extraordinary, when he stood up for the sovereignty of all States within the international judicial order. By that time, his abilities as a public man were internationally acknowledged, and in 1918 he was granted the Grand Officer badge of the National Order of the Legion of Honour from the French Minister Paul Claudel [Lacombe, 1984].

His personal life was marked by the great love that perpetuated his union with Maria Augusta Viana Bandeira, with whom he had five children and a perfect family life. As a hobby, he enjoyed looking after his garden, planning and decorating the house. During his lifetime, he gathered an assorted collection including paintings, sculptures, wooden furniture, personal belongings and a library collection with thirty-seven thousand books.

After his death, the Brazilian government purchased the house, along with his library collection, granting public access to the ensemble. Casa de Rui Barbosa Museum now receives approximately ten thousand visitors annually and is part of a cultural research institution, with a varied collection including book collection, archival collection, museum, historic building and garden, of the Brazilian Ministry of Culture: Casa de Rui Barbosa Foundation.[1] Since 1998, a Preventive Conservation Plan guides the joint preservation of the historic building, gardens and its collection.

The aim of this article is to bring a small report on the Preventive Conservation Plan, its implemented strategies and their results, and the planning steps towards the development of a preventive conservation policy for historic house museums in the Brazilian conservation field.

The Site

The house is located in South-Eastern Brazil, in the city of Rio de Janeiro, currently the second largest city in Brazil, in the neighbourhood of Botafogo. Rio de Janeiro has an impressive natural beauty with quite a diverse topography, consisting of high escarps, hills and valleys, various rock formations, which follows the Guanabara Bay, including natural lagoons and a wide urban forest.

Fig. 1
Casa de Rui Barbosa Museum – main facade. (© Fundação Casa de Rui Barbosa / Claudia Carvalho)

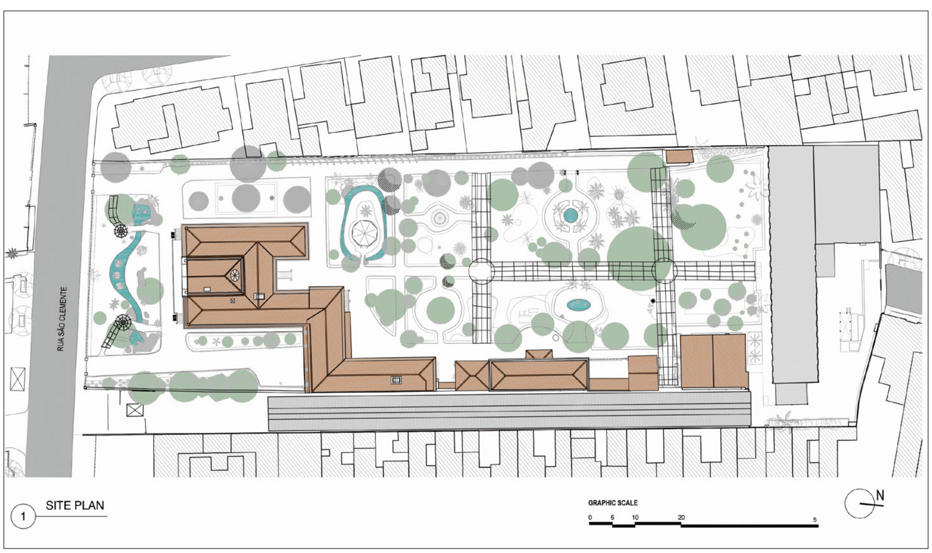


Fig. 2
Casa de Rui Barbosa Museum – site plan. (© Fundação Casa de Rui Barbosa / Núcleo de Preservação Arquitetônica)

The annual mean temperature of Rio de Janeiro is 25°C, and the annual mean relative humidity is over 70%:

"The overall climate of Rio de Janeiro is classified as Tropical Savanna (Aw) by the Köppen-Geiger climate classification system [...]. Seasonal climate is distinguished by temperature and rainfall: the period from November through April constitutes the very hot-humid season, while May through October is the hot-humid season" [Maekawa *et. al.*, 2015, p. 314].

In the 19th century, the city went through a quite large urban operation. Then, the urbanised area started its expansion towards the north and the south, and in the early decades of the 20th century, the urban growth passed through the Botafogo Valley, which was linked to the Rodrigo de Freitas Lagoon. At the beginning of the 19th century, wealthy families, the aristocracy and rich merchants began to move to Botafogo neighborhood, where the house is located, in São Clemente street.

Botafogo developed along São Clemente street, which was established as one of the city's most important thoroughfares. As the city changed, Botafogo became a densely populated residential zone, and Rui Barbosa's property, situated only 600 meters from the Guanabara Bay shoreline, give us testimony of the time when it has been built, portraying the early years of the south zone urban occupation. In the 1970s, with the urban growth boom, the Museum's surroundings were heavily altered, accelerating deterioration processes caused mainly by air pollution, vibration, thermal radiation, and poor soil surface drainage.

The Building

Bernardo Casemiro de Freitas, a Portuguese trader, set up the museum original building in 1850. In 1893, Rui Barbosa purchased the house where he lived with his family from 1895 to 1923. The house is a typical example of the architectural transformations introduced by the arrival of the Artistic French Mission brought to Brazil by the Portuguese King Dom João, the VIth, in 1816. It expresses the continuity of the Luso-Brasilians constructive standards of the colonial period and the introduction of neoclassical repertoire, such as pediment, architraves, Roman arch and sculptures. Its fabric presents traditional solutions, such as external self-supporting walls made of massive bricks, stones and mortar, internal partitioning panels in lath and plaster, a wooden structure and roof in French tiles (fig. 1).

The volume is composed of two conjugate bodies, one U-shaped and the other L-shaped, aligned with the left side of the terrain. The U-shaped body has a high basement, which separates the occupied spaces from soil moisture. It has almost 2.000 square meters, and a 6.000 square meters garden surrounds it (fig. 2).

The garden is currently one of the few green areas in Botafogo. Inspired by the French landscape designer Auguste Glaziou's romantic gardens, it is historically and artistically relevant as a domestic garden with such a treatment. The front garden is more elaborate, providing nobility and honour to the house. The backyard, which provides a domestic atmosphere, presents a metal and wood structure that supports grapevines, and has many fruit trees and several species of flowers, especially roses, Rui Barbosa's favourite.

Besides the preservation of Rui Barbosa's memory, the historic

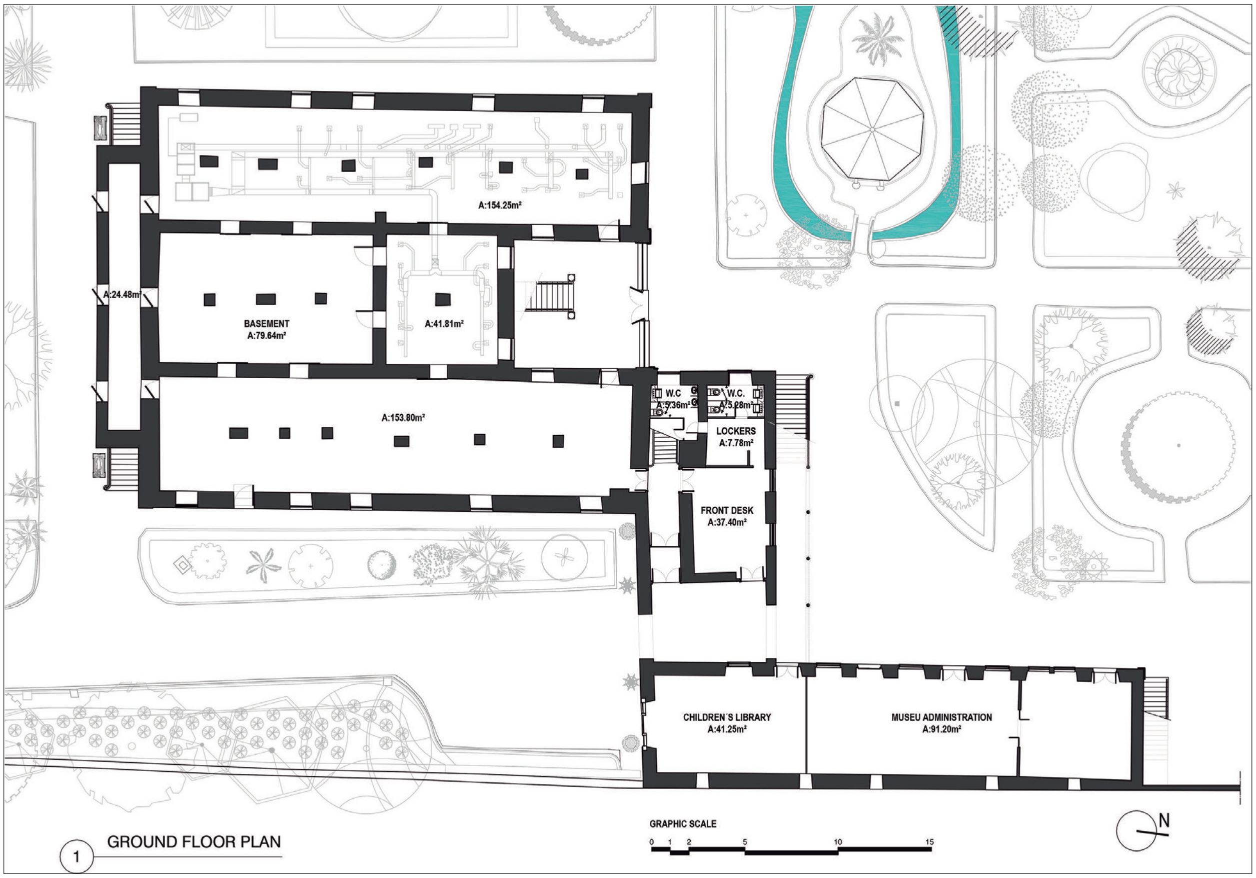


Fig. 3
Casa de Rui Barbosa Museum – Ground Floor Plan. (© Fundação Casa de Rui Barbosa / Núcleo de Preservação Arquitetônica)

house museum reflects the lifestyle of the urban upper classes in the 19th century. The interior follows the traditional layout of the period, in which the social area is located at the front of the house, and the private spaces are located at the back (figg. 3, 4).

The decoration presents stucco linings, wallpapers, hydraulic tiles and cast iron elements. The house's noblest chambers are in the upper levels. It is worth mentioning the service wing – with kitchen, restrooms and the servants' rooms. The highlight, the "Coeur" of the museum is the Library, which remains in their original location (fig. 5).

Preventive Conservation Plan

After its opening as a public space, the house undergone two major interventions, the first one was in the 1970s, and the second in the later 1980s. From the end of the 1990s, the preservation actions seek to integrate the historic building and the collections, considering prevention as a way to minimise deterioration processes, avoiding invasive interventions and ensuring their transmission to future generations in a sustainable way. The Preventive Conservation Plan has consolidated that. This plan seeks to identify the causes of deterioration through

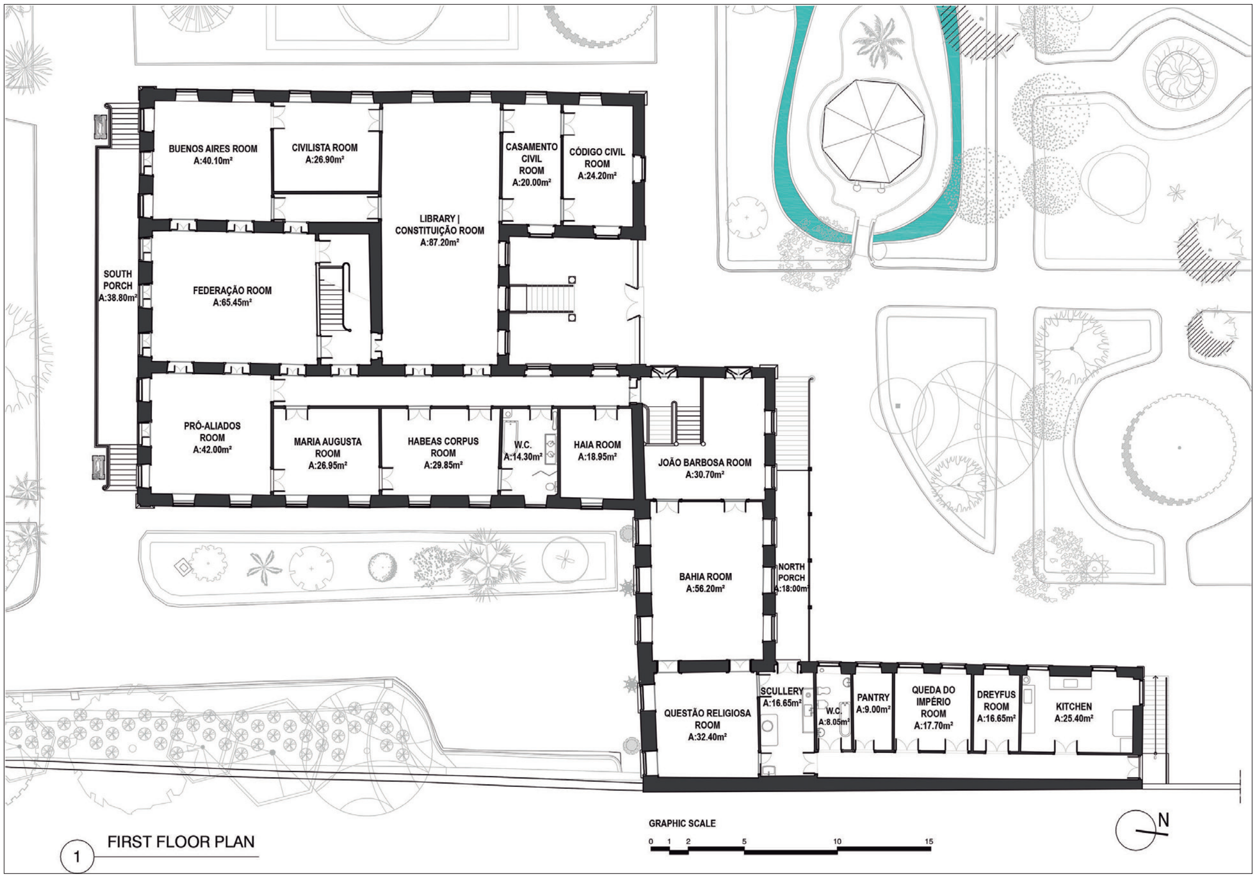


Fig. 4
Casa de Rui Barbosa Museum – first floor plan. (© Fundação Casa de Rui Barbosa / Núcleo de Preservação Arquitetônica)

Fig. 5
Rui Barbosa's library. (© Fundação Casa de Rui Barbosa / Claudia Carvalho)

Fig. 6
System installation on the basement. (© Fundação Casa de Rui Barbosa / Claudia Carvalho)

Fig. 7
Supply air diffusers. (© Fundação Casa de Rui Barbosa / Claudia Carvalho)

monitoring, inspection and survey, as well as to establish mitigation strategies, thus avoiding emergency actions. The first actions targeted the reduction of humidity through the roofs, and the control of biodeterioration through a combat plan addressing termite's infestation. Later, there had been renovations to the garden's drainage system, and restoration of the external windows.

The museum interior environment is moderated by the building's large thermal mass, natural ventilation and natural lighting. The book collection experienced large temperature and humidity fluctuations, biodeterioration and air pollution damages. The major concern of the Plan was to keep the Library in a good conservation environment, without neglect the preservation requirements for the historic building and the human comfort needs for the visitors. An environmental control strategy was considered fundamental for the preservation of the building and the collections [Cassar, 1995].

As a first step, we went through a comprehensive monitoring of environment and condition assessments in order to document conditions of the building envelope, historic interior and collection assessment. The perspective adopted reflects the complex relations between the collections sensitivity, the buildings performance and the effects of several factors on the collection, such as the building itself, the environment, its use, the practices and policies related to management, operation and visitation [Dardes *et al.*, 1998].

The results of this assessment showed that the water was the most important agent of deterioration we need to face, because of the humid tropical climate conditions. Thus, the main goals of the Preventive Conservation Plan was to avoid humidity from soil and from covers, control the climate, define a conservation strategy for architectural surfaces, and develop a continuous process to document the interventions and monitoring their performance. Since 2005, the Preventive Conservation Plan has research-based strategies.[2]

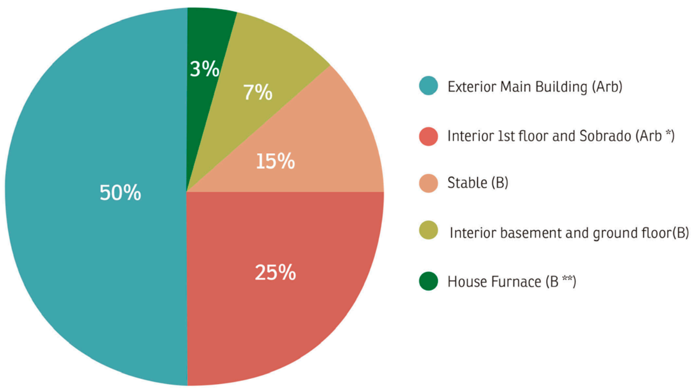
A great step forward in this approach has been the project for the climate control of Rui Barbosa's library. It was initiated in 2004, and developed between the Getty Conservation Institute (GCI) and Casa de Rui Barbosa (FCRB) with a goal of improving the environmental conditions of the book collection. Assessments of the building, the collection, and the environment provided essential information for developing an improvement strategy with an integrated approach that combined the building, collection, and the climate control equipment as one environmental system. Conservation strategies were defined after assessments recommendations, including preservation works in the building envelope, climate improvements in the basement and attic, repair of the bookcases and maintenance of the book collection. In 2006, a ventilation and dehumidification system was installed, with a dehumidifier in the basement, supply air diffusers and return air grilles positioned along visitor paths, and an exhaust fan in the attic (figg. 6, 7 – system installation).[3]

All the interventions for the climate system installations respected the preservation current principles. This system established and maintained a safe environment with a stable relative humidity at less than 65% RH and temperature variations between 22°C and 28°C [Maekawa *et al.*, 2009].

A risk management approach was adopted in 2012 in order to broaden the perspectives of preventive actions, especially concerning the most difficult decisions; to identify the risks to the preservation of cultural heritage in order to reduce them effectively, according to available resources; and to establish resources for an institutional policy of long-term preservation, consolidating the efforts already made.

Due too the very specific context of the Casa de Rui Barbosa Foundation, a multidisciplinary perspective was requested to carry the process. The main objectives to be achieved were the expansion of the perspectives of preventive actions by the integration of collections, buildings and historical sites departments. It was also an opportunity to enhance the skills of staff members related to the integration of research and practice. We applied a model, known as ABC Method, which the overall structure suggests five sequential steps: establish context, identify risks, analyse risks, evaluate risks, and treat risks. There are two ongoing processes: communicate and consult, monitor and review. Three components are used to quantify a collection risk: the rate or frequency, the loss of value to each affected object, and the fraction of the collection affected. A diagram has been developed to aid the quantification of the relative value of each fraction of the collection that is affected by a specific risk, called value pie chart [Michalski and Pedersoli, 2016].

The risk assessment was carried out by a working group on risk management composed by architectural preservation specialist, collections



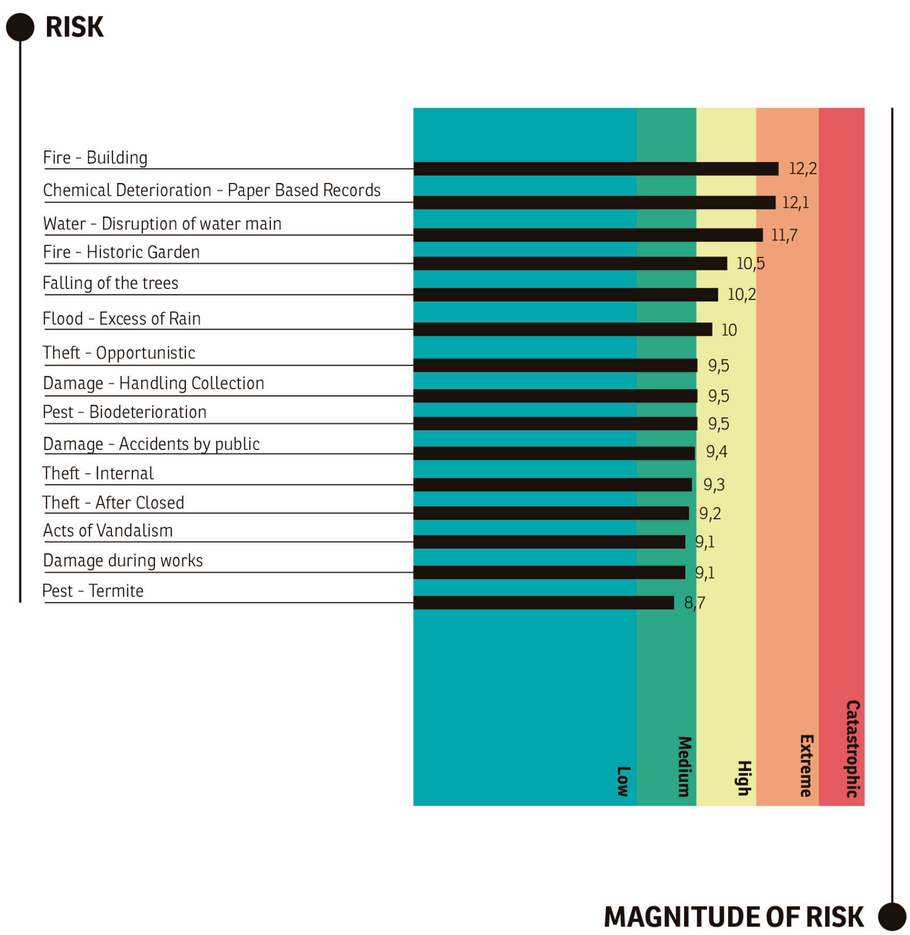


Fig. 8
Value pie of historic building Casa de Rui Barbosa Museum – ground floor plan. (© Fundação Casa de Rui Barbosa / Núcleo de Preservação Arquitetônica)

Fig. 9
Risk to Casa de Rui Barbosa Museum in order of decreasing magnitude of risk. Casa de Rui Barbosa Museum – ground floor plan. (© Fundação Casa de Rui Barbosa / Núcleo de Preservação Arquitetônica)

curator and conservator-restorer and related research assistant. This working group has been trained in the use of ABC Method, by José Luiz Pedersoli Jr (conservation scientist and consultant in risk management for cultural heritage) who coordinated the process. Conducted during eight months in 2012, the group, with about 13 people, identified and prioritised key risks facing the historic house museum, its garden and its collection.[4]

The most complex task was the quantification of the relative value of the different elements of the overall Foundation collection, which required a more detailed characterisation of each item, as well as an agreement between the professionals involved. It was very important to define their importance and relative value for the Institution, its mission and its public, including the various categories of value: historical, artistic, aesthetic, social, religious, economic, scientific, etc.

In this sense, the first level of evaluation concluded that the total value of cultural heritage protected by the Institution resides in the fact that they are gathered under the same management protocols. Thus, it was concluded that, for example, the historical building has the same relative value as the archival collection, since both have as their origin the patron of the Institution. In this way, the historic buildings contribute with 16.67% of the total value of cultural heritage of Casa de Rui Barbosa Foundation.

The subcomponents of the historic building represented in the value pie graph were analysed in detail to quantify the relative value of each component (fig. 9).

To better understand the value pie graph it is necessary to clarify the used criteria to develop this graph. The authenticity of each part has been assessed, and four categories were established: elements that preserves the original characteristics of the period style, such as the exterior of the main building; elements that preserves the ambiance and the original compartmentation, such as the interior of the 1st and 2nd floor, elements with a high degree of change such as interior basement and ground floor and elements that have been completely changed, such as house furnace, current museum café.

A quantitative evaluation followed this process, in which the dimensions, in square meters, were identified, of each element.

Concerning the historic house museum 15 risks were analysed: 3 were identified as of extreme priority, 3 of high priority (fig. 8).

By the collaboration among various professionals, including the institutional managers, we expected to develop a consistent preservation policy based on risk management approach, for historic buildings that house collections. The experience gave us the ability to identify risks, comprehensively, to estimate correctly their magnitude and associated uncertainties, to devise cost-effective solutions to treat those risks. As an additional level, it allowed a spatial resolution making possible to build increasingly more detailed pictures of the situation, especially for those risks that affect locally, causing punctual losses or affecting only limited surfaces or specific elements (fig. 10).

Following the assessment, the project entered a risk management phase with the generation of strategies to reduce each risk. Many options were proposed and evaluated. Each option was analysed to predict

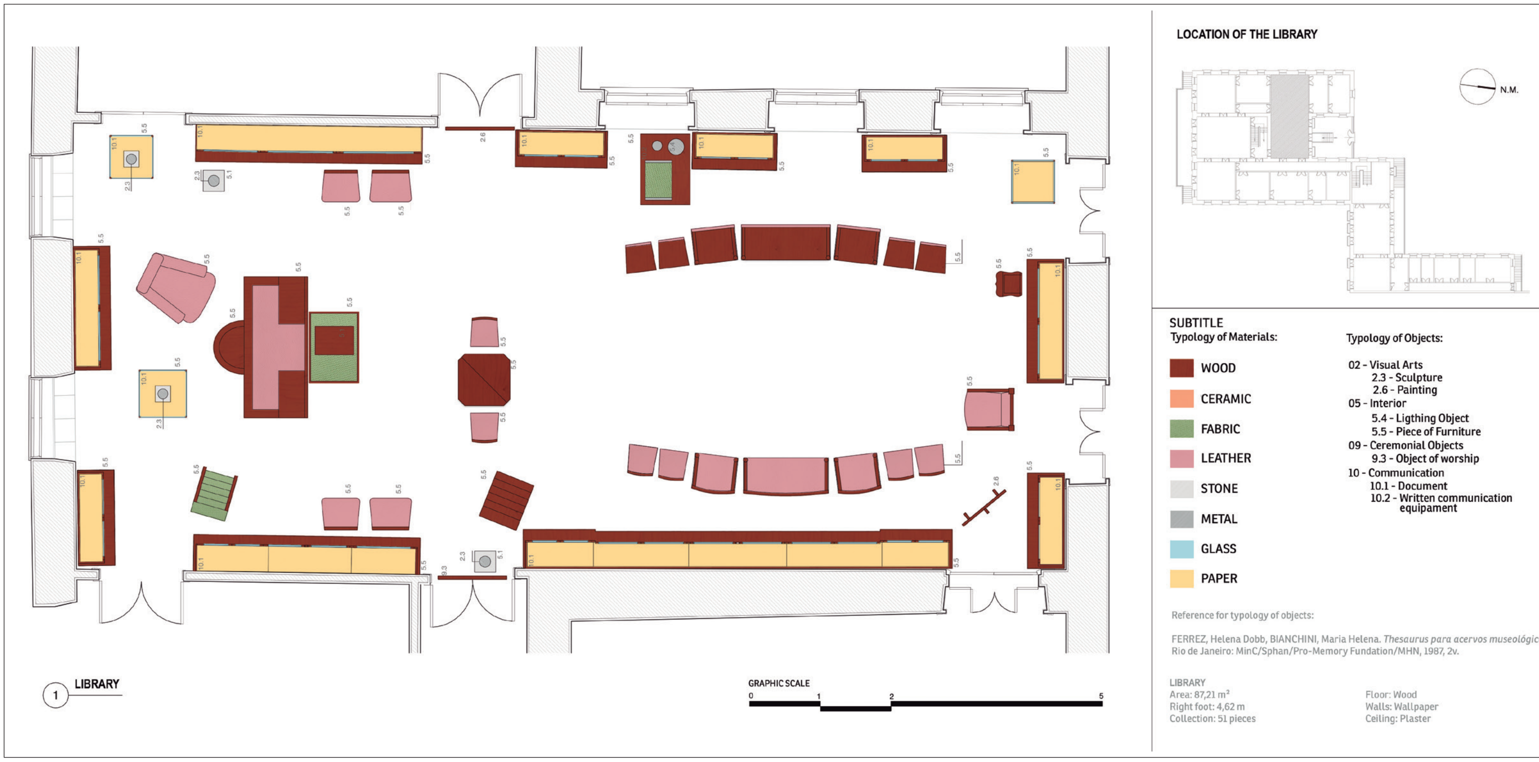


Fig. 10
Library floor plan with the indication of the collection. (© Fundação Casa de Rui Barbosa / Núcleo de Preservação Arquitetônica)

to what degree it would reduce the magnitude of the risk. The cost of implementing the option was also estimated. The cost-effectiveness of each strategy – the reduction in risk magnitude divided by cost – was determined. Options that best addressed the priority risks (extreme and high risks) were recommended [Carvalho *et al.*, 2013].

Just to mention an example, the Foundation made a decision, based on the cost effectiveness, to refurbish the electric system of the historic house museum, because similar to many museums and other institutions holding cultural collections in Brazil and abroad, the greatest risk of extreme priority is that of a large fire which affect a significant fraction of the value collection and typically results in total or near total loss of value in the affected items.

A recent Brazilian publication, *Historic Houses in Brazil*, from the DEMHIST BRASIL [Carvalho, 2013], mapped out the existence of more than 300 museums – as in Brazil, including houses, palaces, common houses, farms and also palaces. However we do know the importance of preventive conservation to manage those important heritage, there is not a regulatory instrument nor a specific methodological base. Our commitment is to contribute to implement this methodological approach, using Casa de Rui Barbosa experience as a reference. Our experience has been discussed among conservation professionals, as the preventive approach is proved to be efficient, sustainable and reliable.

Conclusion

This experience demonstrates that many actions to mitigate risks can be relatively simple, restricted to the technical level, while others, however, will require the participation of other management bodies, some even from outside the Institution. Use the risk management approach can be useful to integrate the management and also the budgetary control processes that are continuous in the Institutions. Our experience also demonstrated that the ABC method is applicable to buildings that house collections.

As observed by Robert Waller, as the risk management approach provide a clear base for requesting resources, it can be interesting to integrate a preservation policy [Waller, 1995].

Our objective, through the experience we developed at Casa de Rui Barbosa Museum is to foster a preservation policy for historic house museum in Brazil that relies on the identification of risks that threaten the joint preservation of buildings and artefacts and in developing strategies for mitigating those risks effectively, according to available resources, articulating multiple visions, conceived as a continuous process.[5]

Endnotes

[1] The mission of the House of Rui Barbosa is the development of culture, research and teaching, dissemination and worship of the work and life of Rui Barbosa (Law 4,693, April 6, 1966). In this way, the institution can contribute to the knowledge of cultural diversity and to the strengthening of citizenship, ensuring the implementation of the other policies of the Ministry of Culture (www.casaruibarbosa.gov.br).

[2] Plan has research-based strategies, and the results are available at the specific website (www.casaruibarbosa.gov.br/conservacaopreventiva).

[3] The climate system for the Rui Barbosa's library was a unique sustainable solution for climate improvement in Brazil, and paved the way to a wide application of this low-cost, relatively simple climate improvement strategy in cultural institutions in hot and humid climates.

[4] José Luiz Pedersoli Jr., a Brazilian conservation scientist, was hired and a team of members from the various sectors of the Casa de Rui Barbosa Foundation worked to support contracted consulting. José Luiz Pedersoli worked in the development of ABC Method, and was responsible for the value pie conception.

[5] The author acknowledges technical contributions of Ms. Isabel Passos, architect of the research project Casa de Rui Barbosa Museum: Preventive Conservation Plan.

Bibliography

Carvalho A. C., *Museus Casas Históricas no Brasil*, Curadoria do acervo artístico cultural dos Palácios do Governo do Estado de São Paulo, São Paulo, 2013.

Carvalho C., Cordeiro P., Costa. F., 'Risk Management as a Tool for the Joint Preservation of Historic Buildings and Collections: the House of Rui Barbosa Plan,' in ArquiMemória: International Conference on Preservation of Historic Monuments, in *Arquimemória 4*, Salvador (BA), 2013.

Dardes K. (ed.), *The Conservation Assessment: a Proposed Model for Evaluating Museum Environmental Management Needs*, The Getty Conservation Institute, Los Angeles, 1998.

Lacombe A. J., *À sombra de Rui Barbosa*, Fundação Casa de Rui Barbosa, Rio de Janeiro, 1984.

Maekawa S., Carvalho C., Toledo F. and Beltran V., *Collection Care and Human Comfort for a Historic House Museum in Hot and Humid Climates: an Alternative to Conventional Air Conditioning Approach*, PLEA 2009, 26th Conference on passive and low energy architecture, Quebec City, 2009.

Maekawa S., Beltran V., Henry M., *Environmental Management for Collections: Alternative Preservation Strategies for Hot and Humid Climates*, The Getty Conservation Institute, Los Angeles, 2015.

May C., *Environmental Management: Guidelines for Museums and Galleries*, Routledge, London, 1995.

Michalski S., Pedersoli J. L., *The ABC Method, a Risk Management Approach to the Preservation of Cultural Heritage*, Canadian Conservation Institute, Ottawa, 2016.

Waller R., 'Risk Management Applied to Preventive Conservation,' in Staniforth S. (ed.) 2013, *Historical perspectives on preventive conservation*, The Getty Conservation Institute, Los Angeles, 1995, pp. 317-327.

Preventive Strategies for Neuschwanstein Castle

Tina Naumović
Head of the Department of Preventive Conservation at the Bavarian Administration of state-owned Palaces, Gardens and Lakes, Schloss Nymphenburg
tina.naumovic@bsv.bayern.de

Abstract
Due to 1.3 million visitors per year, the interior decoration of Neuschwanstein Castle is not in a good state of preservation. It suffers from unfavourable climate conditions, the impact of unfiltered daylight as well as from dust accumulation and from the intentionally (touching) and unintentionally erosion of surfaces.

The first fundamental conservation-restoration campaign ever started in April 2017 and is scheduled to finish in 2021. It is embedded by various preventive strategies to reduce the impact of the visitors to a minimum and to increase the sustainability of the conservation works.

Previous years of climate-monitoring as well as the following comprehensive damage and risk assessment led to the development of mitigation strategies in order to improve the situation of the interiors:

- installation of an air-ventilation system using the hot-air ducts of the original heating system;
- installation of storage facilities;
- installation of a visitor-guiding path;
- installation of adequate light-protection.

The first part of the installation already started. The implementation of all preventive strategies will be completed in 2021.

Keywords
High humidity, condensation problems, light damage, dust, climate monitoring, visitors as moisture source, ventilation system historic air-ducts, low-tech depot.

"Fairytale-King" King Ludwig II started building Neuschwanstein Castle in 1868. Due to the early dead of the king in 1886 it was never entirely finished. Most of the decoration of the precious state-rooms was already completed (fig. 1), but a lot of the subordinated rooms are still in a brick-wall stadium.

Just seven weeks after the Kings passing the castle was opened to the curious public and has since been used as a museum. For this reason, the building and the interior originate from only one short period and are still in their original condition. Most of the unfinished rooms were transformed to offices and common rooms for the staff or into touristic facilities like toilettes and gift shops. With more than 1.3 million visitors per year, especially the interior is exposed to a massive

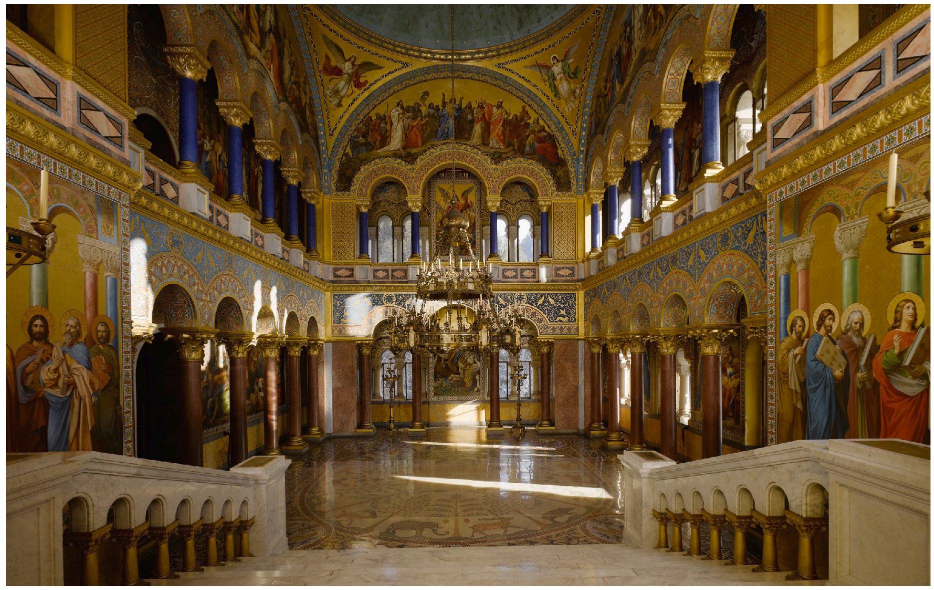


Fig. 1
Neuschwanstein Castle, Throne Hall. The Throne Hall is one of the most precious state rooms in the castle. (© Bayerische Schlösserverwaltung, Rainer Herrmann)

"usage-pressure." The interior decoration is not in a good state of preservation, suffering from unfavourable climate conditions and the impact of unfiltered daylight as well as from dust accumulation and the intentionally (touching) and unintentionally erosion of surfaces.

The climate indicated damages originate from a very high humidity. Condensation problems on the glazing and the outer walls were obvious, mould, salt damages and tracks of liquid water on wall paintings are common (fig. 2). Most of the fabrics on display show heavy light damages, from deterioration of colour to a complete loss of filament stability (fig. 4). Efforts to establish a better light-protection failed, because the need for fresh air for the visitors led to constantly open windows and therefore to direct sunlight exposure. Visitors produce a high amount of dust; textile fibres, skin flakes, hair and dirt trickle off people and sediment on the surfaces. Every dusting cycle "sands" the surfaces and leads to a loss of original substance. Most of the gilded metal surfaces and the varnished oak panels and furniture have lost their original cover over the past decades. To give back some gloss to the surfaces they were improperly treated with different non-siccative oils which embedded the dust completely; dark and sticky, even "furry," surfaces are the consequence (fig. 3). For years the barrier situation along the visitor path was insufficient, erosion because of touching and even vandalism is the result (fig. 4).

Since its opening to the visitors the interior of Neuschwanstein Castle has never been restored or renovated. The first ever conservation campaign started in April 2017 and is scheduled to finish in 2021.

As part of the damage and risk assessment preliminary climate data were collected. The previously mentioned condensation problems were

obvious on the first sight; following detailed surveying and mapping of the damages especially on the wall paintings identified not only the existing damages but also not apparent local touch ups notably on the outer walls (fig. 2). The big amount of damages and losses of the paint layer shows that the condensation is really a high risk for the wall paintings.

The climate monitoring confirmed the assumed desperate climate conditions: due to the fact that the castle is located in an alpine surrounding 900m above sea level, it faces quick weather changes, lots of rain and snow and very cold winters. The castle is unheated, the detected minimal temperature was -4.3°C, the highest temperature measured was 28.9°C. The range of relative humidity is extremely wide spread with daily fluctuations from 30% to 85% relative humidity (RH) (fig. 5).

The conservators aim is to reach a corridor from 45%-65% RH with daily fluctuations lower than 15% RH.

Despite the cold temperatures the castle has around 2000 visitors per day even in winter. In summer it is about 6000 per day. As a result of the bad air quality windows are kept open.

Evaluation of the climate data led to the conclusion that the absolute humidity inside is much higher than outside. The diagrams show that the daily rise of humidity is to 100% connected to the opening hours hence the visitors are identified as the main moisture source (fig. 6). As a result of the high humidity level condensation problems occur leading to big damages on the wall paintings, showing salt problems, mould, etc. On freezing cold winter days the condensed water leads to formation of ice on the surfaces of the cold windows and outer walls (fig. 7).

It is a well-known fact that the presence of visitors increases humidity levels in sites. Nevertheless the high level of the impact is remarkable. Evaporation of humidity from humans originates from the

Fig. 2
Neuschwanstein Castle, Singers Hall, southern oriel. Vis- and UV-picture of the wall painting. In visible lights salt damages, flaking and already lost paint layer are the obvious damages. The different UV-fluorescence shows various phases of local retouches and repairs. (© Bayerische Schlösserverwaltung, Armin Schmickl)

Fig. 3
Neuschwanstein Castle, Dressing Room, wood panel and carved door frame. Years of improper treatment with non-siccative oil led to a sticky surface with embedded dust. (© Bayerische Schlösserverwaltung, Tina Naumović)

Fig. 4
Neuschwanstein Castle, Dining Room. The fabric on the upholstery shows heavy light damages. Formerly the silk was pink, the colour faded via a light rosé to beige. The original vivid colour now can be found only at one area, which was light-protected by an (now stolen) appliqué. (© Bayerische Schlösserverwaltung, Tina Naumović)

Fig. 5
Neuschwanstein Castle, Living Room. Climate sheet showing temperature and relative humidity during 2012. The highlighted green area shows the corridor of 45-65% relative humidity, which correlates to the corridor liked to reach. (© Bayerische Schlösserverwaltung, Tina Naumović)

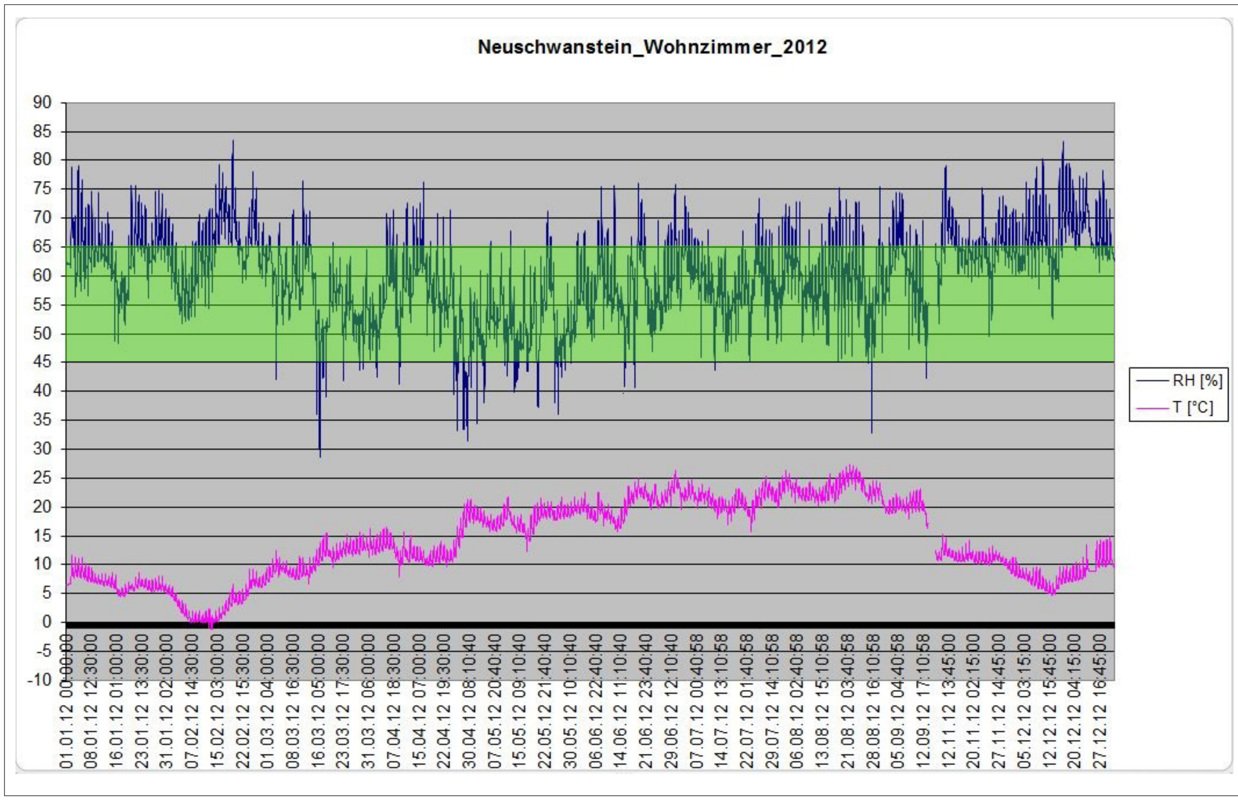


Fig. 6
Neuschwanstein Castle, Living Room. Climate sheet showing the absolute humidity inside and outside in February 2014. The daily rise of the humidity level is entirely connected to the opening hours. Outside the absolute humidity is much lower. (© Bayerische Schlösserverwaltung, Tina Naumović)

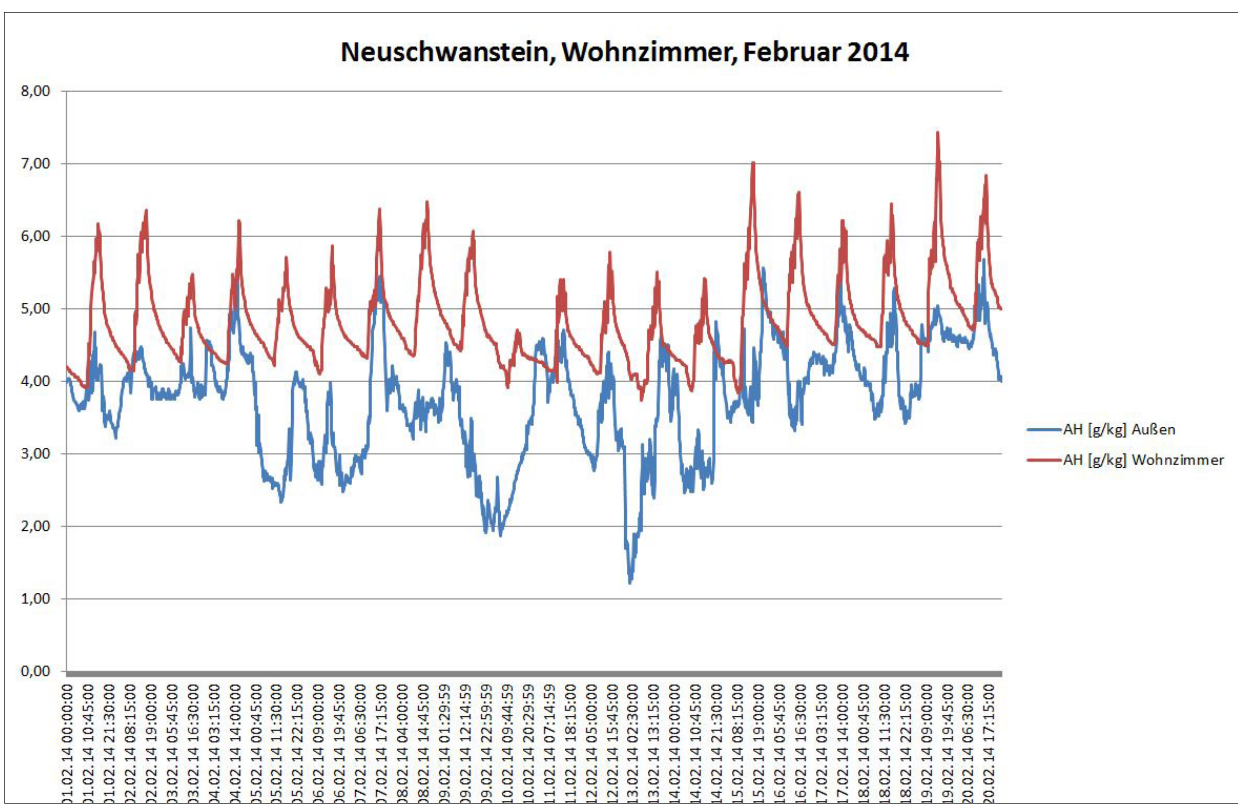


Fig. 7
Neuschwanstein Castle, Living Room, northern oriel. Ice formation due to condensation problems on the painted surface of the outer wall. (© Staatliches Bauamt Kempten, Ralf Gehrke)

metabolism, thus breathing and sweating. In addition, visitors have to enter with their wet jackets and soaked umbrellas on rainy days, because there are no lockers or cloakrooms installed. Due to the visitor tour new facilities cannot be established: entrance and exit are far away from each other to cope with the endless stream of visitors. The threat to the climate conditions in the castle through the wet clothes seemed very obvious on the first sight. Unexpectedly the matching of the climate-data of rainy and sunny days did not show a significant difference.

To develop the most effective mitigation strategy, the Fraunhofer Institute for Building Physics was asked to carry out a comprehensive analysis about the impact of dry visitors compared to wet visitors.[1] Implementing an improved climate monitoring system, tools of climate modelling and test series the Fraunhofer came to interesting results (fig. 8).

The high level of absolute humidity compared to the outside was confirmed and transformed into the absolute amount of water carried inside by visitors. Only for the throne hall there is an impact of more than 13 tons of water per year. Ten tons are caused by the metabolism, only three tons are caused by wet clothes. The practical recommendations were to higher the air exchange rate with the outside air, which mostly is less humid than the air inside. In case that the environmental conditions are inadequate, dry air has to be produced to achieve a sufficient climate control. As a consequence, the installation of a ventilation system with fresh air ventilation, dehumidification and slightly heating was suggested as best solution for the state rooms. The goal is to soften the impact of the visitors in stabilising the relative humidity. To reduce the amount of imported water from the wet clothes, the visitors should be “blow-dried” in the waiting section before entering the state-rooms.

The biggest challenge of installing a ventilation system in historic buildings has its roots in avoiding to ruin the building along the way,

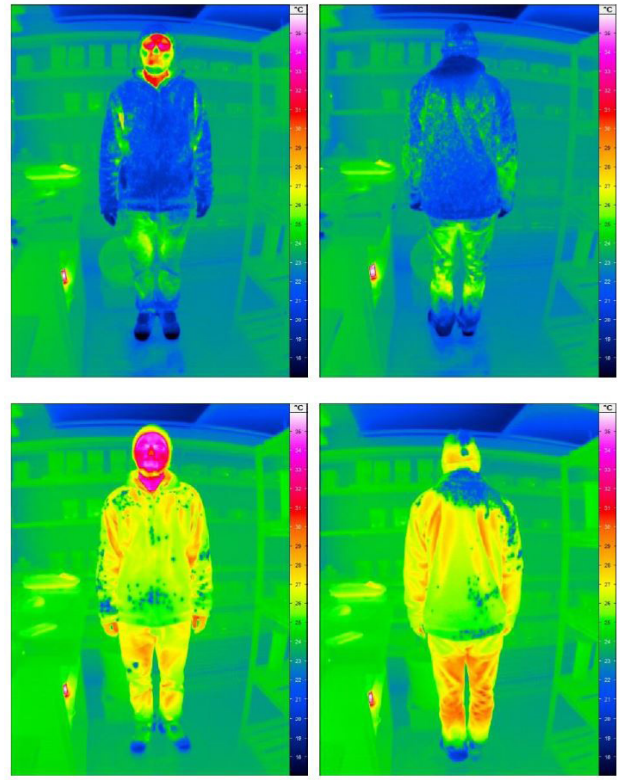


Fig. 8
Research report "Bauphysikalische Voruntersuchung und Klimadatenauswertung in Schloss Neuschwanstein," Fraunhofer IBP, Stefan Bichlmair und Martin Krus, Valley 2016. Infrared picture of a sprinkled volunteer in a climate chamber. The changing surface temperature because of the cooling by evaporation from the wet clothes is shown in different colours.
(© Fraunhofer IBP, Stefan Bichlmair und Martin Krus)

especially in the state rooms of Neuschwanstein Castle which, so far were untouched by building services. For this reason a clear guideline has been established: the priority in planning the ventilation system will not focus on the climate conditions that conservators find appropriate as a museum standard (20 °C / 50% RH) but on the possibilities the building structure is offering. The popular idea of installing massive air-ducts to connect every room with a central HVAC-system in the attic or basement was definitely no alternative.

Fortunately, Ludwig II already installed an inventive hot air heating system including three heating chambers and several hot-air-ducts leading to the main state-rooms. Obviously the still existing technical equipment in the heating chambers is declared as technical cultural heritage and has to stay untouched. At the moment new technical rooms are established in the undecorated unfinished floors in the castle (fig. 6). For the involved engineers the development of the ventilation system was quite challenging because the building structure determines the size of the technical devices.[2] Ventilation, dehumidification and fire protection flaps have to be squeezed in the historic construction in a minimal invasive way.

The installation of the ventilation system in the state-rooms will be completely finished by the end of 2018; hopefully its effectiveness can be proved during 2019. The ongoing climate monitoring will escort the implementation of the ventilation system to ensure that the indoor

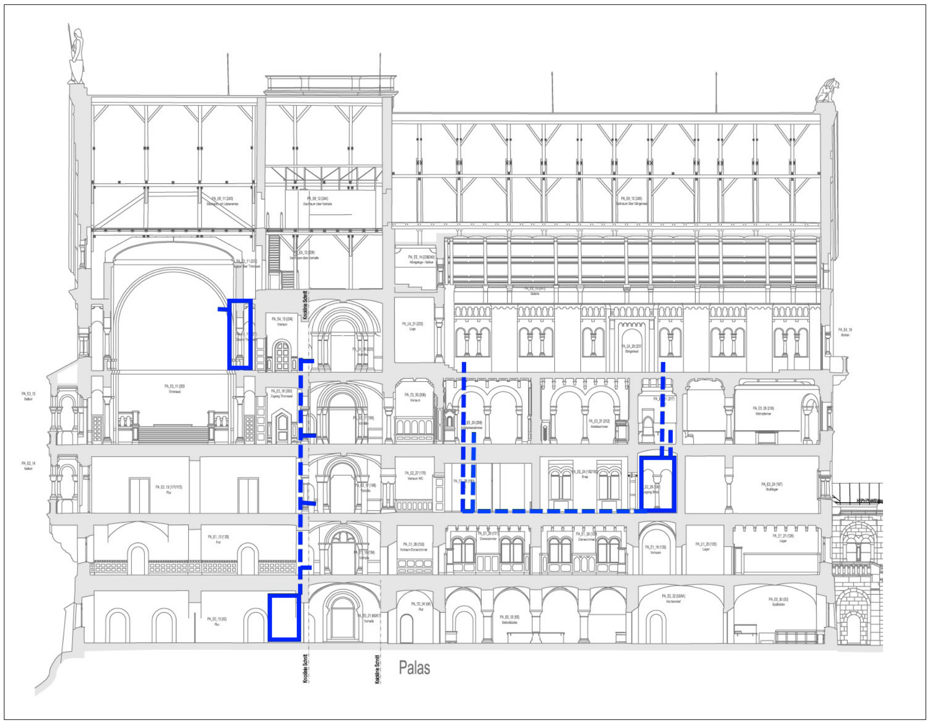


Fig. 9
Neuschwanstein Castle, longitudinal section. Three new technical rooms are established to reach the historic hot-air ducts on the shortest way. (Longitudinal section © Staatliches Bauamt Kempten, Josef Linsinger)

Fig. 10
Neuschwanstein Castle, Ritterhaus, new storage. Unfinished rooms are turned to low-tech storages. Conservation heating and dehumidification will keep the RH under 65%. (© Bayerische Schlösserverwaltung, Heiko Oehme)

climate is affected in the right way.

In addition to the ventilation system in the state-rooms a hot air-heating system has been installed in the waiting section. While queueing for audio-guides and the start of their tour in the undecorated waiting corridor prior to the state-rooms, the visitors get "blow-dried." The system is in charge since February 2018 and although needed climate gates are not yet constructed and the evaluation of climate data is still in process, positive effects are striking: on rainy days the floor is no longer soaked with water, the absolute humidity is lower and on top the visitor comfort in the former cold, wet and windy corridor has improved a lot.

Another example for the aim of a low-tech solution for climate stabilization in the castle is the construction of the new depot. While preparing the conservation-restoration campaign it was obvious that the storage condition for the pieces of art have to be improved. A lot of textiles and furniture are placed into stock to save them from touching and to get enough space for the guided tours. Although the storage situation has "grown" over many years and was therefore a bit chaotic and undefined the climate monitoring in the unvisited rooms showed mostly satisfying climate conditions regarding a stable and mostly adequate relative humidity (45%-65% RH). A new depot was established in an unfinished part of the castle in 2017/18 (fig. 7). For climate control an electric heating cable for *conservation heating* was installed along the outer walls, an insulating cover was put on floor and ceiling and two mobile dehumidifiers were mounted. These devices guarantee low climate fluctuations and help to avoid relative humidity over 65% in order to eliminate the risk of mould for the textiles.

More preventive preparations are currently planned. A visitor-guiding-path which includes a "touch protection" (handrails/glass walls) and a dust-absorbing carpet will be installed after the restoration is finished. It will help to reduce dust-accumulation and to protect the original wooden floors from erosion as well as the artworks and decoration from touching.

The development of an adequate light-protection to eliminate UV-radiation and to reduce daylight exposure is in process; long lasting and elaborate test-series on different UV-protection-films and the non-destructive mounting of light protection screens via magnets on the iron window frames are carried out.

It will take several years to show the effectiveness and sustainability of the applied preventive strategies, though the first results are promising. The close collaboration of architects, engineers and conservators led to satisfactory results on all sides.

Endnotes

[1] Research Report, *Bauphysikalische Voruntersuchung und Klimadatenauswertung in Schloss Neuschwanstein*, Fraunhofer IBP, Stefan Bichlmair und Martin Krus, Valley 2016.

[2] The ventilation system was planned by Büro Jochen Käferhaus, Vienna, in close collaboration with the building authority Staatliches Bauamt Kempten.

Implementation of a Global Assessment of Graphic and Photographic Arts

Abstract

An overall assessment of the graphic and photographic collections of some thirty CMN sites was carried out. The methodology which was used is based on both, lists extracted from the collections' management database and an in situ inspection, one object at a time, of the collections. The prioritisation of the treatments is based on a system of hierarchisation of the alterations, paired with the level of intervention.

Keywords

Graphic arts, preservation, methodology, hierarchisation.

Agnoko-Michelle Gunn
Head of the preventive conservation pole
Centre des Monuments Nationaux (CMN)
agnoko-michelle.gunn@monuments-nationaux.fr
https://www.monuments-nationaux.fr

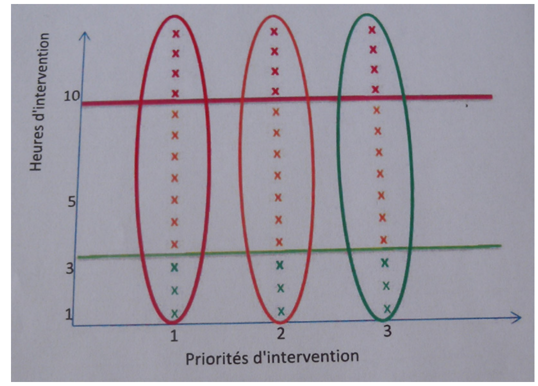
The Centre des Monuments Nationaux has a collection, documentation and an archive of great importance which includes a very wide range of graphic and photographic documents. These graphic documents are very sensitive to environmental conditions, light, inadequate and unstable climate, pollution, poor storage and handling [Merritt and Reilly 2010, p. 67].

Because of this fragility, this collection should not be subjected to permanent exposure. The presence of many glass surfaces in the CMN's monuments is not always in strict accordance with conservation recommendations. Even if some glass surfaces are UV protective, in many cases, these filters are transparent and don't permit the reduction of the level of visible lighting. It is also not easy to implement a rotation policy of the collections, in the affected monuments, for lack of human resources and/or appropriate skills on site. As well as light-related problems, one

	Name	**Title**	**Technical Category**	**Number**
Drawing	887	874	826	921
Print	2145	2141	1250	2616
Photograph	981	924	881	1538
Total	4013	3939	2957	5075

Fig. 1
Result of the search in the Collection Management Database.

Fig. 2.
Illustration of the Intervention Hierarchisation.



must add biological attacks (fungi and insects) which are linked to the generally natural climate of historical buildings and of an often inadequate conditioning. In order to permanently remedy this situation, the CMN has undertaken to set up a multi-year preservation program.

In order to do this, it is necessary to know the conservation conditions at a given moment. A systematic research of the collections was carried out in the CMN collection management database, *Collectio*. Queries were made by site name, title, denomination and technical categories. The results are given in figure 1. According to the chosen query mode, the result is different. “Titles” and “denomination” are very close. Whereas the “technical category” displays much lower results. This one is then discarded. Lists of works in the collections are extracted for each site and compared to collection works found on site, in the exhibition spaces or in storage. The identification on site is done visually, if not, with a description. A colour code is then set up to easily identify on the list, collection objects which are in the categories of the found, the unseen and the extra thus receiving provisional numbers according to a pre-established protocol. Systematic shots are taken of collection pieces that do not have visuals. The visuals are renamed according to their inventory numbers so as to facilitate their integration to the database. The hierarchisation is done according to the more or less preoccupying nature of the alterations: 1-evolutionary, 2-mechanical, 3-inadequate assembly, which is then crossed with the degree of intervention [Gunn and Nicosia, 2017] expressed by the number of hours, less than 3 hours, more than 3 hours and more than10 hours, as illustrated in figure 2.

A statistical assessment could thus be drawn for the provisional measures to come: 30% require immediate treatment, 20% in the short term and 50% in the medium and long term.

Bibliography

Gunn A. M., Nicosia G., ‘Construction d’un outil de hiérarchisation de la gravité des altérations : matrice pondérée de décision’ in *AprévU, Les nouvelles rencontres de la conservation préventive, 8,9 juin 2017,* Paris, Association des Préventeurs Universitaires, AprévU, 2017, pp. 171-185.

Merritt J., Reilly J. A., ‘Preventive Conservation and Light,’ in *Preventive Conservation for Historic House Museums,* AltaMira Press, USA, 2010, p. 67.

The Queen's Rooms during building works, Palace of Versailles.
© EPV/Danilo Forleo

ROUND TABLE 1

Preventive Conservation Experiences in Public and Private Historic Houses

Chairman
Noémie Wansart
Research Assistant,
Palace of Versailles

Speakers
An Breyne
Ben Cowell
Stefano Della Torre
Almut Siegel

Project Presentation of SiLK
Guidelines for the Protection of Cultural Property

Abstract

Cultural treasures in museums, archives and libraries are continually threatened by damage and in some cases by irretrievable destruction. Awareness of this has become particularly acute through disastrous events of the past years, including the fire at the Duchess Anna Amalia Library in Weimar in 2004 and the collapse of the building housing the Historical Archive of the City of Cologne in 2009. However, subtle dangers that arise from unfavourable environmental influences or incorrect usage can also have devastating effects on objects.

The Konferenz Nationaler Kultureinrichtungen – KNK (Conference of National Cultural Institutions), a cooperative association furthering the interests of 23 nationally significant cultural institutions of various sizes and orientations in the former East Germany, among those the Prussian Palaces and Gardens Foundation Berlin-Brandenburg (SPSG), has confronted these vulnerabilities with the introduction of the SiLK – Guidelines for the protection of cultural property, a digital safety and security guide for cultural assets.

Almut Siegel
Architect in charge / Department of Preservation of Monuments, Prussian Palaces and Gardens Foundation Berlin-Brandenburg (SPSG), Project manager, SiLK – SicherheitsLeitfaden Kulturgut – Guidelines for the protection of cultural property, Federal Office for Civil Protection and Disaster Assistance (BBK)
siegel@konferenz-kultur.de
www.konferenz-kultur.de

Keywords

Protection, cultural property, safety, risk analysis, risk assessment, security management, online-tool, prevention.

"SiLK," in German "SicherheitsLeitfaden Kulturgut," is a state-funded project for the protection of cultural property, which was initially funded by the German Federal Minister of Culture and Media (BKM). Since last year, the funding was taken over by the German Federal Office of Civil Protection and Disaster Assistance (BBK). Until now only available in German, the English version of the SiLK guidelines was recently put online so that now everybody worldwide has the opportunity to use it.

SiLK is an online-tool for assistance, which makes interactive risk analysis possible with recommendations for care and treatment in addition to offering comprehensive information. It should raise awareness for potential risks that could threaten the collections, but also buildings and parks.

The main principle and focus is on prevention. SiLK helps staff evaluate the protection efforts of their own institution. Potential hazards

Fig. 1
Screenshot of SiLK website: questionnaire "fire."

Fig. 2
international SiLK conference 2015 in the «Händel-Haus» in Halle / Saale.
(© Konferenz Nationaler Kultureinrichtungen / Christian Ditsch).

are made visible by these guidelines, but they do not stop at this point. They make proposals for improvement and offer tips and possible solutions and are by this an instrument for self-help.

SiLK covers the following 14 topics: 1) general security management, 2) fire, 3) flooding, 4) theft, 5) vandalism, 6) accidents/malfunctions, 7) deterioration/wear and tear, 8) climate, 9) light, 10) pests and mould, 11) pollutants, 12) severe weather, 13) earthquakes, 14) violence.

Each topic has an associated introduction, an interactive questionnaire and a knowledge base, with the questionnaire forming the core element – each containing about 15 to 30 questions (fig. 1). After answering, users obtain a "traffic light assessment:" "Green" indicates a given minimum standard. If the minimum standard is not reached ("Red") or if an on-going threat exists ("Amber"), the assessment will include recommendations for action or mitigation measures. The conclusion can be saved as a PDF document and printed. The use of SiLK is for free and there is no need for registration. The aim is to be practical, easily accessible and easy to use.

Besides keeping the SiLK guidelines up-to-date, the SiLK team holds lectures, makes publications and provides information material. The project furthermore organises workshops and conferences (fig. 2) and therefore has meanwhile become a platform for communication and discussion for all kinds of topics related to the protection of cultural property in Germany and beyond.

Bibliography

SiLK – Guidelines for the protection of cultural property,
http://www.konferenz-kultur.de/SLF/EN/index1.php?lang=en.

Conservation and the Living Home

Ben Cowell
Director General,
Historic Houses
ben.cowell@historichouses.org
www.historichouses.org

Abstract
Discussions about conservation often take place in the context of buildings and collections that may once have been inhabited, but which are now sustained for their value as heritage sites. In reality however most heritage remains in private hands, and most conservation is therefore a private endeavour carried out beyond the realms of charitable or publicly funded heritage organisations. In the UK, there are over eight times as many properties in independent hands (as represented by Historic Houses) as there are mansion houses owned by English Heritage and the National Trust put together. Many Historic Houses places remain lived-in family homes. What is the appropriate level of conservation control to apply in a house that continues to be a lived-in family home? Our organisation offers advice to owners that helps them find a pragmatic balance.

Keywords
Historic, house, private, owner.

Historic Houses[1] represents the UK's largest collection of independently owned historic houses and gardens. Our members include over 1,500 Grade I and II* listed historic houses and gardens (or their equivalents in Scotland, Wales and Northern Ireland). Our member properties are connected by the fact that many of them remain lived-in, family homes. What impact does this have on their conservation approaches?

Our member houses sustain themselves largely by private endeavour. Historic Houses properties across the UK welcome 26 million visits each year, contribute over £1 billion to the economy and generate 33,700 full time equivalent jobs. As tourist attractions, events venues and rural business hubs, Historic Houses places are catalysts of rural prosperity and cultural lynchpins for local communities. As well as opening for tourism day visits, historic houses operate as wedding venues, venues for corporate events, holiday accommodation providers, film sets, and a whole host of other business uses.

A great many works of art hang on the walls of independently owned houses. For example, there are fifty times as many artworks held under

Fig. 1
Conservation activity at Marchmont House, Scotland, winner of Historic Houses/Sotheby's Restoration Award 2018. (© The Curries)

Fig. 2
The Hon Nicholas Howard brushes the first sheet of gold leaf onto the lantern on the dome of Castle Howard, Yorkshire. (© Mike Cowling / Turnstone Media)

the conditional exemption scheme as there are in the National Gallery. Yet few public grants are available for conservation work in private houses, and tax incentives are generally limited to capital tax arrangements (such as the possibility of seeking conditional exemption from the full application of inheritance tax, in return for opening a house and collection to public access). Nevertheless, private owners of significant listed properties clearly have obligations towards the ongoing care and conservation of their heritage assets.

At Historic Houses, we offer owners the chance to attend workshops on housekeeping, in order to introduce them to the basic principles and techniques of the conservation of historic objects as well as specific techniques for caring for different sorts of materials. In reality, a more pragmatic set of decisions are necessary when considering conservation in the living home. Artworks may be on the walls of rooms that are still in active use for social events and general family life. Precise control of sunlight, temperatures and humidity needs to take place with regard to human needs and comforts as well as to the long-term care of collections. This is the pragmatic reality of much conservation work in the UK, therefore.

Endnotes
[1] www.historichouses.org.

Monumentenwacht Interieur...
Who? What? Why?

Abstract
Monumentenwacht: an ideal partner in support for maintenance of historic buildings and interiors.

Keywords
Preventive, conservation, historic, interiors.

An Breyne
An Breyne, Hoofddeskundige
Monumentenwacht Interieur,
Limburg province
mowa@limburg.be
an.breyne@patrimoon.be
www.monumentenwacht.be

Belgium has two main regions: a Flemish and a French region. Monumentenwacht only exists in Flanders, not in the French region and Brussels. Each province in Flanders has his own detachment, which is separated in two teams: one for the exterior and one for the interior maintenance. To guide the different provinces, there is Monumentenwacht Vlaanderen.

Monumentenwacht is an organisation that helps each owner or executive of an historical monument, protected or private: partnerships, society and public board or church councils.

When they join Monumentenwacht, they receive multiple maintenance folders to inform and help raising the awareness on the maintenance and repair of historic buildings and their interiors.

The main objective of Monumentenwacht Intérieur is to assist, encourage and support owners and managers of historically valuable heritage. Such as churches, chapels, railway stations, houses, castles, etc.

We provide the following services: inspections, advices and emergency repairs.

On demand by the owner we perform an inspection/survey on the interiors and the objects (fig. 2). This systematic control happens on a regular basis, at least every four years, to examine their state of preservation. The detailed survey/report we impose, includes the condition of the interior, of the objects and the damages. It is a manual with recommendations for better preservation and/or maintenance and conservation. Included we give the owners onderhoudsfiches: maintenance cards who are a particular guideline for the inspected interior or object. I have some examples of such reports as well as some maintenance cards.

Deeds, not only words... We also perform some small urgent works:

Fig. 1
Removing mould on a polychrome thirteenth-century shrine.

Fig. 2
Inspection of a polychrome nineteenth-century sculpture.

we remove dust or mould, we carry out a treatment against bugs in wood or anoxia treatments, we secure paint layers of sculptures and paintings, we properly pack the objects for storage and so on.

On demand we also organise free workshops and symposia, to explain and show how to treat the objects correctly. An example is maintenance of metal, how to storage textile.

We are objective and non-commercial, that makes it possible to achieve the maximum result with a little budget as possible.

We are a partner in conservation and management to maintain their building, the historically valuable interiors and objects, so it's possible to keep them for future generations.

The reliable relationship with our members is very important to achieve our goal. We are a partner for owners and managers of historically valuable heritage in providing them with advice and help for their individual needs.

As I already quoted, not only words but action, with emergency repairs it is possible to avoid an expensive and invasive restoration (fig. 1). For the "big" restoration jobs, ex. a whole interior, we refer to professional restorers or architects.

A stitch in time saves nine.

Preventive Conservation in Villa Reale di Monza: Strategies and Tools for a Long Term Planning

Abstract

The Villa Reale in Monza is an Austrian Imperial residence built in 1780-83, designed by the architect Giuseppe Piermarini, and it is surrounded by a huge park which includes several historic buildings. In the following decades the Villa was completed and enriched under the rule of Napoleon I and of the Savoia dynasty.

The Villa interiors are characterised by decorations executed from the end of 18th to the end of 19th century. It has been abandoned for many decades and in 2014, thanks to a thorough restoration carried out in the frame of a public-private partnership agreement, the central part of the Villa has been permanently opened to the public.

It is an interesting case study under different perspectives: complexity of the conservation issues; preventive and planned conservation approach adopted for the management activities; dedicated information systems for facility and property management; public-private partnership and integration of conservation and promotion.

Keywords

Planned conservation, knowledge management, IT tools, public-private partnership, prevention.

Stefano Della Torre
Politecnico di Milano,
ABC Department
stefano.dellatorre@polimi.it
www.abc.polimi.it

Alessandro Lai
Politecnico di Milano,
ABC Department
www.abc.polimi.it

Alessandra Pili
Politecnico di Milano,
ABC Department
www.abc.polimi.it

Rossella Moioli
Consorzio Villa Reale e
Parco di Monza, Consultant
rossellamoioli@libero.it
www.reggiadimonza.it

Eleonora Rosso
Nuova Villa Reale Monza spa
e.rosso@villarealedimonza.it
www.villarealedimonza.it

The contribution focuses on the Conservation Plan as a tool for risk assessment in sight of a long term conservation. The tool enables to analyse the interaction of the building, the interiors and the various hazards. The relationships between historic furniture, decorations, collections, and the built structure have a central role in understanding the deterioration mechanisms, as well as in the assessment of risks and in the management of conservation activities.

The adopted tool is a relational database, expressly studied for the implementation of a correct conservation methodology on complex historic buildings. The database has been populated first with a big amount of data coming from the final "as built" reports of the conservation works ended in 2014, then with the report of the general inspection carried out in summer 2016, then reporting every relevant event.

At least in Italian context, this implementation of planned inspections, small repairs, consideration of risk factors in facility management, is quite innovative, and much more interesting as this happens

Fig. 1
The Villa Reale in Monza, facade. (© Consorzio Villa Reale di Monza)

in the frame of a public-private partnership agreement [Moioli *et al.,* 2018].

This action research has been implemented in the frame of two projects: Monza and Brianza Cultural District and JPI Heritage+ project CHANGES (Cultural Heritage Activities: New Goals and Benefits for Economy and Society). Thus the authors had the opportunity to participate in the whole process: since the restoration works to the first monitoring/control activities.

The expected results of this on-going case include the optimisation of data collection, the effectiveness of prevention, the evaluation of costs in a long term perspective, the integration between conservation and public enjoyment.[1]

Endnotes

[1] Acknowledgements: Nuova Villa Reale Monza spa; Consorzio Villa Reale e Parco di Monza; Fondazione Cariplo; Provincia di Monza e Brianza; JPI Heritage+Program.

Bibliography

Moioli R., Boniotti C., Konsta A., Pili A., 'Complex Properties Management: Preventive and Planned Conservation Applied to the Royal Villa and Park in Monza,' in *Journal of Cultural Heritage Management and Sustainable Development* 8 (2), 2018, pp. 130-144.

Vernacular Houses in the Weavers Settlement
of Paithan, Maharashtra, India.

ROUND TABLE 2

Preventive Conservation and Architectural Envelope: Cure and Maintenance Protocols

Chairman
Pedro Vaz
Secretary General,
Portuguese Presidency

Speakers
Flavia Belardelli
Ruichita Belapurkar
Pedro Vaz

Royal Palace of Caserta, Preventive Conservation of Stone Facings of Huge Facades

Abstract

As a result of the collapse of some fragments of the stone cladding, recent restoration work began on the façades of the Royal Palace of Caserta. Work was carried out on over 64,000 m^2, lasted for three years and cost 16 million euros. It has therefore become essential to define a strategy to prevent the causes of stone deterioration while at the same time monitoring the conditions of architectural mouldings, in order to avoid the risk of fresh damage or detachment as well as limiting future intervention costs.

Flavia Belardelli
Responsible for the architectural conservation of the Royal Palace of Caserta
flavia.belardelli@beniculturali.it
www.reggiadicaserta.beniculturali.it

Keywords

Caserta, Royal Palace, stone deterioration, monitoring system.

Diagnostic studies and tests performed during restoration work revealed that detachments were generally due to the infiltration of water into the limestone.

On the top of the outer wall there is a gutter built into the masonry, which collects rainwater from the roof. The growth of weeds, or even shrubs, on top of the outer walls had obstructed the gutter thus blocking the drainage system and has caused the penetration of rainwater into the joints between the blocks and the core of the stone. The water absorbed by the stone froze into ice in winter, thus damaging the limestone, consuming the calcite along the lines of the geological veins and causing both large and small fragments of masonry to break off and fall to the ground. In fact, most cracks were concentrated in the big projecting cornice immediately below the gutter.

Therefore it has proved necessary to define a strategy in order to protect cornices, pillars, columns, capitals and coatings from damage caused by water infiltration and to monitor the state of conservation of the stonework, in this way taking the first steps towards a general system of preventive conservation.

As an experiment, an automatically timed system was installed to spray the gutter at the base of the roof with an herbicide, to prevent the growth of weeds. The device is operating on the crowning of the southern and western external façades.

Fig. 1
Before restoration: degradation of stone mouldings caused by rain water.

All horizontal surfaces of the mouldings of the façades, which are exposed to rain, have been covered with coatings of water repellent to prevent water infiltration into the stone material.

A monitoring system was installed in the corner of the main façade, one of the most critical areas of the building, to verify stability and measure the effect of external temperature variations and environmental vibrations on stone blocks. It consists of a series of sensors connected to some data loggers that transmit temperature values and any micro-routing to a peripheral device. The system monitors the most vulnerable stone blocks, with regards to geometric configuration, projecting dimension, rain exposure, and precise location in the architectural structure. Specialised software records the data and gives off alarm signals when the values exceed the safety threshold, allowing the control of the slightest deviation from the horizontal axis, which would in turn indicate the need to check the conditions of the façade stones using a basket lift.

All the information obtained during the restoration, through instrumental surveys such as 3D laser scanners, infra-red thermography and magnetometry, have been collected on a single platform (Integrated Diagnostic System).

The system will make it possible to compare the state of conservation of the façades before restoration with those that will be recorded after a few years, repeating the survey by use of a laser scanner. It will thus be possible to monitor the state of conservation of the façades and plan maintenance work in a timely manner to prevent the deterioration of building materials.

Bibliography

M. De Gennaro, D. Calcaterra, A. Langella, *Le pietre storiche della Campania dall'oblio alla riscoperta*, Luciano Editore, Naples, 2013.

Portuguese Presidential Palace's Structural Weaknesses Survey

Pedro Nunes de Brito Serra Vaz
General Secretary of the Presidency of the Republic, National Palace of Belem
pedrovaz@presidencia.pt

Bárbara Lhansol da Costa Massapina Vaz
Faculty of Architecture, University of Lisbon, Polo Universitário da Ajuda
blvaz@fa.ulisboa.pt

Abstract

The Palace of Belem was a Lord's Country House, started to be built in the 16th century, mainly built in the 17th century and with a lot of additions and changes until the 20th century. In 1726 the Portuguese King John V bought the House and it became a Royal small palace until 1910. After the Republican Revolution, the palace became the Presidential Palace of Portugal.

Being the Head of State's Office, the palace is a political centre, and a place of representation of the State, receiving representative guests from all over the World.

Because of its old construction, stability was designed by ancient methods. In 1755 Lisbon had a huge earthquake and most of the buildings afterwards were built using a new anti-seismic system. Belem was not affected by this earthquake, but the building was built before these concerns.

On the Presidency's demand, the National Laboratory of Civil Engineering (LNEC) made in May 2014 a structural weaknesses survey in order to identify possible damageable areas in case of an earthquake.

This survey aims to assess the risk and give the right information to the preventive structural reinforcements, which will have to be done in the respect of the Heritage Conservation principles.

Keywords

Presidential Palace, structural survey, risk assessment, reinforcements.

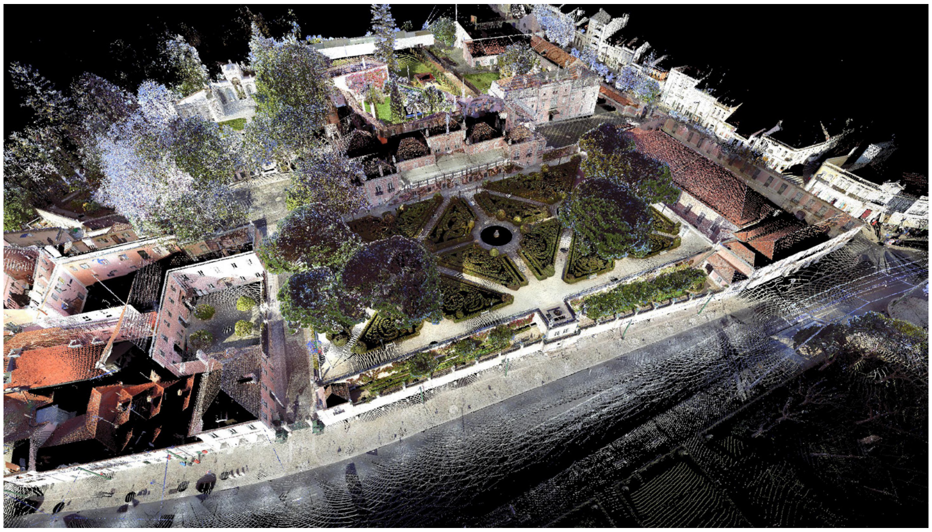


Fig. 1
Point Clouds: 3D laser scan and digital photogrammetry (381.5 M points), ArcHC_3D Research Group, FA, Univ. Lisbon.

Context of the Building

Being the President's official office, the palace has been for more than a century a political centre, a place for ceremonies for the representation of the State, receiving major political guests from all over the world. Because there is the Presidency's Museum inside, the compound receives public every day, especially on weekends, when all the major ceremonial rooms are open to public visits.

Regarding all this context, stability and structural security is vital for the preservation of the cultural asset and as part of the global security of the users and guests.

But because of its old construction, stability was designed by ancient methods and techniques, using traditional materials. In 1755 Lisbon suffered a huge earthquake, estimated to have been a level 9 earthquake in Richter Scale. Due to the collapse of almost all the buildings in town centre, all the new buildings afterwards were built using a new anti-seismic system, called "gaiola pombalina," a type of wooden 3D grid named after the Prime Minister of the time, the Marquis of Pombal.

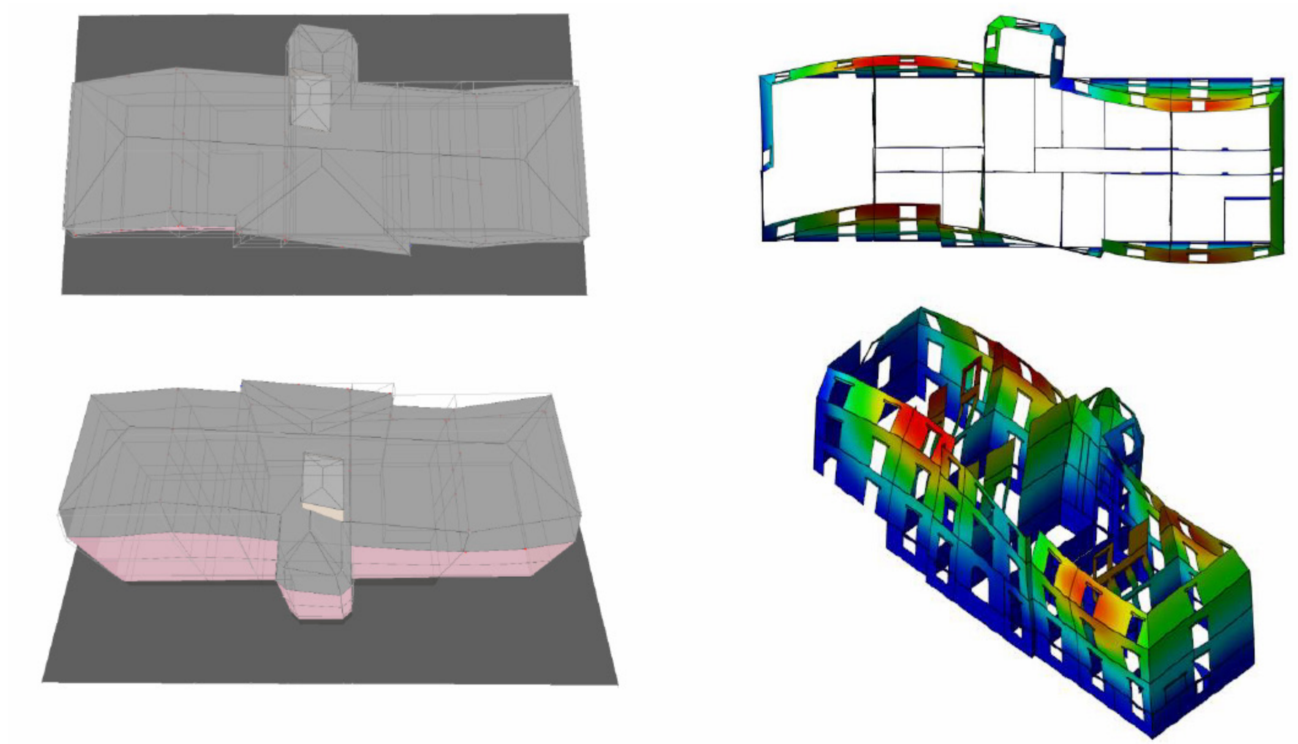
The Survey

On the Presidency's demand, the National Laboratory of Civil Engineering (LNEC) made in 2014 a structural weaknesses survey to identify possible damageable areas in case of an earthquake. A virtual 3D vector model was made to assess seismic stability. Some vulnerabilities were then identified and needed further analyses.

A 3D scan made in 2011 (fig. 1) was used to manipulate the entire complex as if it was a model, allowing to see it from several different perspectives, including 2D elevations and finding problems that were invisible from the ground. Some distortions found in the exterior walls of the main rooms were noticed at the time and became under surveillance. After 7 years, another 3D scan was done to the same problematic areas to monitor its evolution.

After the final LNEC report, a formal procurement within experts of this construction system from Portuguese Engineering Universities was made to design the structural reinforcements. The work was commissioned to the "Lest," The Structure's Laboratory of the Minho University.

Before starting to define reinforcement solutions, a very much detailed survey was made by a Research Team of Minho University to identify the strength, the modulation, the conservation state, the joints and the sanity of each piece in order to get the perfect characterisation and definition of every component. Moderately destructive tests like flat-jacks (simple at first and then double) and cores (wall samples) were made, as well as non-destructive tests like resistograph tests, sonic and radar tests, thermographic camera pictures, humidity measures,



etc. The cores were taken to the Minho University Laboratory and compressed until collapse, in order to know its resistance. This information, with all the other data from the survey was photographed, listed and then gathered into a 3D model, virtually shaken to estimate the structural behaviour of the buildings in the case of an earthquake (fig. 2).

Fig. 2
Experimental results and mode shapes from modal analysis, Inst. Sustainability Innovation in Structural Engineering, University of Minho.

Conclusion

Culturally relevant assets built in seismic areas such as the Portuguese Presidential Palace example need special attention to its stability and physical integrity. Estimated structural behaviour needs study in order to assure that minimum conditions of safety, both for the preservation of the cultural asset and for the people inside, will prevail in an event of an earthquake.

Bibliography

P. Lourenço (coord.), *Palácio de Belém, Levantamento Estrutural e caracterização de Materiais*, R.2016-DEC/E-28, ISISE, U. Minho.

P. Vaz, *Conservação do Património e Funções de Estado*, PhD Thesis, Faculty Architecture, University of Lisbon, 2016.

Traditional Maintenance Methods of Vernacular Houses in the Weavers Settlement of Paithan, Maharashtra for Preservation of Built Fabric

Ruichita Belapurkar
Architect
ruchita.belapurkar@gmail.com

Abstract

Traditional courtyard houses known as wadas, evolved across the western part of India in response to the climate. The wadas of Paithan, Maharashtra were studied in this research as they display a unique combination of technology, spatial planning, art and decoration. Due to availability of modern materials, the maintenance calendar of the wadas has deviated from the traditional cycle. The traditional methods of maintenance as well as preventive conservation were studied and correlated with the Hindu calendar of festivals. The study will help in the feasibility of reviving this traditional maintenance system and calendar.

Keywords

Vernacular architecture, traditional knowledge systems, maintenance cycles.

Fig. 1
Photo showing a variety of materials used in constructing the external envelope. (Source: author)

Month Marathi	Season	Festivals	Gregorian Month	Climatic Condition	Maintenance Cycle
Chaitra	Vasant (Spring Harvest Season)	**Gudi padva** New Year	March and April	Avg. Temp. – 32° C Humidity < 18%	Cleaning of entire house
Vaishakh	Grishma (Summer)	**Akshaya Tritiya** Auspicious day for remembrance of the ancestors			
Jyeshtha		**Vat Pournima** Women pray for longevity and health of husbands and family	May and June	Avg. Temp. – 36° C Humidity < 27%	
Ashadha	Varsh (Monsoon)	**Guru Pournima Divyanchi Amavasya**			Cleaning of all oil lamps (traditional lamps)
Shraavan		**New season for fishing**	July and August	Avg. Temp. – 30° C Humidity > 70%	
Bhadrapada	Sharad (Autumnal Harvest Season)	**Ganesh Chaturthi Anant Chaturdashi**			Cleaning of entire house
Ashwin		**Nauratra Dussera Kojagiri**	September to Mid-November	Avg. Temp. – 26° C Humidity < 50%	Cleaning of rooftops
Kartik	Hemanta (Autumn)	**Diwali**			Cleaning of entire house including preventive maintenance of wooden members.
Marghashirsha			November and December	Avg. Temp. – 22° C Humidity < 35%	
Pausha	Shishira (Winter)				
Magha		**Maha Shivratri**	January and February	Avg. Temp. – 22° C Humidity < 30%	
Phalguna	Vasant (Spring Harvest Season)	**Holi** Celebration of Spring			

Fig. 2
Ornamented teakwood columns in the wadas of Paithan.

Table 1
Linkage between festivals, seasons, climatic conditions and maintenance cycle of wadas of Maharashtra.

Traditional courtyard houses in the western part of India, particularly Maharashtra, known as wadas are built in local stone or brick in lime mortar and a structural wooden frame consisting of teak columns and beams that act as tie members for the structure.

The wadas in Paithan vary from the typical wadas of Maharashtra in their architecture as they are asymmetric and ornate (fig. 1 and 2).

The Marathi people follow the Shalivahana Hindu calendar where the Shaka New Year starts with the festival of Gudhi Padwa.[1] The weather and climatic conditions are interlinked as the festivals follow the lunar calendar and mark beginning of seasons.

The wadas are routinely maintained by the women of the household according to the Hindu calendar, with major maintenance done before the main festivals of Diwali and Gudi Padva (table 1). The maintenance cycle involves preventive maintenance of the wooden, stone and brick members to prolong their life along with cleaning and waterproofing of the roof.

The data collected and the practices observed display a deep rooted traditional knowledge system in place regarding the maintenance cycle of structures and links directly to the seasons and the community.

Notes

[1] http://www.theinfolist.com/php/SummaryGet.php?FindGo=Maharashtrians.

Bibliography

Belapurkar R., *Conserving the Historic Core of Paithan*, SPA, Delhi, 2016.

Morwanchikar R. S., *Woodwork of Western India*, D P Taneja, Delhi, 1985.

Pavillon Français, Estate of Trianon, Versailles.
© EPV/Danilo Forleo

ROUND TABLE 3

Preventive Conservation and Management of Climate in Historic Houses

Chairman
Sarah Staniforth
Former IIC President, International Institute for Conservation

Speakers
Veronica Ambrosoli
Danilo Forleo
Philippe Goergen
Sarah Staniforth
Aurora Totaro

International Environmental Guidelines and Collections in Historic Houses and Palace Museums

Sarah Staniforth
Former IIC President, International Institute for Conservation
sarah.staniforth@nationaltrust.org.uk

Abstract

This paper will examine the reasons why international environmental guidelines for museums are not appropriate for collections on display in historic buildings and if implemented will lead to atmospheric conditions that are likely to cause damage to the structure of the building. Since the mid-20th century, recommended conditions for temperature and relative humidity for museum collections have become closely defined and have been determined more by the need for human comfort and what can be achieved by HVAC (heating, ventilating and air-conditioning systems) than what will reduce the rate at which collections deteriorate.

In 2014 IIC and ICOM-CC published environmental guidelines with a number of statements including the need to better understand the complexities of the relationship between the museum environment and the deterioration of collections, and the need to reduce the carbon footprint of museums. The following year the international Bizot Group of museum directors published the Bizot Green Protocol which broadened the environmental specification recommended for international museum exhibitions to 16-25 °C and 40-60% RH with fluctuations of no more than plus/minus 10% RH in 24 hours.

The IIC/ICOM-CC guidelines state that care of collections should be achieved in a way that does not assume the need for air-conditioning. This is particularly relevant for collections housed in historic buildings since the introduction of the plant and ductwork needed for air conditioning systems may damage the fabric of the building. There are also risks associated with changing vapour pressure inside the building compared with the outside by humidification and dehumidification which can result in moisture movement drawing salts through the structure or water condensing in cold spots.

This paper will propose that by broadening temperature specifications, environmental conditions can be achieved that minimise deterioration of collections by limiting fluctuations in relative humidity using passive and low energy methods of climate control (fig. 1).

Fig. 1
Climate monitoring of the French Pavilion, Trianon estate, Palace of Versailles. (© EPV/ Didier Saulnier)


Synergy

“Sense and Sensibility:” Microclimatic Control and Preventive Conservation in Historic Houses. The Villa Necchi Campiglio Case in Milan

Veronica Ambrosoli
Preventive conservation and restoration manager,
FAI – Fondo Ambiente Italiano
v.ambrosoli@fondoambiente.it

Aurora Totaro
Preventive conservation and restoration manager,
FAI – Fondo Ambiente Italiano
a.totaro@fondoambiente.it
www.fondoambiente.it

Abstract

The FAI – Fondo Ambiente Italiano is the main non-profit foundation for the protection, the preservation and the enhancement of Italy’s natural and artistic heritage.

As demonstrated by this conference, attention is increasingly focused on the prevention of degradation, by acting on the environment in which the object is exhibited and not on the object itself. In other words, prevention practices are brought forward whereas conservation-restoration treatments have become almost exceptional.

Within the heritage managed by FAI, historical houses are particularly interesting cases to analyse. Indeed in these residences, the “sense” for respect of museum standards often contrasts with “sensibility,” the desire to maintain the conditions of this particular reality unaltered.

The case of Villa Necchi Campiglio in Milan, a building from the Modern Movement built between 1932 and 1935 by Piero Portaluppi (Milan 1888-1967), is iconic from a methodological point of view and is used as a model for all FAI properties.

Keywords

Collection conservation, preventive conservation, climate control, climate history.

In 2005, for the purpose of transforming a private house into a museum open to the public, the necessary adaptations were made to the buildings for its new functions while respecting climate standards for museums.

The climate monitoring facilities were installed in all the rooms and the data loggers allowed us to have an accurate diagram of the temperature, humidity and lighting values, as well as their variations over the seasons.

The analysis showed how the average values are not in line with the recommended museum standards. As historic house Villa Necchi Campiglio is a “system” were heritage is extremely diverse and it is necessary to seek a compromise between “climatic history,” that is the thermo-hygrometric conditions in which the objects have lived over time, and the values derived from museum standards.

The Villa has many glazed surfaces which have a lower thermal

Fig. 1
The conservatory of Villa Necchi Campiglio, an example of a glazed area where anti-UV films have been applied. (© Archivio FAI)

Fig. 2
The living room of Villa Necchi Campiglio, where the collections are extremely varied and different types of objects coexist. (© Archivio FAI / Giorgio Majno, 2008)

resistance then the rest of the building, naturally implying more radiation. As far as the reduction of light is concerned, we have therefore applied an anti-ultraviolet film on the Villa's historical window glasses, with the use of technical curtains or double-curtains.

To offset the increase in temperature, the efficiency of the system of fan coils installed in the house has been increased thanks to a large emission of cold air. In addition, the presence of vegetation and blinds limits "over-heating," and at the same time, the opening of windows during the day by Villa personnel allows better air circulation.

The house's unique characteristics, like double glazing, ensures a reduction of heat loss during the winter. This is further minimised by the hot air emitted by the fan coil units.

Once again, the compromise between "sense" and "sensibility" is achieved by progressively replacing incandescent light bulbs, where possible, with energy-saving LED bulbs. It is now possible to produce light bulbs suitable for historic houses that produce a "warm glow" effect that is reminiscent of old-fashioned candlelight.

Partial Bibliography

Ambrosoli V., Totaro A., 'La conservazione delle case-museo del FAI,' in *Strumenti per la gestione del patrimonio culturale: la proposta del FAI*, Milan, 2014.

Della Torre S., *La conservazione programmata del patrimonio storico-architettonico. Linee guida per il piano di manutenzione e consuntivo scientifico*, Milan, 2003.

Lucchi E., Totaro A., Turati F., *Villa Necchi Campiglio: diagnosi e gestione energetica* in "Casa&Clima," n°60, Year XI, March-April 2016.

Pavoni R., Zanni A. (ed.), *Case-museo a Milano: esperienze europee per un progetto di rete* in conference proceedings, 16 March 2005, Milan.

Sandwith H., Staiton S., *The National Trust Manual of Housekeeping*, London, 2006.

Climatic Monitoring of the South Central Body of the Palace of Versailles. Identification of the Collections Risk Thresholds

Danilo Forleo
In charge of preventive conservation and head of the EPICO programme, National Museum of the Palace of Versailles and Trianon
danilo.forleo@
chateauversailles.fr

Abstract

The identification of the risk thresholds related to the collections environment as well as easily observable deterioration indicators on the collections represents a fundamental element of preventive conservation assessment methods. The scientific literature concerning the deterioration process of the collections is very rich, nevertheless it is often very difficult to extract simple information for the monitoring of the conservation conditions of the collections. The application and the simplification of these principles, given the time constraints and the need for pragmatism that the collections manager faces everyday, is therefore essential. This principle guided the EPICO team's work whose first results were exploited in the context of the monitoring of the conservation conditions of the South central body of the Palace of Versailles, closed to the public in 2015 to 2018 for the renovation of the technical network, for fire safety and improvement of air treatment. Among the controlled parameters, climate was an essential element for monitoring the conservation conditions of the protected collections in situ and of the construction work.

Keywords

Preventive conservation, historical houses, climate control, risk threshold.

We present here the parameters taken into account for the identification of the thresholds for exceeding the temperature and relative humidity values that can be a risk for the collections kept in situ in the space of the work area. Climate regulation was carried out by an air handling unit (AHU) that provided heating in winter with a target of 13°C and all season continuous ventilation without the addition of humidifiers/dehumidifiers. The results of this treatment during the three years of the construction work were very satisfactory, it guaranteed the conservation of the collections which were inspected regularly and was a big energy saver.

Temperature and relative humidity control, objectives:

– be alerted only in the event of a real danger to the collections and avoid the risk of "desensitisation" resulting from repeated, irrelevant alerts for which corrective actions are not necessary (e.g.

MAX. THRESHOLDS: RH 90% or T 25°C

- The threshold of 90% RH is based on the minimum time for mould germination (24 h) on organic substrates at 25°C.
- At 90% the differences are more dangerous than in the intermediate ranges between 40% and 60% RH (mechanical deteriorations).

MIN. THRESHOLDS: RH 30% OU 5°C

- The threshold of 30% is based on the reaction time of the hygroscopic materials

Ex. unpainted wood/varnish reacts after 5/7 days of exposure at RH < 30%
30% is the breaking point for traditional paintings (canvas system, glues, film), a network of cracks is likely to develop.
Alarm time: 60 minutes – if the T C° or RH% exceed these thresholds, the alarm is triggered after 60 minutes.

FLUCTUATION THRESHOLDS: 6°C or 10% HR

Alarm time: 60 minutes – if the T C° or RH % exceed these deviations in a period of 60 minutes, the alert is triggered. These thresholds complete the warning system on rapid fluctuations related to possible malfunctions of CTAs

COMFORT THRESHOLDS: RH 40-75%; T°C 10-20°C

- Compliance range based on T and RH limits below mould germination conditions (75% of RH and 25°C for 15 days).

Alarm time: 24 hours – if the ranges of T°C and RH% exceed these thresholds, the alarm is triggered after 24 hours. This setting is based on:

- response time of the collections most sensitive to climatic fluctuations conserved in situ: 5-7 days at RH rates of less than 30%
- Reaction time to the alert by the team of preventive conservation and corrective action brought by CTA technicians: 2 days
- Return time to the desired values after the correction of the instructions (taking into account the capacity of the CTA, the inertia of the building, the sensitivity of the materials to the deviations of RH%): 2 days

The alert is therefore sent beyond 24 h of compliance ranges, which allows a return to correct climatic conditions (5 days) before the estimated reaction time of the materials of the most sensitive collections (5-7 days for unpainted wood or varnish/paints).

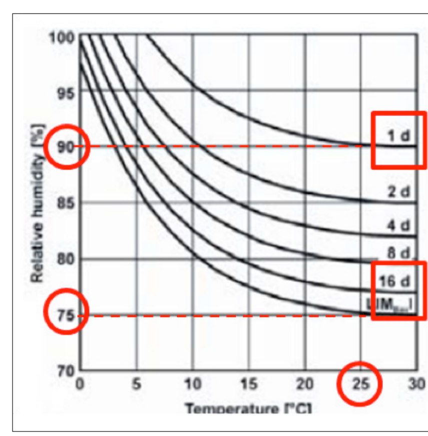
Fig. 1
Setting of alert thresholds.

exceeding the threshold of 75% RH ±5% and a permanence of this rate for 3 hours).

– React before an irreversible modification of the materials of the collections occurs following a deterioration of the climatic conditions.

Thanks to a telemetry system it was possible to ensure real-time climate monitoring of the construction site with an email/SMS alarm report in case of exceeding the risk thresholds for the collections.

Fig. 2
Prediction of mould fungus formation on the surface of and inside building component [Sedlbauer, Martens, 2001].



Identification of the Temperature and Relative Humidity Thresholds

Several factors were taken into account:

– the results of the studies carried out on the response of the collections' materials exhibited in real conditions of climatic fluctuations.
– The risk of mould development.
– The building's inertia and the performances of the CTAs.
– The average response time to the alert: return to the ideal climatic conditions ≤ time for raising doubt on the alert by the conservation team + time for care and application of the new directive by the teams in charge of the regulation of the CTAs.

Bibliography

Roche A., *Comportement mécanique des peintures sur toile: mécanismes de dégradation*, Cnrs Editions, 2003.

Strojecki M., Łukomski M., Krzemień L., Sobczyk J., Bratasz Ł., 'Acoustic Emission Monitoring of an Eighteenth Century Wardrobe to Support a Strategy for Indoor Climate Management,' in *Studies in Conservation*, n. 59, 2014, pp. 225-232.

Conservation State and Conditions of the Collections at the Historical Museum of Villele, Reunion Island

Philippe Gœrgen
Head of the Preventive Conservation Department, Centre for Research and Restoration of the Musées de France (C2RMF)
philippe.goergen@culture.gouv.fr

Aurélie Mac Luckie
Restorer
am.restauration@gmail.com

Jocelyn Perillat
Chargé d'étude documentaire, C2RMF
jocelyn.perillat@culture.gouv.fr

Natacha Provensal
Advisor of the Museums – Visual Arts, Dac océan indien
natacha.provensal@culture.gouv.fr

Abstract

The climatic study and the monitoring of the collections of the four museums on the Reunion Island from 2015 to 2017 show that the temperature and the relative humidity inside the historical museum of Villele are high but stable enough for a non-air-conditioned building. The good general condition of the exhibited collections and the absence of evolutionary degradation attest to a certain "acclimatisation" of the collections. By returning to light management and ventilation closer to the vernacular way of living (by adapting anti-intrusion devices) probably allows for the improvement of conservation and visiting conditions.

Keywords

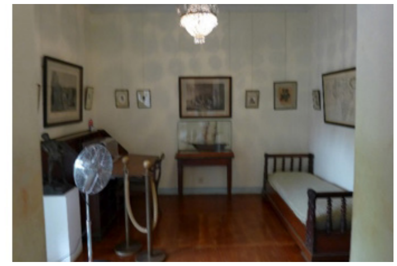
Conservation, museum, historic house, tropical environment.

At 478 m above sea level on the West coast of the Reunion Island, the Villele Museum, one of the oldest sugar producing estates on the island, homes the furniture and decorative arts of a wealthy landowning family from colonial Reunion. It exhibits prints,

Fig. 1
West facade of the Museum. (© C2RMF-PhG)

1. Entrance

2. Entrance, gallery



3. Bureau

4. Bedroom

5. Salon

6. Dining room

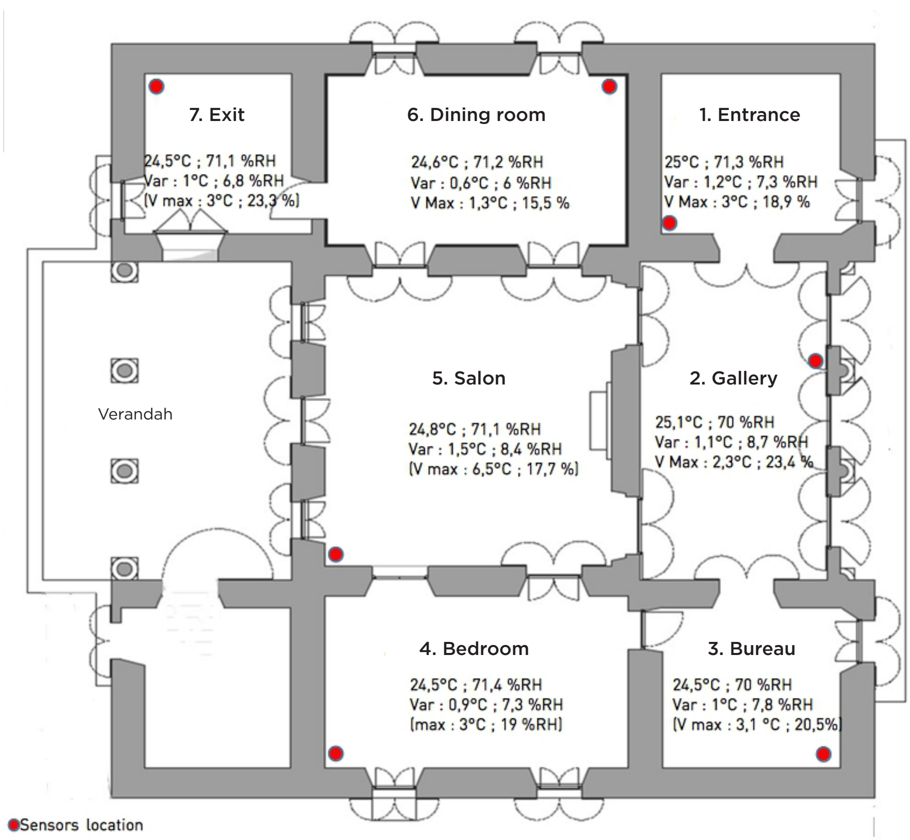


Fig. 2
Climatic data (photographies and slide C2RMF-PhG).

Outdoors climate	T°C Ext	%R HExt	Var T°C Ext	Var %HR Ext
Average	22	80,1	6,5	19,4
Minimum	13,6	46,4	2,1	1
Maximum	32,1	100	11,4	41,4

illustrations, maps and plans, oil paintings, tapestries and clothes, crockery and silverware [Barbier, 2014] under a humid tropical climate that is variable depending on the season, the altitude, exposure to trade winds and rain.

The mansion significantly reduces the outdoor humidity from 80.1% RH to about 70.8% RH but its indoor temperature at 24.7°C is 2.7°C higher than the outside temperature at 22°C.

The building dampens the average daily variation of 6.5°C and 19.4% RH outdoors and a 1.07°C and 7.4% RH indoors, the same as the buildings measured in Guyana [Gœrgen, 2013].

The atmosphere of the house is homogenous with small differences of 0.6°C and 1.4% RH between the rooms.

The condition report campaign of the collections identifies some starts of corrosion but reveals no recent fungal infection or serious alteration.

But the current measures against intrusion, which are closing doors and windows, block the building's original natural ventilation, increase the temperature and favour confinement. To open shutters for a better visibility also contravenes the traditional use of filtering light.

Conclusion

Under the measured climate, the visual and macro-photographic examination does not reveal any significant degradation of the collections. An instrumented mechanical study is however necessary to evaluate the conservation of the collection pieces in the long term. In the meantime, a management of the building which is more attentive to the historical architectural project, therefore with more of a heritage nature, would undoubtedly further improve the collections and the visitors' comfort.

Bibliography

Barbier J., 'Le musée de Villèle à La Réunion entre histoire et mémoire de l'esclavage. Un haut lieu de l'histoire sociale réunionnaise,' in *In Situ* (Online), 20 | 201, 2014.

Gœrgen Ph., Carita D., 'Climat tropical et musées : bâtiments, vitrines et collections,' in *Les sciences de la conservation du patrimoine et le développement durable : acquis, recherche, innovation*, 50 ans du CRCC, 32 mn, 2013. https://www.youtube.com/watch?v=vXfO8Z3tVIA.

Carriage for the crowning of Charles X, Carriage Museum, Palace of Versailles.

ROUND TABLE 4

Preventive Conservation and Light in Historic Houses

Chairman
Kerren Harris
Preventive conservation team leader, Historic Royal Palaces

Speakers
Kerren Harris
Nicholas Kaplan
Rob Van Beek
Emily Wroczynski

Balancing Conservation Risk Management and Enhancement of Light Within Historic Royal Palaces

Abstract
Choosing how and when to control and use light within historic spaces involves finding a balance between conservation risk management and enhancement. This article outlines how Historic Royal Palaces has used both traditional and innovative techniques to control natural light within display rooms, which are sympathetic to the architecture and atmosphere of the historic spaces, whilst also using enhanced artificial lighting to help visitors to view artworks and interiors as they may have originally intended to be seen.

Keywords
Historic lighting, light management, LED lighting, explaining tapestries.

Kerren Harris
Preventive Conservation team leader, Historic Royal Palaces, Hampton Court Palace
Kerren.Harris@hrp.org.uk

Kathryn Hallett
Preventive Conservation Manager, Historic Royal Palaces, Hampton Court Palace
Kathryn.Hallett@hrp.org.uk

Victoria Richards
Preventive Conservation team leader, Historic Royal Palaces, Kensington Palace, Kensington Gardens
Victoria.Richards@hrp.org.uk

Constantina Vlachou-Mogire
Senior Conservation Scientist, Historic Royal Palaces, Hampton Court Palace
Constantina.Vlachou-Magire@hrp.org.uk

Kate Frame
Head of Conservation and Collection Care, Conservation Management, Historic Royal Palaces, Hampton Court Palace
Kate.Frame@hrp.org.uk

This article aims to present an holistic review of research, technologies and methodologies for the management and augmentation of visible and ultraviolet (UV) light within the six heritage sites managed by Historic Royal Palaces, the independent UK heritage charity that looks after the Tower of London, Hampton Court Palace, the Banqueting House, Kensington Palace, Kew Palace and Hillsborough Castle.

Natural light levels are traditionally mitigated using UV window filters and window blinds, but the historical significance and variety of windows at each palace requires preventive conservators to research and develop innovative solutions to achieve high standards

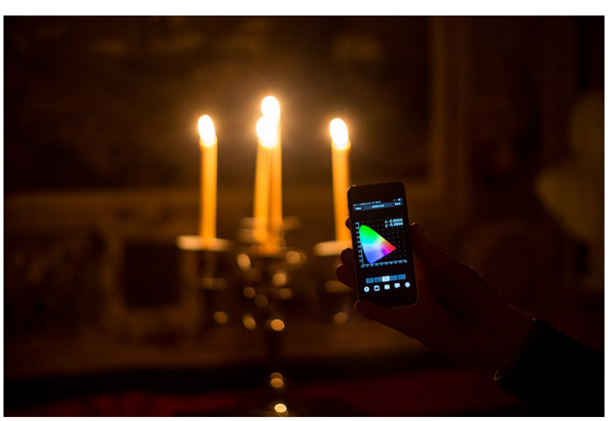


Fig. 1
Technical trial of historic candlelight at Kensington Palace.

Fig 2.
Window protection considering architectural views.

of conservation for individual artworks, within the overall holistic preservation of historic State Rooms. Aesthetic and physical consideration extends to internal and external architectural views of windows. Recent research includes bespoke risk-based solutions using (for example) electrically switchable LCD window films that are pressure mounted into window linings using magnet systems with no permanent fixings into historic stonework.

Next, a technical trial of historic candlelight, carried out at Kensington Palace, investigated the appearance of State Rooms in historically accurate lighting, and identified artificial (LED) lighting options for replicating this. Measurements recorded spectral output, colour temperature, colour rendering index, lux levels and flicker of historically accurate candle light, and a series of LED candle lamps were chosen for the lamp aesthetic, colour temperature, lumen output, dim ability and supplier availability. This trial aimed to inform decisions on lighting choices to ensure that a balance is achieved between the use of lighting to achieve an historic effect, whilst striving to optimise the conservation-safe illumination of individual works of art and meeting visitor expectations of artwork viewing conditions.

Finally, an award-winning scientific research project, *Henry VIII's Tapestries Revealed*, showed how digital light effects could be used to produce a virtual colour reconstruction of an important tapestry at Hampton Court Palace. This research resulted in an animated projection within an immersive exhibition that profiled conservators' work and the use of light technology in explaining tapestries to enthralled visitors.

This review of one organisation's experience aimed to initiate discussion between delegates to evaluate and share conservation-safe solutions for the management of lighting within historic houses, within the context of modern visitor expectations.

Bibliography

BSE/SLL, *Lighting Guide 11: Surface Reflectance and Colour*, Chartered Institution of building Services Engineers, London, 2001. http://en.licht.de/en/service/publications-and-downloads/lichtwissen-series-of-publications/.

Henry VIII's Tapestries Revealed (Youtube video, accessed on 12 July 2018), https://www.youtube.com/watch?v=Xzp6CVZnh8c.

Mapping the Big Picture: Time Lapse Documentation with GoPro™ Cameras

A Method for Monitoring Light in Historic Interiors

Nicholas Kaplan
Graduate Fellow
Winterthur Museum, Garden & Library

Patricia Silence
Director of Conservation Operations
Colonial Williamsburg Foundation
psilence@cwf.org

Joelle Wickens, PhD
Preventive Conservator and Associate Director of the Winterthur/University of Delaware Program in Art Conservation,
Winterthur Museum, Garden & Library

Emily Wroczynski
Marshall Steel Fellow,
Colonial Williamsburg Foundation
ewroczyn@gmail.com

Abstract

Purpose-built museums often choose specific lighting technology and rotate objects on display. Historic interiors have rooms where objects remain on view indefinitely. The latter is true for the Colonial Williamsburg Foundation (CWF) and Winterthur Museum, Garden & Library. CWF's historic area includes 18th-century structures and period rooms with collections on display. Winterthur's 175-room historic house showcase the founder's collection of American decorative arts.

These two institutions have partnered together in an on-going pilot study for visual monitoring of light in historic interior displays using GoPro™ action cameras. The primary goal of the study is to provide an overview of natural light on the interior over the course of a year. This presentation focused on data collection and the decision-making process for equipment choices. Preliminary results were shared to demonstrate potential for quantitative assessment paired with qualitative visual data.

Keywords

GoPro™ camera, light monitoring, real-time capture, metadata.

This project is implemented at CWF, a living history museum in Virginia and at Winterthur near Wilmington, DE. The case study interiors are described in table 1. This study will inform exhibition guidelines by accounting for seasonal light changes.

The study is inspired by S. Weintraub's c.2000 GoPro™ experiment seeking a location with the least amount of natural light exposure for a painting in the Frick Collection. A literature review found few studies with affordable real-time capture models vs. predictive modeling methodology.

Camera options including surveillance systems and multiband imaging equipment were investigated, but ultimately action cameras were preferable for their built-in wide-angle lenses (fig.1). GoPro™ was chosen specifically for brand reliability. GoPro™ designs offered the smallest footprint for discreet placement within interior displays. These cameras do not require an external WiFi network, but do need a power supply. Most models are compatible with third-party equipment,

<table>
<tr><th></th><th>CASE STUDIES / CAMERA PLACEMENT</th><th>DATA COLLECTION</th></tr>
<tr><td rowspan="2">COLONIAL WILLIAMSBURG FOUNDATION (CWF), VIRGINIA</td><td>GoPro Hero5 Session™ (38 x 38 x 35 mm)
Thomas Everard House, 1718 1st Floor Dining Room

• Southern exposure
• High quality, reproduction wallpaper and furniture
• Evaluate efficacy of blind closure</td><td rowspan="2">Conservation technicians download camera data weekly

• Incorporated into existing collections care routine
• One jpeg image/min 24 hrs/day

Integrated Light Metering = averaged
ISO max = 400
EV comp = 0.0
f/2.8 fixed aperture
White Balance = auto

• QP102 card mid gray card placed in interiors across from cameras to assist with white balance and normalization</td></tr>
<tr><td>GoPro Hero Original™ (42 x 60 x 30 mm)
Wetherburn's Tavern, c. 1736
The Porch Room (fig. 1)

• Southern exposure
• Accessioned furniture/collections
• No blinds</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>WINTERTHUR MUSEUM, DELAWARE</td><td>GoPro Hero4 Black™
CamDo Blink™ (41 x 59 x 43 mm Overall)
Winterthur Museum Billiard Room (fig. 1), 7th floor (2 cameras placed)

• Eastern and western exposure
• Views at or above tree line permit direct sunlight
• Long-term exhibition of varied collection materials
• Monitoring seasonal shifts to inform installation of sensitive materials</td><td>SD cards collected and replaced weekly
• CamDo Blink controls camera operation
• One jpeg image captured every 5 minutes (4:00 am-10:00 pm)

Night mode shutter speed max = 2 sec
Integrated Light Metering = averaged
ISO max = 100
EV comp = 0.0
f/2.8 fixed aperture
White Balance = native

• X-Rite Color checker placed in interior across from cameras to assist with white balance and normalization</td></tr>
</table>

Table 1
Description of installation of cameras and preliminary settings for pilot study.

like the CamDo Blink intervalometer, which powers the camera on and off at preset intervals.

Initially, there were technical issues related to interruptions of the power supply, which left gaps in data collection. The GoPro™ Hero5 Session had some problems with overheating and auto shutoff. These issues were resolved by replacing SD cards, completing a firmware hard factory reset and updating software.

Fig. 1
Wide-angle GoPro™ images showing Wetherburn's Porch Room with E. Wroczynski, D. Brooks, and A. Blake-Howland and the Billiard Room with N. Kaplan.

Image metadata is being analysed with the command line program Exiftool. Of interest specifically is the "light value," which the cameras use to determine automatic functions like shutter speed and is comparable to lux averaged over the camera's field of view. As a year of data is collected, protocol is being developed for processing images into a compressed, stacked view to help identify patterns of exposure. Settings and workflow are described in table 1. Final conclusions will be compared to architectural predictive light modelling.[1]

Endnotes

[1] Acknowledgements: A. Blake-Howland, D. Brooks, M. Henry, E. Oskierko-Jeznacki, J. Schneck, M. Truax, S. Weintraub

The Influence of Artificial Light on Historic Interiors

Rob van Beek
Architect at the Dutch Government Real Estate Department, Cultural Heritage and Art section
Rob.vanbeek@rijksoverheid.nl
www.rijksvastgoedbedrijf.nl

Abstract

We try to keep our historic rooms in the best possible condition, the room itself together with the items in it. We do that to be able to experience the interior in its original beauty, not only now but also in the future. What we see in practice, often well-preserved items are exhibited under such poor lighting conditions that it seems as if the objects are poorly preserved, that cannot be our intention! To be able to see all colours, we need light with a spectrum that contains all colours. Daylight, candle light and the incandescent light bulb all have a continuous spectrum. This is often not the case with modern energy-efficient light sources like compact fluorescent and LED lightbulbs. LED's seems to be the future but is difficult to select the right LED light source. Some will do in a certain room while others will give a more satisfying result in a different setting.

LED Lighting, a Blessing or a Disaster?

In order to see and experience a historic interior, we need light. However, this light, natural or artificial, is also damaging the materials in that space. There is a distinction between physical damage and visual damage. Physical damage involves the actual deterioration of colours and materials, visual damage occurs when an item is no longer visible in its original beauty because of the poor quality of the light under which it is displayed. The process of physical quality alteration of materials will go slowly over the years. Visual damage can occur instantly, simply by switching on the wrong type of light. Physical damage is mostly irreversible, visual damage caused by poor lighting can be repaired.

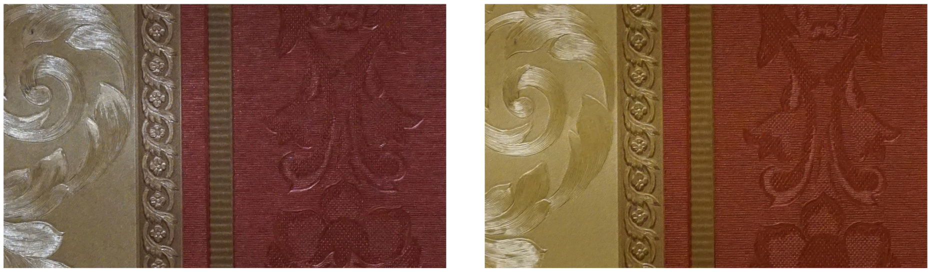


Fig. 1
Same wallpaper; different lightsources.

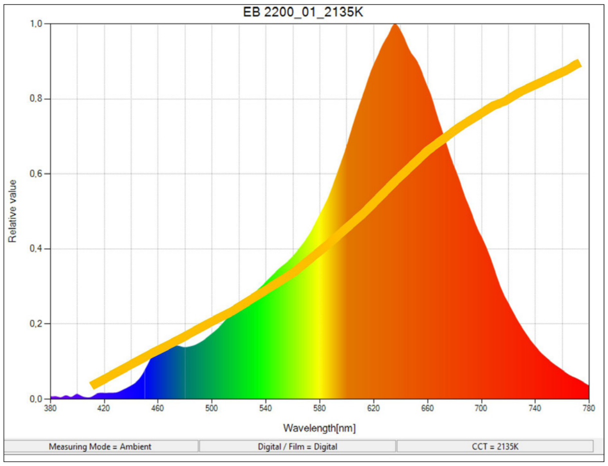


Fig. 2
Spectral distribution.

It is important to know the light conditions in a room and detect harmful situations to avoid physical damage. The goal must be to minimise the harm caused by light, and on the other hand maximise the visual overall quality of the interior. LED light seems to be the solution. LED light contains no ultra violet radiation and generates not much heat. On the other hand, the quality of LED light is not consistent. The phased out incandescent light bulbs from all manufacturers offered the same high-quality light, with LED that is not the case.

Candles are in many cases first replaced by incandescent candle bulbs and now, hundred years later, by LED candle bulbs. The first replacement meant almost always an increasing of the light level. The second one not only that, but also a decreasing of the quality of the light. Increasing light levels can be desirable, a loss of light quality must be avoided at all cost.

Modern LED luminaires can be small and provide additional light in a room without being visible themselves. Visually, only light is added to a room. This light is not authentic, the room and the items in it has never looked like this before. On one hand we try to preserve an authentic interior as well as possible, on the other hand we show that space to the public in a historically seen incorrect way. Adding light to a historical space can still be an ethically responsible solution. After all, the authentic low light level was not a conscious choice of the designer or architect. Technically it was simply not possible to create higher light levels. Artificial light was a scarce article until 150 years ago, when higher light levels became available, great use was made of it. Designers from previous centuries would probably also have added more light to their interiors when that would have been possible.

LED technology is relatively new, unfamiliarity has led to many wrong applications in recent years, also historical interiors have suffered visual damage and lost part of their beauty.

Bibliography

Van Beek R., Van Bommel W., Van der Geest H., *Electric Light in Historic Interiors*, Rijksgebouwendienst, 2011. English translation as pdf available on the internet.

Periodic maintenance in the Gallery of Tapestries.
© Governatorato SCV – Direzione dei Musei

ROUND TABLE 5

Preventive Conservation and Collection Care in Historic Houses

Chairman
Katy Lithgow
Former Head Conservator, National Trust

Speakers
Francesca Baldry
Thomas Bohl
Iris Broersma
Elfriede Iby
Katy Lithgow

The Sanitary Check of the Tapestries Deposited by the Mobilier National: the Example of the Senate

Thomas Bohl
Former Head
Curator of the Tapestries collections at the Mobilier national
Thomas.Bohl@louvre.fr

Abstract

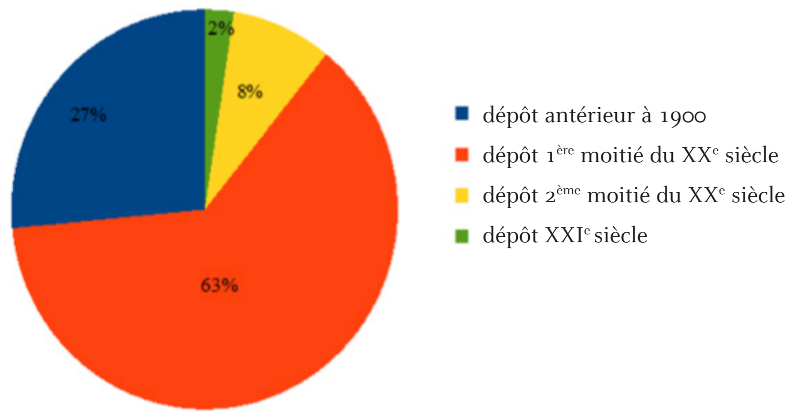
The conservation question and the restoration of the tapestries is decisive for the Mobilier national and its custodians. On the occasion of exchanges between the institution and the Senate, where are deposited a hundred tapestries, the two institutions decided to reflect on the subject. The need to take stock of the conservation state of the deposited tapestries, to facilitate the planning of future restoration operations, to reflect on suitable presentation conditions and to encourage an active deposit policy based on a rotation principle, has emerged as a crucial issue. A working group composed of agents from the Mobilier National (Thomas Bohl – heritage curator, Sophie Joly – conservator, Emilie Lagrange – in charge of preventive conservation) and the Senate (Frédérique Faublée, assistant administrator head of Heritage management) was constituted in order to draw up during the year 2015 a "sanitary check" of the deposited tapestries. It was conceived in three stages: a study of preventive conservation principles for textiles and in particular for tapestries, a review carried out by conservation place (presentation conditions) and by artwork (report), accompanied by recommendations, and finally a proposal for a multi-annual calendar for the restoration of the tapestries accompanied by a quantified estimate of the operations to be carried out, intended to facilitate the budgetary preparations of each institution.

Keywords

Tapestries, sanitary check.

It is, of course, difficult to implement in the context of a deposit policy in public administrations the commonly accepted rules for the preventive conservation of textiles. Nevertheless, a certain number of recommendations were issued during this sanitary check. They relied on a systematic survey of the lighting in each room where a tapestry is presented. In some cases, high values, between 300 and more than 1000 lux have been observed, leading to specific recommendations. In a global way, besides the proposals for improving the environment (installation of filters, closing of curtains and shutters, cutting the light during periods of non-activity), it is the rotation principle that has been encouraged.

Fig. 1
Results of the appraisal of the deposits from the Mobilier National.



Indeed, the sanitary check found that 90% of the tapestries in the Senate in 2015 had been deposited before 1950, with more than a quarter of the deposits prior to 1900. If the rotation principle appears as a compulsory precondition for the good management of the deposits, the question of the creation time of the deposited pieces also imposed itself as an important data to analyse. Indeed, the distribution of the tapestries is uneven, the majority of the deposited pieces being anterior to 1950, thus already subjected to consequent illumination. However, Mobilier National is rich of many tapestries woven during the second half of the 20th century and today, very little exhibited until then, and also perfectly representative of the continuity of excellence know-how of the Gobelins and Beauvais manufactures. The replacement of old tapestries, when they are not part of the historic setting, was thus encouraged in order to limit their lighting during the next years.

For each of the Senate's studied reception or office spaces, we drew up a summary condition report of all the exhibited tapestries in order to program restoration interventions, if necessary and, depending on the conservation state of the work, propose its replacement by another tapestry. In order to facilitate the programming of restorations, a score of 1 to 4 was assigned to each piece depending on its condition and the urgency of the planned intervention.

Restoration and rotation have thus emerged as the two pillars of the deposit tracking policy to be pursued during the coming years in the Senate. The appraisal of the situation in 2015 is conceived as a work tool for the teams of the Senate and the Mobilier National. This should ensure the best management of these leading art pieces.

Preventive Conservation at Villa La Pietra: Management, Collaboration, Education

Abstract

Villa La Pietra is located in the hills of Florence, Italy. It was the home of the Acton family between 1903-1994. In 1994 its collections were bequeathed to New York University (NYU). Preventive conservation measures have been implemented step-by-step during the last two decades. In March 2018 a one-week environmental monitoring campaign was conducted by two graduate students from NYU's Institute of Fine Arts' conservation program. Such collaborative projects are an essential component of the Villa's mandate for education and provide the students with a work experience while contributing to the long-term preservation strategy of the estate.

Keywords

Window films, LED, light monitoring, relative humidity monitoring, education.

Francesca Baldry
Collection Manager for the Acton Collection, Villa La Pietra, New York University, Florence, Italy
francesca.baldry@nyu.edu
https://lapietra.nyu.edu/

Hannelore Roemich
Professor of Conservation Science, Conservation Center of the Institute of Fine Arts, New York University
hannelore.roemich@nyu.edu
https://www.nyu.edu/gsas/dept/fineart/conservation/index.htm

Preventive Conservation at Villa La Pietra

In 1994, the collections – comprised of more than six thousand artworks, a library of 12,000 volumes and an archive of photographs, contained within a historic 15th century Villa and gardens – were left to NYU. NYU's Institute of Fine Arts (IFA) established a holistic

Fig. 1
Sala da Pranzo – Monitoring RH and temperature. (Source: Katherine Parks, Villa La Pietra, NYU Florence)

Fig. 2
Rotonda – high priority location for light monitoring. (Source: Lowry Palmer, Villa La Pietra, NYU Florence)

approach for the care of the estate in partnership with the Italian State Fine Arts authorities (Soprintendenza). This collaboration is an essential component of the Villa's sustainable conservation plan [Ducey-Gessner *et al.,* 2016].

Faculty and students of the IFA's Conservation Center have been performing conservation treatments every year, for one or two weeks. The first preventive conservation project in March 2018 offered the

YEAR	AREA	IMPLEMENTATION
1999/ 2000	Pest Management	Chemical treatment of wood-boring beetles in 1999. Since 2000 anoxic treatment with nitrogen. Inspections during dusting sessions.
2003	Climate Control System	Automatic A/C system control. Additional spot readings and recordings of RH and temperature.
2003	Visitor Management	Guided tours restricted to 15 people. Shoe covers, mats under carpets, stanchions. Volara and Mylar protection under art objects on furniture. Regular checks of hanging systems and supports. 6000 visitors per year.
2003	Storage	Two climatized spaces. Survey in 2013.
2003	Particulate	Regular dusting by conservators-restorers.
2003	Security	Fire alarm system in compliance with the Italian and American regulations.
2003	Condition Documentation	Condition surveys are completed or on-going for all parts of the collection.
2003-2014	Light Control	2003: shutters closed when there are no visits. 2006: Blue Wool Standard in 3 rooms. 2014: UV-filtering windows films in 13 rooms.

Table 1
Step-by-step implementation of preventive measures at Villa La Pietra.

students a training opportunity in the conservation challenges particular to historic homes.

Katherine Parks (2nd year student) undertook a survey of devices for recording relative humidity (RH) and temperature currently used at the Villa. Equipment and workflows for monitoring will be upgraded as a result of this study. Hobo data loggers are considered as an option and were tested in a trial run (fig. 1).

Soon Kai Poh (3rd year student) concentrated on the assessment of lighting conditions, starting with areas of high levels of daylight (fig. 2). The window films (Llumar – Helios THE80) installed in 13 rooms in 2014 and the installation of LEDs are effective measures, which reduce the risk of damage by UV to a minimum. An overview of measures implemented since 1999 is given in table 1.

Bibliography

Ducey-Gessner A., Beyer C., Dommermuth J., Marincola M., Trupin D. L., Perrone Da Zara C., 'Building an Effective Decision-Making Model for Conservation of the Acton Collection, Villa La Pietra, New York University in Florence,' in Seymour K., and Sawicki M., *The Artifact, Its Context And Their Narrative: Multidisciplinary Conservation In Historic House Museums*, International Council of Museums – Committee for Conservation (ICOM-CC) and Committee for Historic House Museums (DEMHIST), Los Angeles, 2016, pp. 1-16.

Is the Answer 42? Developing a Performance Indicator for Preventive Conservation

Katy Lithgow
Former Head Conservator,
National Trust for England,
Wales and Northern Ireland,
UK
katy@perry-lithgow.co.uk.
www.nationaltrust.org.uk

Abstract

The National Trust owns over 350 properties of which 250 are historic houses containing over 1 million objects. Preventive conservation is prioritized as the most cost effective way of caring for them. Since 2003, the Trust has used a Conservation Performance Indicator (CPI), alongside other performance measures such as income and visitor numbers, to assess whether condition is improving, declining or remaining static year on year. Since 2017 the CPI has been standardized to provide greater management insight into seven asset categories, of which one covers collections and historic interiors. This paper discusses how different types of preventive measures can be compared to infer their impact on condition; and whether reducing performance to numbers helps or hinders the professional profile of conservators.

Keywords

Preventive conservation, conservation performance indicator, historic house museums.

Historic house collections and interiors are one of seven categories that the National Trust (NT) for England, Wales and Northern Ireland uses to describe whether, through annual comparison of previous scores, the condition of its assets has improved, stayed the same, or declined (fig. 1). The Conservation Performance Indicator (CPI) was developed in 2003 to enable the condition of these assets to be reported on numerically, alongside other key indicators such as visitor numbers and financial performance. Originally it was considered that each property's individuality meant they could not be compared [Lithgow *et al.*, 2008]. However, the desire for improved management insight led to the CPI being revised in 2014 to enable national conclusions to be drawn by standardising the measures.

Conventional risk management calculations [e.g. Karsten *et al.*, 2012] do not allow the direct correlation of condition with risk. In addition, the Trust does not have comprehensive inventories and condition records of its cultural heritage assets. Consequently the CPI for cultural heritage uses progress on dealing with known remedial conservation priorities (condition measure 1) alongside effectiveness of managing

CONDITION: Measure 2: Preventive Conservation Please also refer to the technical guidance document for a description of each of the bands "Very Low" through to "Very High"
The scores generated by this spreadsheet and the data behind these should be used with professional judgement; an individual environmental factor may be more or less important for some of our collections and interiors. The spreadsheet suggests a weighting where "1. Physical damage prevention" contributes most to the score and "6. Insect pests" the least, again professional judgement should be applied here to sense check this for the specific Collections and Interiors CPI Feature.

Measure	Definition	Very High Score 4	High Score 3	Medium Score 2	Low Score 1	Very Low Score 0	Notes/Justification	Score (from 0 to 4 for each criteria or N/A)	Suggested Weighting
1. Physical damage prevention	Nos of objects/ surfaces damaged (accidents, wear and tear) since last CPI review	Only 1 or 2 have acquired minor damage (Condition Code B)	3-10 have minor damage (Condition Code B); 1-2 noticeable damage (Condition Code C)	3-10 have noticeable damage (Condition Code C)	More than 10 have noticeable damage (Condition Code C)	Any with considerable damage (Condition Code D)	3 objects have acquired minor damage B), none have acquired noticeable damage (C)	4	6
2. Custodial neglect/ displacement or loss	% of inventoried objects missing (both showrooms and stores)	0-1%, or no more than 20 objects, whichever figure is smaller	2%, or no more than 21-40 objects, whichever figure is smaller	3%, or 40-79 objects, whichever figure is smaller	4% or 80-99 objects, whichever figure is smaller	5%+, or more than 100 objects, whichever figure is smaller	75 objects unlocated out of an inventory of 10,000	4	5
3. Dust management/ Cleaning Hours	Recommended level of cleaning hours achieved annually based on housekeeping challenge*	100% target achieved	80%-99% target achieved	60-79% target achieved	40-59% target achieved	Less than 40% target achieved	Band B property (HM) achieved 73% of sustainable cleaning hours	4	4
4. Light	High sensitivity dosimeters meet target. No unacceptable light induced damage	All high-sensitivity dosimeters < 150k lux hrs; if none, all mod-sensitivity dosimeters <600k lux hrs.	Average of high-sensitivity dosimeters <150k lux hrs; if none, all mod-sensitivity dosimeters average <600k lux hrs pa	Average of high-sensitivity dosimeters 150k -300k lux hrs; if none, average of mod-sensitivity dosimeters 600k-1mill lux hrs.	Average of high-sensitivity dosimeters +300k-600k lux hrs; if none, average mod-sensitive dosimeters >1 mill lux hrs.	Average of high-sensitivity dosimeters >600k lux hrs; if none, no light monitoring carried out.	Average of high sensitivity dosimeter 140k lux hours	4	3
5. Relative Humidity (RH)	25th percentile of time in 40-65% band for all collections spaces (target: 25th percentile > 85). No unacceptable RH induced damage.	>85%	70-85%	50-69%	20-49%	<20%	Readings within 40-65% RH for 92% of the year	4	2
6. Insect pests	No active insect pest attack	IPM in place and results up to date. No evidence of active insect pest damage	Pest traps deployed, results up to date. Minor active insect pest damage (Condition Code 2, Stability Code IV)	Pest traps are deployed but full IPM not practised. May also be moderate active insect pest damage (Condition Code 3, Stability Code IV)	Pest traps deployed, but full IPM not practised. May also be severe active insect pest damage (Condition Code 4, Stability Code IV)	No pest traps deployed, full IPM not practised, not aware whether insects active or not. May also be evidence of insect pest damage.	IPM in place, readings up to date and sent in, no evidence of active insect pest infestation.	0	1

Suggested weighted score:	**95**
Suggested score if all elements are weighted equally:	**83**

Asset Category	Average Feature Condition Score (%)
Landscape & Setting	56.7
Archaeology	54.5
Nature & Wildlife	51.4
Gardens & Parks	50.2
Buildings & Structures	49.9
Natural Resources	46.8
Collections & Interiors	43.4

Fig. 1 (above)
All NT asset categories listed according to 2017 results.

Fig. 2 (left)
The Preventive Conservation element of the Condition Measure in the National Trust's (NT) Conservation Performance Indicator for Collections and Interiors.

risks by house staff through preventive conservation (condition measure 2, fig. 2) to indicate whether condition has changed or not, in a priority order reflecting NT conservation practise. Defining performance bands for each criterion, and weighting the results according to prioritisation of the severity of the risk, enables inputs (such as housekeeping hours) and outputs (RH and light levels) to be compared with outcomes (e.g. numbers of objects manifesting changes in physical state – damage – per year). Other conventional risk factors (e.g. fire, flood, theft) are managed through other asset categories (i.e. buildings). The state (completeness, date) of underpinning knowledge (inventory/catalogue, and conservation record) is used as a confidence factor to moderate remedial and preventive measures.

Results suggest that in 2017 historic house collections and interiors are in a worse state than other asset categories. Causes include increasing hours of access and number of visitors without a corresponding investment in preventive measures to manage light, pollutants (particularly dust), and disassociation, whilst RH and IPM results give less concern. These measures, practised for over 25 years in some cases, are more rigorous than for other asset categories, which, perversely, means that conservators' interpretation of these results is even more important to demonstrate the value of their professional judgement over and above the spreadsheet. For the profession and their clients (property staff) it will be important to ensure that the pursuit of the number does not become divorced from the question, which is how best to ensure NT historic house interiors and collections can be enjoyed and passed on to future generations, in line with the organisation's core purposes.

Bibliography

Adams D., *The Hitchhiker's Guide to the Galaxy*, Pan, London, 1979.

Karsten L., Michalski S., Case M., Ward J., 'Balancing the Preservation Needs of Historic House Museums and their Collections Through Risk Management,' in *The Artifact, its Context and their Narrative: Multidisciplinary Conservation in Historic House Museums*, GCI 2012, Los Angeles, Paper 10, 2012. http://www.icom-cc.org/ul/cms/fck-uploaded/documents/DEMHIST%20_%20ICOM-CC%20Joint%20Interim%20Meeting%202012/10-Karsten-DEMHIST_ICOMCC-LA_2012.pdf.

Lithgow K., Staniforth S., Etheridge P., 'Prioritizing Access in the Conservation of National Trust Collections,' in *Conservation and Access: Contributions to the IIC London Congress 2008*, 15-19 September 2008, International Institute for Conservation of Historic and Artistic Works, London, 2008, pp.178-85.

Preventive Conservation in Schönbrunn Palace – Preventive Conservation of an Heterogeneous Collection

Elfriede Iby
Head of research and documentation of the Schloß Schönbrunn Kultur und Betriebs.ges.m.b.H. and chief curator of Schönbrunn Palace, Imperial Apartments of the Viennese Hofburg, Schloss Hof
Schloß Schönbrunn
Iby@schoenbrunn.at

Abstract
Schönbrunn with its apartments in the palace and its gardens, dating back to the 18th century and ongoing use by the imperial family of the Habsburg dynasty, belongs to the most frequented sights of Austria. The amount of visitors in the historic building as well in the gardens are increasing each year and had reached more than two millions in the palace and around 6,5 millions in the gardens with its bosquets, fountains, sculptures and garden architecture. As the whole sight was outsourced in 1992 in form of a private company, but still in the possession of the Austrian Republic, the corporate mission of the company is to use and protect the historical sight with all its parts. Therefore, this mission provokes the big challenge and beside restoration work, the preventive conservation is one of the most efficient strategies to fulfil the high responsibility, which has to be assumed by the company. Preventive conservation is even more important in historic buildings, as the implementation of modern structures, i.e. climate control systems, are not realisable: it would destroy that, which has to be protected.

Keywords
Cultural heritage, historical buildings, preventive conservation, climate control, curatorial cleaning, dust, damages.

Since 1996 on the UNESCO World Heritage sights listed, Schönbrunn is one of the most important monuments and cultural sights of Austria. The imperial apartments of Schönbrunn Palace are open to the public 365 days a year, without any closing day.

The amount of almost two million visitors a year and other commercial and/or cultural use provoke a considerable challenge to fulfil the corporate mission pretended by the Republic of Austria.

Since 1992 in various European initiatives regarding preventive conservation many initiatives in the field of restoration and preventive conservation of the construction itself and the dependent environment features were undertaken. From the year 2000 ongoing, a very ambitious concept as part of preventive conservation has started and a curatorial cleaning-program has been elaborated.

Due to intensive use of the historical apartments (visitors, receptions

Fig. 1
Condition monitoring of the representive Salon on the ground floor. (© Schloß Schönbrunn Kultur- und Betriebsges.m.b.H.)

etc.) and the impact of dust, humidity and different risks of damages an annual curatorial cleaning campaign was established, being accompanied by preventive interventions and by recording the annual condition. The campaign includes:

– staff training before starting the annual campaign between autumn and spring;
– cleaning of circa 60 rooms with historical refurbishing and circa 2.500 items by the cleaning staff under the supervision of a restorer;
– cleaning of circa 20 rooms with very sensible and delicate superficies (i.e. lacquer, paper, textile) by restorers;
– condition report and documentation of each room / each item, entering directly in the database;
– immediate interventions by restorer (fixing loose parts) if needed to stabilize the condition.

All this components/informations lead to a comprehensive condition monitoring being inserted into a database.

The stabilization of an indoor climate and a long termed climate concept serving for the demanded preventive conservation and also satisfying visitor's demands is one of the biggest challenges in times of the worldwide climate change.
Already existing measurements are:

– structural interventions like closing open courtyards to avoid uncontrolled indoor climate;
– supply of preconditioned air (temperature and humidity) via historical tunnels and chimneys;
– elaboration of practical devices/guidelines like i.e. for opening/

Fig. 2
Condition monitoring of the painting "Family Portrait of Maria Theresa" via insert database. (© Schloß Schönbrunn Kultur- und Betriebsges.m.b.H.)

closing windows, introduction of local and individual air conditioners, providing humidity and its service and care;
– permanent climate measurement in selected historic rooms.

All the existing data of the climate measurements need further on professional analyses and interpretation of the climate data with the result, that the indoor climate can be stabilized even within this extensive use of the historical rooms.

Another tool of the preventive conservation concept is the Visitor's Flow Management. It includes:

– limited number of visitors (800 persons/hour);
– connected with the analogue and online-ticket sale and reservations in advanced;
– directly controlled at the gates;
– permanent discussion with conservators if an increasing number of visitors could be arguable regarding the preservation of the historic rooms and items and its long termed protection.

Bibliography
Kippes W. *et al.*, *Climate in Museums and Historical Buildings*, Wissenschaftliche Reihe Schönbrunn, vol. 9, Schloß Schönbrunn Kultur- und Betriebsges.m.b.H, Vienna, 2004.
Iby E., 'Forschung, Dokumentation und Sammlungsmanagement,' in Kippes W., Sattlecker F., S*chloß Schönbrunn Kultur-und Betriebsges.m.b.H. 20. Jahre Denkmalpflege 1992-2012*, Wissenschaftliche Reihe Schönbrunn, vol. 11., Schloß Schönbrunn Kultur- und Betriebsges.m.b.H., Vienna, 2012, pp. 53-61.

Het Huys ten Donck: Steps Towards Professional Collection Care

Iris Broersma
Architect and researcher in historic interiors, Het Huys ten Donck Foundation
www.erfgoedzorg.nl
iris@erfgoedzorg.nl

Catharina Groeninx van Zoelen
Director, Het Huys ten Donck Foundation
www.huystendonck.nl
catharina@huystendonck.nl

Martine Posthuma de Boer
Independent conservator, MPB Conservation-Restoration
www.linkedin.com/in/mposthumadeboer/.
mposthumadeboer@gmail.com

Abstract

This three-years project aims at a methodical implementation of collection care that complies with the limited means of the foundation. It was developed as a step by step approach of knowledge development, knowledge transfer and team building. Exchanges between the local community, professionals and students gathered around a common interest in this important Dutch manor house resulted in an enchanting first year. The involvement of professionals from the fields of textiles, metals, stucco, historic interiors, preventive conservation, collection management and communication also made this an interdisciplinary project.

The project fits in a broader plan to reconnect the manor house to the local community and to the cultural community of the nearby city of Rotterdam. The first year showed promising results.

Keywords

Housekeeping, collection care, volunteers, local community, academic cooperation, knowledge transfer.

Het Huys ten Donck was built in 1746 by Otto Groeninx van Zoelen (1704-1758, mayor of Rotterdam), as *maison de plaisance*. Finishings were added all throughout the 18th century, mainly in Louis XV style and include great plasterworks by the Italian stucco masters Castoldi and fabulous woodcarvings by anonymous Dutch craftsmen. The French gardens were later adopted to landscape style with addition of several follies (also national monuments). Since the 1920s the house has been inhabited on a permanent base, after the first adaptions since completion of the house. The moveable collection is strongly related to the house's and family history and consists of objects from the 16th until the 21st century [Thoen, 2006]. Today the estate is run by a charity foundation, set up in 1978 and the house is inhabited by the 9th and 10th generation descendants of the builder. This results in a warm authentic homey style. Guided tours are provided every season and the house is let for photo and film productions, weddings and corporate dining.

Fig. 1
Staff and volunteers of *Het Huys ten Donck* and students of the Reinwardt Academy at the rear of the house after a joint session of knowledge transfer in June 2017. (© Johan Kruithof, De Combinatie Ridderkerk)

Goals of the Foundation and its collection care project:

– to attain an economically, environmentally and materially sustainable exploitation of the estate;

– to reposition the estate for the future and re-establish close connections with the local community;

– to develop and install a collection care plan including good housekeeping with the support of local volunteers;

– to protect the vulnerable collection for side-effects of the upcoming project on renewable energy.

A Three Years Project and a Pilot in 2017

Funds were raised to start a pilot under professional guidance. The ambitions include installation of a team of volunteers, knowledge transfer, customized working methods and procedures for good housekeeping, collection management, cooperation with the academic field and sharing the results.

"Work in Progress"

At the end of 2017 the intermediary results show:

– a team of 12 volunteers, driven and enthusiastic, who are working at the house two to three times a month under professional guidance. Several workshops held, knowledge transfer, development of some procedures, methods and schemes for housekeeping.

– Exchange between volunteers and 12 students from the University of Amsterdam, 30 students from the Reinwardt Academy and their professors (fig. 1).

Fig 2
The Grand Reception Hall with temporary storage for curtains and paintings with regard to the building works. (© C. Groeninx van Zoelen)

– Completion of global risk analysis, basic list of objects per room, damage assessments, advices. Establishment of protective measurements, including the development of a temporary storage for textiles and paintings (fig. 2).

Looking Forward to 2018 and 2019

Steps for the upcoming period include:

– completion of the *Donck's Guide for Good Housekeeping*. Short videos to share the experiences. Formulation of a collection management plan. Start monitoring on pests, climate, light and physical damages.

– Summer projects, master classes and special interest gatherings to publically share the house's craftsman work.

Bibliography

THOEN I., *Het Huys ten Donck en de familie Groeninx van Zoelen,* Stad en Bedrijf, Rotterdam, 2006.

03

Science Applied to the Preventive Conservation of in Situ Collections: Essential Support for Conservation Diagnostics and Actions

For several years, science has become a fundamental branch in the scientific approach of heritage material conservation, the contribution of new technologies are recognised as indispensable in the field of restoration but also of curative and preventive conservation. The third axe of the conference aims to link recent high-level scientific research and practical consequences that these results can have on collection management.

In situ observations by English Heritage, the Getty Conservation Institute, Yale University and the Fondation des Sciences du Patrimoine are major realities in this field, and particularly research on the response of materials to deterioration factors with slow and cumulative effects (climate, light, dust...).

These themes are particularly significant for the collections in historic houses, which are often exhibited in a very different environment from the ideal conditions advocated in the standards of conservation of museum collections. Contrary to the 1990s approach, based on the observation of the behaviour of samples processed artificially in a laboratory, the current research focuses on the observation of collections in real exhibition conditions. The analysis of this response is a very supportive tool for decision-making, that includes, for example, the choice of climate treatment within historic buildings.

This same approach has guided the EPICO team in researching and then extrapolating deterioration indicators that can be used in the day-to-day management of historic houses. The aim is to identify with field equipment deterioration sources to act effectively before they produce an irreversible effect on the material of the collections.

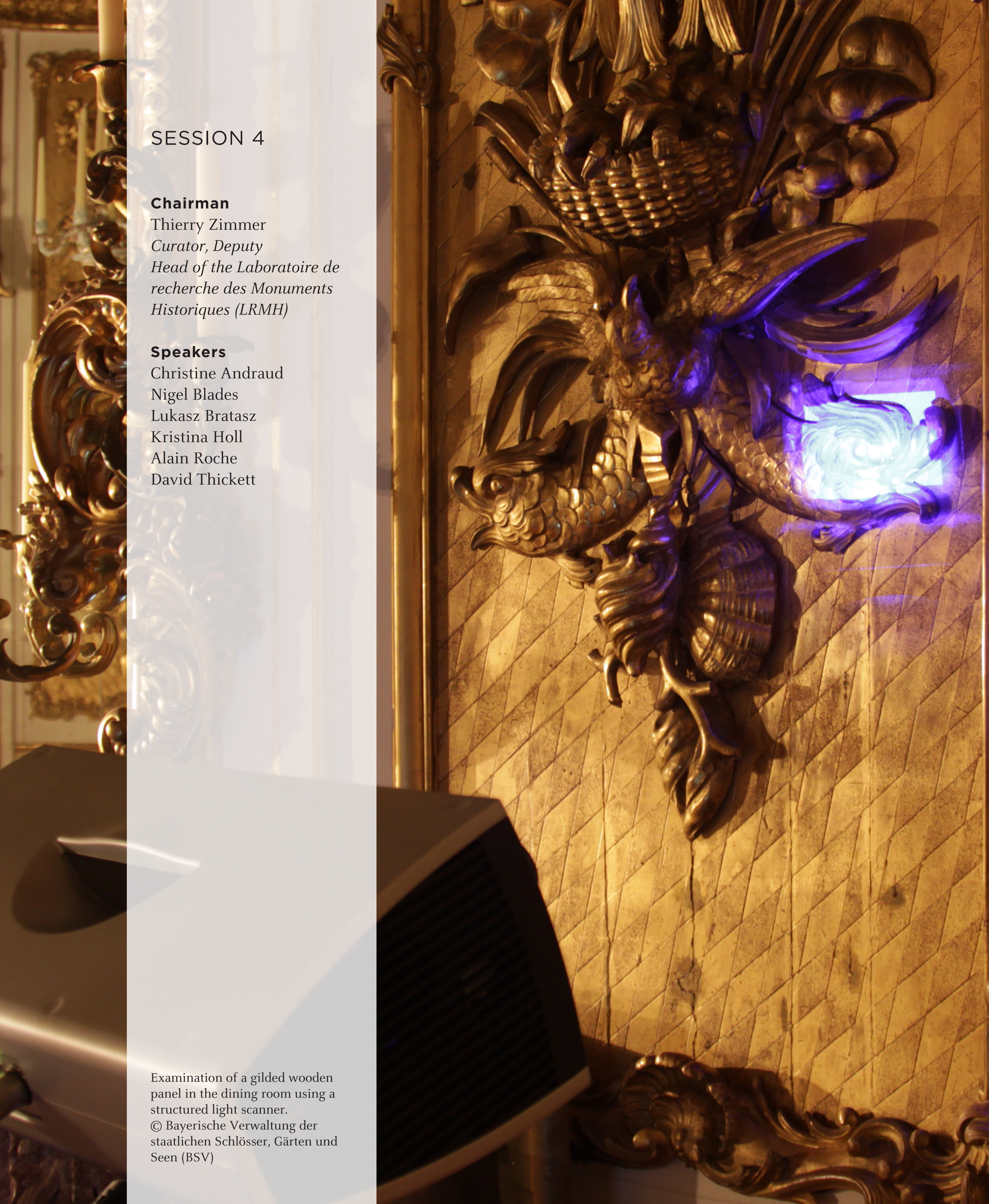
Themes:

1. Studies in hard science applied to the diagnosis of degradation phenomena (response of the object's materials to conservation conditions).
2. The exploitation of these researches for the identification of simple and exploitable deterioration indicators during ordinary preventive conservation activities.

SESSION 4

Chairman
Thierry Zimmer
Curator, Deputy Head of the Laboratoire de recherche des Monuments Historiques (LRMH)

Speakers
Christine Andraud
Nigel Blades
Lukasz Bratasz
Kristina Holl
Alain Roche
David Thickett



Examination of a gilded wooden panel in the dining room using a structured light scanner.

Using Science to Assess and Predict Object Response in Historic House Environments

Abstract

Conservation assessment of objects is essential in historic house environments. Tight environmental conditions are not possible without very significant and often undesirable, alteration to the building fabric. Scientific techniques can support conservation assessment.

Periodic inspection techniques have been applied to furniture, ivory, and paintings. However, it can be very difficult to assign any damage observed, to particular environmental events. Continuous monitoring techniques can overcome this, with the effects of environmental fluctuations being obvious in the high frequency measurements.

The high cost or expertise required means these techniques will only be available in some instances. However, the results from these studies are ideal to develop damage functions to better assess other environments. Research has developed new damage functions and verified published functions. English Heritage collects data about all observed damage (and instrumental analysis) on its collections. This approach, although still developing, has proved extremely powerful to assess complex environments and develop evidence based risk assessments.

Keywords

Acoustic emission, digital image correlation, RH fluctuations.

David Thickett
Senior Scientist,
English Heritage
david.thickett@english-heritage.org.uk
www.english-heritage.org.uk

Vladimir Vilde
History of Art Department,
University College London
vilde.15@ucl.ac.uk

Paul Lankester
English Heritage
paul.lankester@english-heritage.org.uk
www.english-heritage.org.uk

Emma Richardson
Material Studies Lab,
Department of History of Art,
University College London
e.richardson@ucl.ac.uk

Conservation assessment of objects is essential in historic house environments. Tight environmental conditions are not possible without very significant and often undesirable alteration to the building fabric. The recent CEN historic environment standard depends on conservation assessment to determine an object's stability or otherwise [BSI, 2010]. Scientific techniques can support conservation assessment and in some instances sensitive, portable instruments can detect damage before it is visible to the naked eye.

Attribution of damage cause is very common within conservation, both to improve environments where required and during auditing. Many deterioration phenomena look visually similar and scientific analysis can help differentiate in some situations. Analytical equipment is becoming more portable and less expensive, widening the situations in which it can be used. Additionally several pieces of non-invasive equipment are now available. This reduces the ethical issues with analysis, although most sampling for detecting or understanding deterioration can be balanced against greater future loss. Non-invasive techniques also allow replicate analysis to characterise the generally heterogeneous surfaces encountered and multiple measurements on the same spot at different times, from which deterioration rates can be derived [Thickett *et al.*, 2017].

Science has been used to develop criteria-anchored systems to visually describe mould growth and culture and molecular methods to identify the species present and risk. It is beginning to be used more widely to track chemical deterioration. The identification of corrosion products often indicates the source of corrosion. The quantification of soluble salts in stone and ceramic, combined with thermodynamic modelled yield least damaging temperature and RH ranges to minimise future damage. The state of conservation of paper, leather and enamels can be determined. However this paper will focus on physical deterioration, primarily caused by RH fluctuations. This is not a review paper and although examples will be presented, they are chosen to explore certain points and not as a comprehensive review of the field

Every instance of potential environmental damage across English Heritage's collections is investigated. The prime driver for this is our approach to standards based on the previous behaviour of the collections, conservation science and the rooms control capacity [Thickett *et al.*, 2012]. Hence knowledge of adverse behaviour is essential. A minimum data: including the date the damage was observed; the estimated date when the damage was last observed to not be present; two images (a general one of the object and a close up of the damage) are collected and a years worth of environmental data from the room the object is in. Extra monitors are often put out to determine the relationship between the room sensor and the object environment. Further environmental analysis is frequently undertaken for diagnostic purposes. The damage may be further investigated analytically, with corrosion products, salts or mould species identified.

The accuracy of audit data is often questioned. Methods are available to assess and improve inter-surveyor bias [Taylor, 2017]. The other major source of error is sampling error, as collection sizes and resources often preclude full audits. Data from five existing full audits was resampled digitally to assess this error. The sampling method was that used in English Heritages audit methodology [Xavier-Rowe, 2011]. The results were assessed in terms of the percentage of unstable (category 3 and 4) objects and compared to the value for the full audit set. The digital resampling was undertaken 100 times for a 5% sample. The distribution of data was tested for normality using the Shapiro-Wilk test with alpha value of 0.05, and found to be normally distributed [Shapiro

Material/location	Full audit percentage unstable	Mean of 5% audit	Standard deviation
Archaeological iron, whole EH estate on display	2.56	2.53	0.83
Paintings, whole EH estate on display	2.24	2.29	1.12
Gilded furniture, whole EH estate on display	1.98	1.94	0.98
Wide range of fine and decorative arts objects at Audley End House	1.70	1.81	1.26
Wide range of fine and decorative arts objects at Apsley House	2.87	2.98	1.34

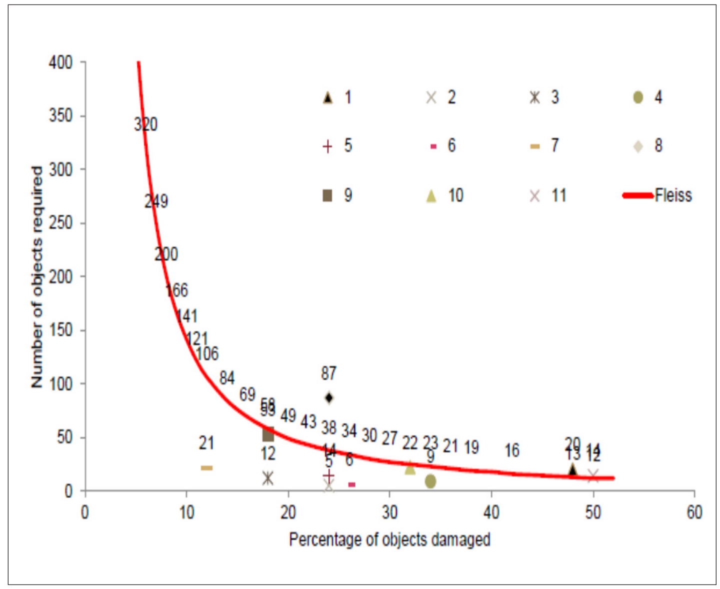
Table 1
Results of digitally resampling full audits at 5%, 100 times.

and Wilk, 1965]. Hence the standard deviation was calculated. Results are shown in table 1.

As can be seen, at 95% confidence interval (2 standard deviations), the data from the single material type audits has a narrower distribution. Auditing a mixed collection increases the sampling errors. This is quite likely due to an increase in the variation of the objects.

One use of audit data could be to try and relate object response to environment in the spaces audited. The number of objects required to provide statistically significant results is important for this approach. Display rooms will generally have more aggressive environments, as they are much more difficult to control in rooms open to the public than generally closed stores. Unfortunately, the number of objects present limits the potential sample size. Most historic rooms have slightly or very different environments from each other. The number of a particular object type is often limited in a room. The epidemiological field has developed statistics to determine the number of objects required to form a significant study at different damage rates in the two groups [Fleiss *et al.*, 2003]. Results from this work (using alpha and p value of 0.05, essentially meaning there is a 1 in 20 chance that the two comparison groups do not represent the whole population from which they are drawn) are shown in figure 1. Assuming one group is in non-damaging conditions, then the difference in damage rate, expressed as a percentage of objects damaged forms the x axis (if the second group has been damaged by the conditions the difference is lower). As can be seen object numbers required for each group increase dramatically as the damage rate (difference) decreases. The damage database gives the number of damaged objects of a particular type in a room, when combined with a count of all object of that type, the different in damage

Fig. 1
Number of objects required for a statistically robust comparison of two groups of objects.



rates can be assessed. A small set of results are plotted on figure 1. The numbers are also marked on figure 1 for ease of comprehension.

As can be seen, well over half of the instances shown did not have enough objects present at the damage level measured to provide statistically robust information. Careful selection is required for rooms and collections for studies using such an approach. One advantage of using sensitive analytical techniques, is as the difference in condition that can be detected, can be much smaller than by visual examination. This reduces the number of objects required for robust statistics. This number can frequently be limiting as shown.

Periodic Measurements

A range of inspection techniques have been applied to collections. These include commonly: photography and crack measurement, visually, with gauges or with measuring microscope. Photogrametry, 3D laser scanning, electronic speckle interferometry and digital image correlation have also been applied in a few instances [Dulieu-Barton *et al.*, 2005]. Measurements are sometimes applied periodically. Most reported instances have been of just two sets of measurements, with an attempt to link changes to the environment experienced.

In Situ Digital Image Correlation (DIC) Development

In order to deploy DIC in situ, some aspects must be taken into account that differ between a laboratory and the context of a historical building. DIC is an imaging technique that can be very sensitive, able to measure sub-pixel movement. This technique is based on comparing images over time, extracting a displacement map over the image

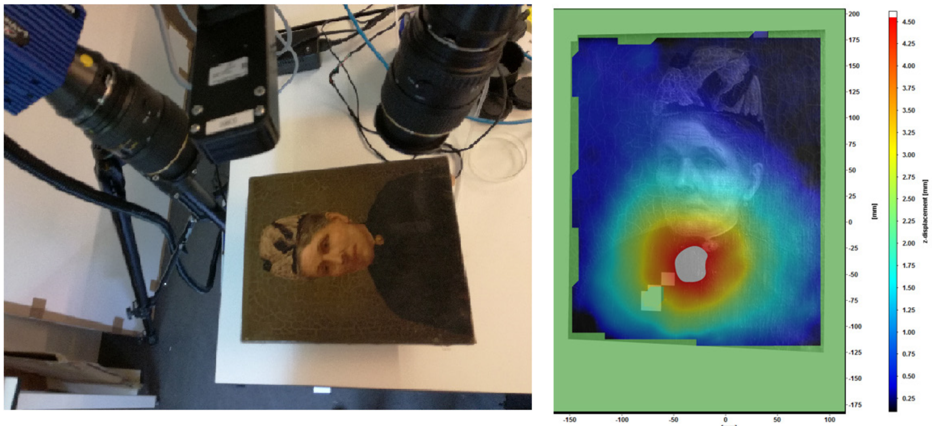


Fig. 2
DIC setup observing a canvas painting (left), out-of-plan displacement map (right).

that can highlight deformations and defects. In many cases, computer vision cameras will be used, these have larger sensor of higher quality producing less noise than commercial ones. However, their price and required handling limit their accessibility. Additionally, as micro-meter displacement are being measured, the experiment needs to be conducted in a very stable environment with low vibration. This is generally not the situation that we encounter in historic buildings.

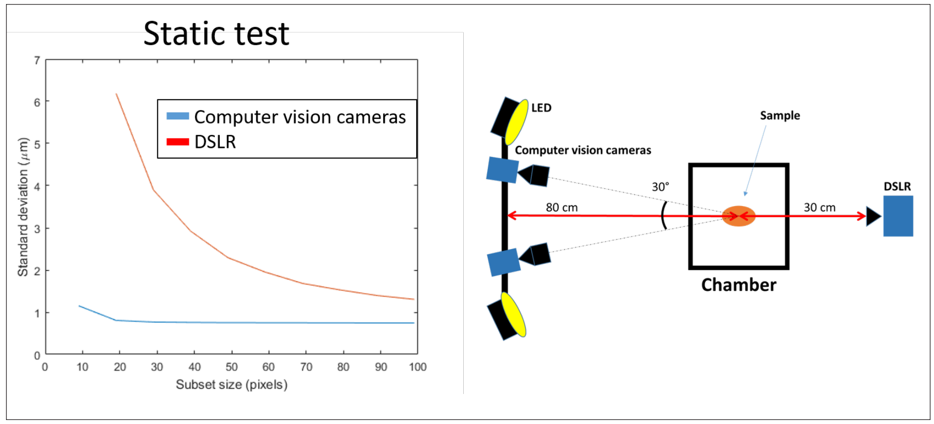
The main feature that can complicate a DIC measurement of artworks is the image's pattern. It is required to have random features on the observed surface. Industrially, a pattern is usually applied onto the tested material. This cannot be done on many artworks, as we wish to have no interaction with the object and only rely on the imaging over time.

The restriction on pattern application is not limited to cultural heritage. Studies looking at damage under water (where the pattern may dissolve), rely on the natural pattern of the material. The same approach can be applied on many artworks where aesthetic details, cracks, brush strokes, can form random features. But this excludes objects that have featureless surfaces or large areas in plain colours. Additionally some artworks include both, such as a portrait with many details on the character and a plain dark background. These limitations require a thorough assessment of the pattern before any measurement is considered.

Initial tests applying a small displacement at the back of a portrait allowed the displacement to be located and measured (fig. 2, right). The rather plain background was not an issue as its surface was uneven, limiting dead points only to reflection of light, changing the pattern. But this particular experiment, despite being able to measure displacement without applying any pattern, resulted from a significant movement of the painting compared to the sensitivity of the instrument.

Further tests show that change in RH and moisture absorption can

Fig. 3
Comparison between the computer vision setup and a single DSLR.



also be detected on a painting. However, they were done in a controlled environment. The question remains regarding how much of the data can be trusted and how the environmental changes, such as the light intensity, will impact the results. By moving the painting during the previous test, the light reflection on the varnish changed the pattern observed by the camera creating dead points. We can easily expect such errors from a measurement in situ alongside vibrations.

Before deploying a camera on site, it is crucial to make the instrument accessible to an heritage institution and suitable for stand-alone experiments. To do so, we compare results of standard sample with a random speckle between a full computer vision setup and a single commercial camera as shown in figure 3. The graph shows the random error versus the displacement map resolution. Whilst this data is not sufficient to give the absolute accuracy of the system, it is crucial to assess how the cameras are seeing the patterns over time. This will fluctuate, creating virtual displacement. Even though the computer vision cameras have significantly less noise despite being further away, the DSLR had a very reasonable error level up to 6μm which is promising.

With this in mind, we can start to monitor real painting on site, starting by assessing their pattern and the impact of the environment on it. In the best case scenario, the object should move by a well defined distance which will be compared with the displacement measured through DIC. In practice, it is not possible to move the painting or the camera, on site down to the micrometer precision. Therefore we started to consider the random error as featured in figure A2. Several paintings from the Wellington Collection at Apsley House (English Heritage) were considered. Overall, the landscapes worked better since they include more details on both foreground and background. The portraits were more complicated with often a plain background and homogeneous regions on the foreground (cloth, part of the face, etc.). The random error measurement gave good results for most of

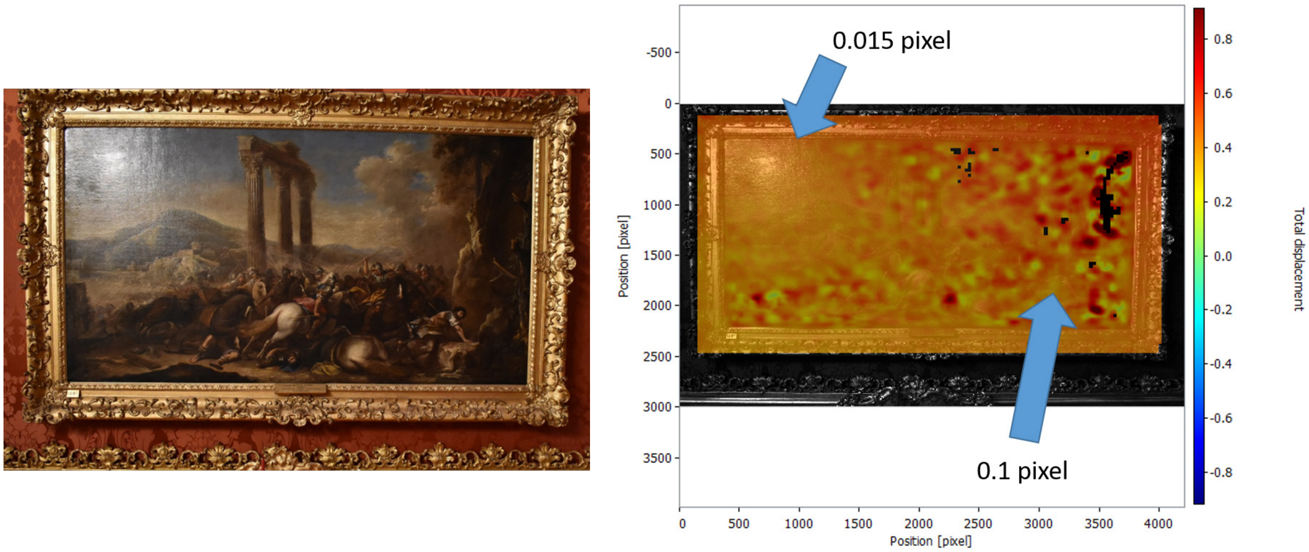


Fig. 4
Random error measured of a painting.

the painting observed. It demonstrates the potential feasibility of long term monitoring of the painting, if changes due to RH are significant enough to be detected. However, reflection of light strongly impacted the noise measurement as shown in figure 4.

The reflection on the varnish in the top left corner, enhanced the canvas pattern through the painting layer giving more defined random features in this area. However, the ambient light can affect this pattern, shifting the error and this can be confused with real movements by the camera. This could be solved by carefully controlling the lighting. Hence we should continue this research to evaluate how such error can be accounted for during the data analysis.

Indirect Tracing

For physical damage, generally associated with RH fluctuations, periodic measurements have the major drawback in that unless a quite extreme event occurs it is difficult to assign the damage to a particular fluctuation, or combination of fluctuation and previous conditions. The measurement intervals are often long and the environment in historic buildings, frequently changes. Continuous measurements can allow the linking of response to particular episodes or exploration of this. The terminology "tracing" has been used by some researchers. A selection of methods is shown in table 2. Some of these methods have been applied to long term monitoring of objects in situ, others have the potential for such application, but the authors have not seen any reported instances.

With the exception of mass and moisture content all the methods listed in table 2 require firm attachment to the object surface, which can

Technique	Applied to	Issues	Reference
Strain gauges	Wood	Requires very flat surface, temperature dependence	
Linear voltage differential transducer	Cracks in furniture and panel paintings		Knight and Thickett, 2007
Bragg fibre	Panel paintings, tapestries	Fibre stiffness can affect object response	Dulieu-Barton et al., 2005
Deformetric kit	Panel paintings	Need space behind the panel	Uzielli *et al.*, 2012
Mass	Furniture, sculpture, ivories		Thickett et al., 2006
Moisture content	Furniture		Thickett, not published

Table 2
Continuous measuring techniques.

be problematical. All of the methods are indirect, in that they measure a property of interest such as length, but not damage. Interpretation of the data is required to infer a damaging event, which requires a deep understanding of the mechanical properties of the object being measured. This is problematic, as mechanical testing, which is destructive, requires significant sample sizes and most data is only available for modern and not aged materials.

Direct Tracing

A more direct method is acoustic emission. Small sensors detect high frequency vibrations when rigid materials undergo micro cracking on deformation [Strojecki *et al.*, 2014]. The sensors can be pushed against the object without attachment. The scale of damage detected is very significantly below what can be seen by visual inspection. The technique has been used for enamels, stone, metals and wood in cultural heritage. Wood is amongst the most difficult materials to measure, with rapid attenuation of the signal, moisture affects and large differences in response due to growth directions [Kawamoto and Williams, 2002]. The signals from wood are relatively weak and background noise is a major limitation in a location. This determines the practical detection limit. The noise originates from two sources; electromagnetic and physical activity [Diodati *et al.*, 2001]. Differential sensors are the least sensitive to electromagnetic noise of those available. There is a general background level of noise, normally removed by a setting a threshold value below which signals are not recorded. Additionally, there are periodic noise events of a similar magnitude to those from micro-cracking in wood. Some are correlated with the shock, visitor movement induces in objects, either directly or through vibration of (especially) wooden floors. The use of two sensors in anti-correlation mode is used to avoid recording such events. The two sensors are placed far enough apart (generally over 6 cm) to not respond to the same event in the wood. Events are only recorded that occur on just one sensor, assuming an

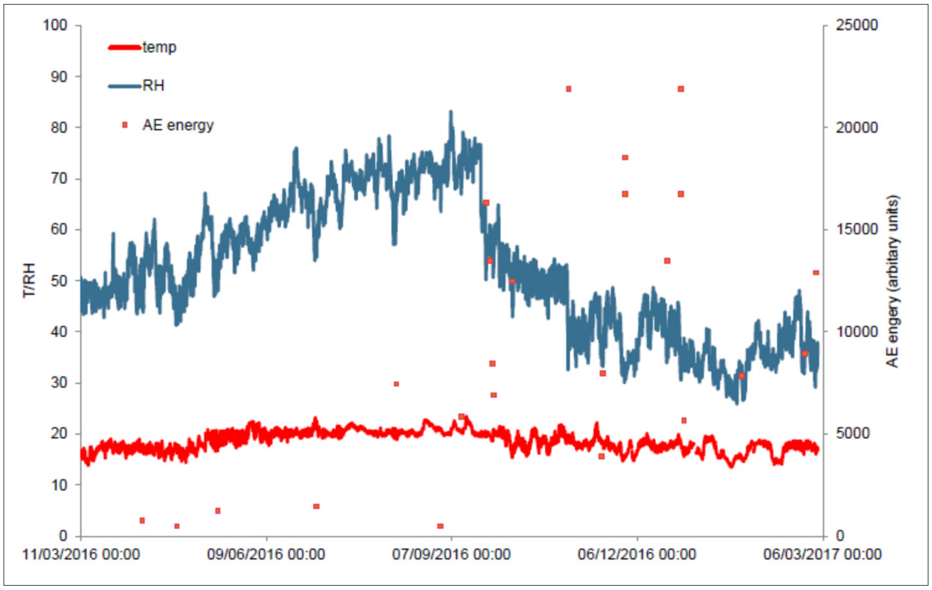


Fig. 5
Acoustic emission and climate measured from and around mahogany chest.

event recorded on both sensors is noise. The most common application has been to monitor crack extension by placing a sensor on a crack tip. An 18th century walnut veneered pine chest was monitored at Walmer Castle. A physical acoustics PAC 125 system was used with two WD sensors in anti-correlation mode. The use of preamplifiers allowed the equipment to be placed some distance (5 m) away from the chest so as not to visually disturb the historic interior. The provision of electricity sockets is also often very limited in historic buildings. Shock monitoring was undertaken at the same time with MSR 145 tri-axial loggers.

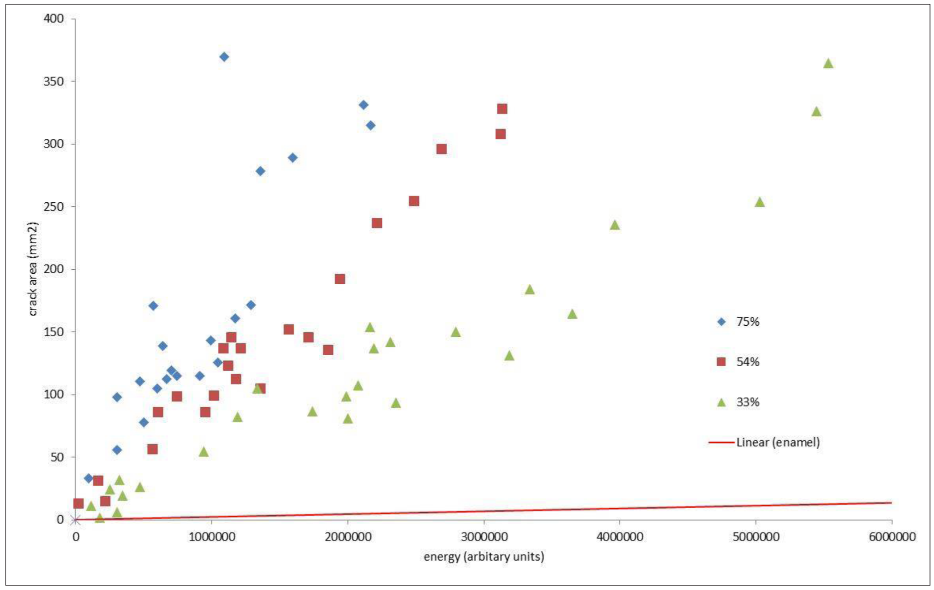
Results of a year's monitoring are shown in figure 5. Any events coincident (within a second) of shock event over 0.1 g were excluded.

There are a number of acoustic emission events throughout the year. The most intense, highest integrated energy events appear at dryer periods. Full discussion of the results is beyond the scope of this paper and will be discussed with a corpus of similar monitoring in a future publication. The very high temporal resolution allows analysis of correlation with environmental data. The acoustic emission events are recorded over a fraction of a second and can be correlated with shock events, to remove this source of noise.

A series of calibrations were undertaken with 1 mm walnut strips equilibrated to 75, 54 and 33% RH. These were pre-notched (1 mm by 2 mm) and pulled apart in an Instron tensile tester. The crack area increase on crack length extension was correlated with the amount of acoustic emission measured. Each calibration was carried out with 5 samples. Calibrations are shown in figure 6 along with one for enamels.

There is a significant difference in acoustic emission response to the

Fig. 6
Calibration of acoustic emission energy generated by crack growth at different RH values.



same crack extension at different RH values due to the different moisture contents of the walnut. All the wood responses are very significantly less than the enamel. Only the low extension part of the enamel response is shown. The calibration, using optical determination of the crack length has a low sensitivity (measurement interval of 0.2 mm), which means the calibration curve is mainly above the level of acoustic emission detected on objects.

These calibrations were applied to signals generated within 24 hours of >63%, 44-64% and <44% to produce figure 7.

With the different acoustic response of the wood at different RHs taken into account, the distribution of the amount of cracking changes and the drop from 75 to 50% now appears to be the most damaging. There is a drawback with this approach. It gives more readily accessible and understandable results, but relies on calibrations with modern wood, and hence becomes a less direct method. Further research is required to determine if the acoustic response is the same for modern and aged wood.

Damage Functions

With a few exceptions, the high cost or expertise required means these techniques will only be available in some instances. However, the results from these studies are ideal to develop damage functions to better assess other environmental data.

The environments in historic buildings are generally complex. It is often difficult to translate the results of laboratory experiments for these environments. This has led to a situation where we have a good understanding of safe limits (where there is absolutely no risk

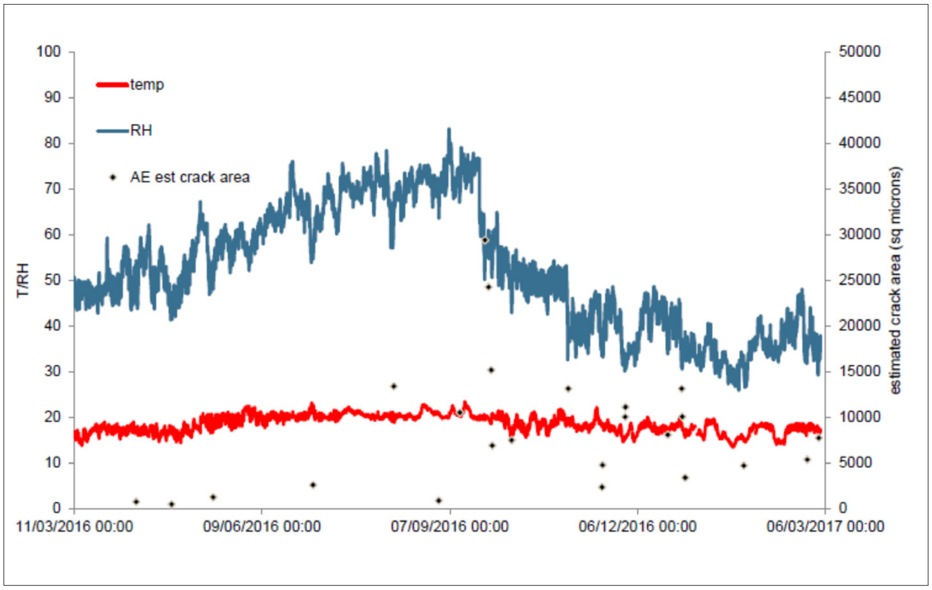


Fig. 7
Acoustic emission data from fig. 5, recalibrated to compensate for RH.

to objects), but next to no comprehension of how much risk there is when we move beyond these limits. These safe limits are impossible to maintain within the vast majority of historic buildings. A promising approach to determine risk, is the use of numerical damage functions. The response of a large group of objects is measured and mathematically correlated with the RH conditions. This mathematical function can then be used to assess other environmental RH data to give an indication of the risk. This approach has already been elaborated to some extent in several instances shown in table 3.

This approach is also helpful for processes such as corrosion that depends on both concentrations of pollutant gases and RH, and sometimes, temperature [Thickett, forthcoming].

The database of observed damage has been very useful to test and calibrate these damage functions. Work has been undertaken investigating and comparing mould outbreaks, indicating a better correlation with two of the four published damage functions to instances observed across English Heritage's estate [Thickett *et al.*, 2014]. Work is planned in the near future to investigate instances of physical damage. This approach, although still developing, has proved extremely powerful to assess complex environments and develop evidence based risk assessments.

Conclusions

Scientific methods can aid in determining object response in some instances. There are significant restrictions with their use on historic objects, but many examples where these have been successfully overcome. One major advantage is enhanced sensitivity, which has been

Function	Notes	Reference
HERIe	Finite element analysis	Heri-e
BS EN 15757	Mathematical method based on experience	BSI, 2010
Variety of methods developed into damage functions		Lankester, 2013
Data analysis at different fluctuation periods		Pretzel, 2014
Mould on wood	Four published functions based on laboratory experiments	Thickett *et al.*, 2014

Table 3
Damage functions.

shown to be particularly important for the statistical comparison of response to environments.

Digital image correlation can be used with more conventional cameras, making it accessible to heritage institutions, and long term monitoring as it can be easily battery powered. The natural pattern of canvas painting does work in many cases, but not all painting can be observed, in particular those lacking features. Even though movement can be monitored, the sensitivity of the technique will depend on the painting, due to the pattern quality. Ambient RH fluctuations might be too small to be detected for some, whilst easily measured for others.

Acoustic emission has been shown to be particularly useful, and the limits of detection due to noise levels assessed.

Developing results into damage functions is an area with very significant future potential. This may lead to great improvements in assessing environmental data.

Bibliography

BSI, BS EN 15757:2010 *Conservation of Cultural Property – Specifications for Temperature and Relative Humidity to Limit Climate Induced Mechanical Damage in Organic Hygroscopic Materials*, BSI London, 2010.

Diodati P., Piazza S., Del Sole S., Masciovecchio L., 'Daily and Annual Electromagnetic Noise Variation and Acoustic Emission Revealed on the Gran Sasso Mountain' in *Earth and Planetary Science Letters*, 184, 2001, pp. 719-724.

Dulieu-Barton J. M., Dokos L., Eastop D., Lennard F., Chambers A. R., Sahim M., 'Deformation and Strain Measurement Techniques for the Inspection of Damage in Works of Art' in *Reviews in Conservation*, 6, 2005, pp. 63-73.

Fleiss J. L., Levin B. and Paik M. C., *Statistical Methods for Rates and Proportions*, 3rd Edition, Wiley, New Jersey, 2003.

Heri-e available at http://herie.mnk.pl/ (accessed on 29 June 2018).

Kawamoto S. and Williams S. R., *Acoustic Emission and Acousto-Ultrasonic Techniques for Wood and Wood Based Composites*, United States Department of Agriculture Forest Service Report, FPL-GTR-134, 2002.

Knight B., Thickett D., 'Determination of Response Rates of Wooden Objects to Fluctuating Relative Humidity in Historic Properties,' in *Museum Microclimates*, T. Padfield and K. Borchersen (ed.), LP Nielsen Bogtryk, Hvidovre, 2007, pp. 85-88.

Lankester P., *The Impact of Climate Change on Historic Interiors*, PhD University of East Anglia, 2013.

Pretzel B., '[Un]Reasonable – Broadening Acceptable Climate Parameters for Furniture on Open Display,' in *ICOM-CC 17th Triennial Conference Preprints*, J. Bridgland (ed.), Melbourne, 15-19 September 2014, art. 1507, 10 pp. International Council of Museums, Paris, 2014.

Shapiro S. S., Wilk M. B., 'An Analysis of Variance Test for Normality (Complete Samples),' in *Biometrika*, 52 (3-4), 1965, p. 591-611.

Strojecki M., Łukomski M., Krzemien L., Sobczyk J., Bratasz Ł., 'Acoustic Emission Monitoring of an Eighteenth-Century Wardrobe to Support a Strategy for Indoor Climate Management' in *Studies in Conservation*, 59(4), 2014, pp. 225-232.

Taylor J., 'Improving Reliability in Collection Condition Surveys by Utilizing Training and Decision Guides,' in *Journal of the American Institute for Conservation* 56(2), 2017, pp. 126-141.

Thickett D., David F., Luxford N., 'Air Exchange Rate; A Dominant Parameter for Showcases,' in *The Conservator*, 2006, pp. 19-34.

Thickett D., Luxford N., Lankester P., 'Environmental Management Challenges and Strategies in Historic Houses,' in *The Artifact, its Context and Their Narrative*, Postprints of ICOM-CC-DEMHIST conference, ICOM, Los Angeles, 2012, pp. 1-11.

Thickett D., Lankester P., Pereira Pardo L., 'Testing Damage Functions for Mould Growth,' in J. Bridgland (ed.), *ICOM-CC 17th Triennial Conference Preprints*, 15-19 September 2014, Melbourne, art. 2103, 9 pp., International Council of Museums, Paris, 2014.

Thickett D., Cheung C.S., Liang H., Twydle J., Gr Maev R., Gavrilov D., 'Using Non-Invasive Non-Destructive Techniques to Monitor Cultural Heritage Objects,' in *Insight*, 59(5), 2017, p. 15.

Thickett D., 'The Frontiers of Preventive Conservation,' Preprints of IIC conference, in studies in Conservation, 63(supp1), 2018, pp. 262-267.

Uziellia L., Cocchia L., Mazzantia P., Tognia M., Jullien D. B., Dionisi-Viciac P., 'The Deformometric Kit: A Method and an Apparatus for Monitoring the Deformation of Wooden Panels,' in *Journal of Cultural Heritage*, 13(3), 2012, pp. S91-S101.

Xavier-Rowe A., Fry C., 'Heritage Collections at Risk' in J. Bridgland (ed.), *ICOM-CC 16th Triennial Conference Preprints*, 15-19 September 2011, Lisbon, art. 2103, 11 pp. International Council of Museums, Paris, 2011.

The King's bed chamber,
Palace of Versailles.
(© EPV/ Danilo Forleo)

Multi-View-Monitoring of Dimensional Changes of Wooden Panels Due to Changes in the Microclimate at Linderhof Palace

Abstract

Every year 500,000 visitors come to see Linderhof palace, by King Ludwig II of Bavaria. The indoor climate in the small palace is highly affected by the high amount of visitors. Until recently, the only way to obtain fresh air was by opening the windows. Due to this, the original historic furnishings were exposed to high humidity levels which fluctuated widely. In February 2017 an innovative ventilation system was installed to solve this problem. The goal of the research project was to examine how the historic furnishings respond to both the former and current climate situation. A method to investigate the reaction of various surfaces to changes in the microclimate generated by the ventilation system was developed by a multi-view-monitoring (MVM). A combination of three different non-destructive optical methods: structured light scanning, 3D-microscopy and time-lapse photography has been applied to different object surfaces. The monitoring has been conducted in daily and seasonal cycles.

Dr. Kristina Holl
Research officer and conservator, Bayerische Verwaltung der staatlichen Schlösser, Gärten und Seen (BSV)
kristina.holl@mytum.de

Max Rahrig
Kompetenzzentrum für Denkmalwissenschaften und Denkmaltechnologien – KDWT, Otto-Friedrich-Universität Bamberg
max.rahrig@uni-bamberg.de

Dr. Katrin Janis
Bayerische Verwaltung der staatlichen Schlösser, Gärten und Seen, Schloß Nymphenburg
Katrin.janis@bsv.bayern.de

Keywords

Micro climate, monitoring, historic furnishing, ventilation system, preventive conservation, structured light scanner, 3D-microscope, time-lapse photography.

Previous Climatic and Conservation Situation in Linderhof Palace

Linderhof Palace was built in the 19th century (1870-1874) for King Ludwig II of Bavaria. The palace is situated in the heart of the Bavarian foothills of the Alps (ca. 950 a.s.l.). For more than 125 years the palace has attracted hundreds of thousands of visitors each year (fig. 1). This number of people has had a huge influence on the indoor climate and has contributed to the decay of the vulnerable original furnishings.

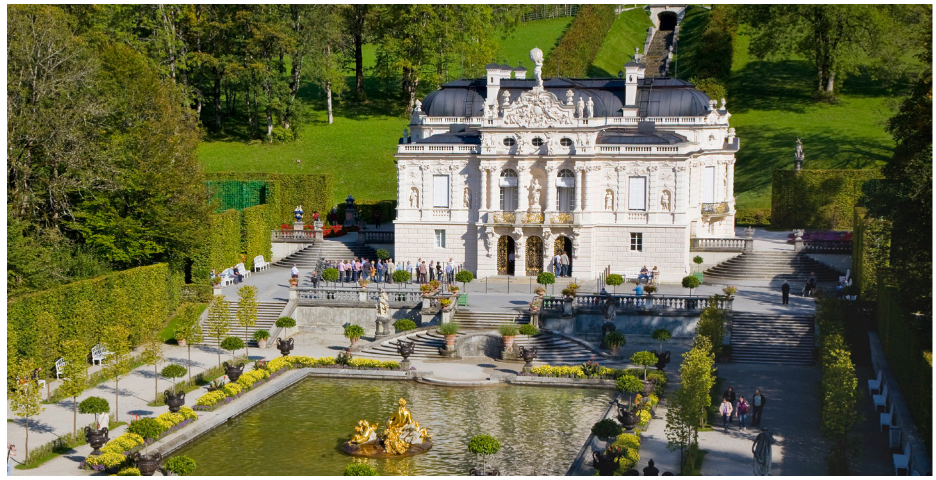
Since 2008 the impact of the indoor climate on the historic furnishing has been examined by two research projects in close cooperation with the Fraunhofer Institute for Building Physics (national project "Climate stability in historic buildings" 2008-2013 and European project "Climate for Culture," 2009-2014).

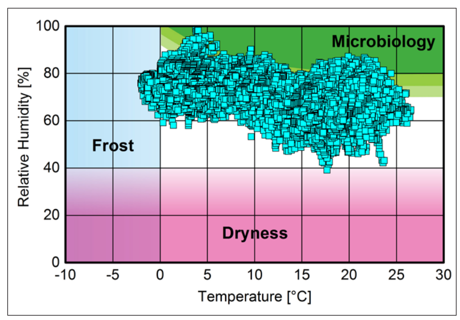
There are two main climatic problems in Linderhof. The first occurs

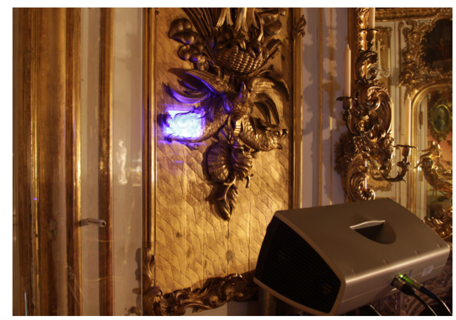
Fig. 1
Linderhof Palace built for King Ludwig II of Bavaria – exterior view of the southern façade. (Source: BSV)

Fig. 2
Scatter diagram of RH and T of the hourly data taken in the bedroom between February 1st 2008 and June 1st 2011. (Source: Fraunhofer IBP)

Fig. 3
Examination of a gilded wooden panel in the dining room using a structured light scanner. (Source: BSV)







mainly in the northern part of the palace where the relative humidity is much too high (fig. 2). The statistical analysis of temperature (T) and relative humidity (RH) in the bedroom, measured hourly for three years showed an annual average of 71% RH, reaching a maximum level of 96.8% RH. To minimise the risk of mould growth and other negative impacts on the historic furnishings, such as swelling of surfaces, a mean value of 60% RH is recommended. Secondly, the short term fluctuations are extreme. In summer, as soon as the first group of visitors enters the palace, the windows are opened to counter the damp atmosphere. Throughout the day, T and RH inside the palace rise steadily, and after closing time, decrease again. During a single day the fluctuations may exceed 20% RH [Bichlmair *et al.*, 2013]. Assessments of the state of preservation of the historic furnishings were conducted as well [Holl 2013, Holl 2016]. Climate-induced damage such as cracks in the wood, flaking gilt and paint layers as well as mould growth was found, especially on the painted and gilded wooden furnishings.

Innovative Airing Strategy in Linderhof Palace

For the long-term protection of the Palace a ventilation system was installed. The control system is based on the European standard 15757 “Conservation of Cultural Property – Specifications for T and RH to limit climate-induced mechanical damage in organic hygroscopic materials" [DIN EN 15757]. Based on that standard the Fraunhofer Institute for Building Physics devised the specifications for the indoor climate in the palace [Bichlmair *et al.*, 2013]. The aim of the specifications was two-fold: first, the RH in the bedroom should be reduced to the level of the adjacent rooms (the RH in the adjacent hall of mirrors averaged 62% RH over three years). A RH level of 62% was specified, allowing ± 6% RH fluctuations on a monthly average. The second aim was to limit the short term fluctuations so that most of the time an average monthly fluctuation of ± 8% RH is not exceeded. The T should follow the seasonal cycle with little interference. The upper limit is 20 °C, and at low temperatures the difference between the indoor T and that of the air supplied by the ventilation system must not exceed 6 Kelvin. However, the main aim is to control the RH, not the T, and the key criterion of the control of the air inlet is to not exceed 40% RH. The volume flow is adjustable by a frequency converter and can vary depending on the number of visitors [Holl *et al.*, 2015]. As well as the installation of the ventilation system, a research project was carried out to conduct a scientific and conservation assessment of the system. The project "Wissenschaftliche Begleitung einer Maßnahme zum präventiven Schutz vor Umwelteinflüssen in Schloss Linderhof" was funded by the DBU (German Federal Environmental Foundation) from 2013 till 2018.

Development of a Multi-View-Method for Monitoring Microclimate Changes on Wooden Panels

Climatic fluctuations may have a different impact on artworks depending on their material properties and thickness. An artwork such as a panel painting usually consists of different materials and layers (e.g., priming, several colour layers, coating) and each one reacts differently regarding swelling and shrinking. The divergent behaviour of each layer can cause stress inside the composite material. Both short and long term fluctuations have an impact on artworks: short term fluctuations which occur on an approximately daily cycle will affect the surface more, especially when there is already damage present. Fluctuations which occur over a longer period will also affect the inner layers and the support. Therefore, depending on the frequency and amplitude, climate fluctuations can cause a variety of damage, such as deformation or cracking of the support or loosening of the surface. Thus, it is complex to know which climate fluctuations are really damaging to the collections.

According to Michalski, the highest stress in objects is caused by fluctuations which last longer than the response time but are shorter than the relaxation time [Michalski 1993, Michalski 1996]. However, outside a laboratory environment the response and relaxation times

Fig. 4
Left: time-lapse pictures with a SLR-camera in the eastern tapestry room. Right: 3D-microscopy of the wall paintings in the bathroom. (Source: BSV)

of different objects can only be estimated.

For the case of Linderhof Palace it was clear at the beginning of the research project that due to the ventilation system, both the pattern of atmospheric fluctuations and the average values of the indoor climate would change. Therefore, in order to judge the effect of the new system there was a need to document the reaction of the historic furnishings to the changes in climate. Climate-induced damages are not easily documented as they usually only occur over long periods, so for their detection a multi-view-monitoring (MVM) technique was developed. The idea was to combine three non-destructive-testing methods (NDTs) alongside detailed climate monitoring in order to investigate the effects of both short and long term climate fluctuations.

To evaluate the changes caused by the new climate, it was necessary to document the regular seasonal changes of the historic furnishings in advance. This was carried out with a structured light scanner (SLS) (fig. 3). For the examination of the effects of short term fluctuations on already damaged surfaces, areas such as loosened parts of a gilded wooden panel were chosen. The investigation of these surfaces

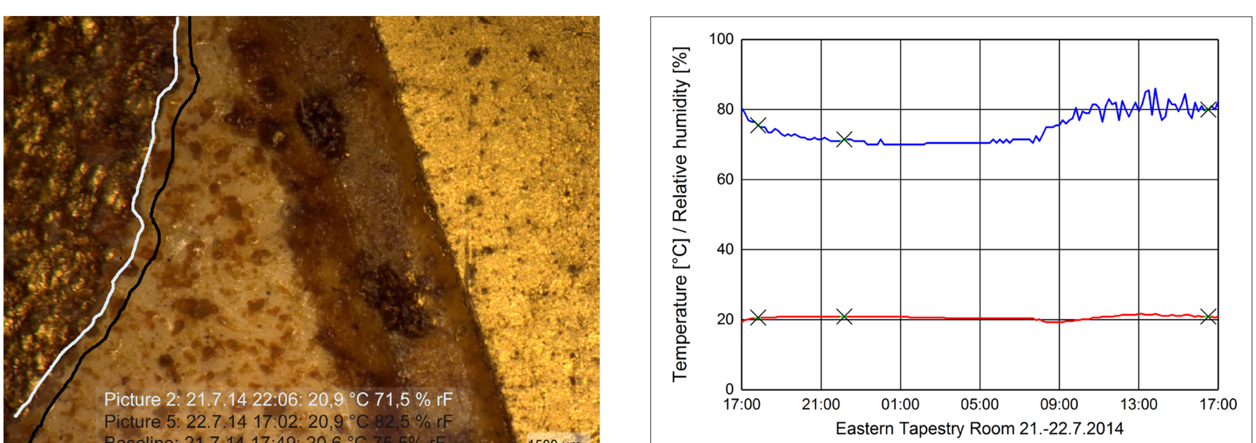


Fig. 5
Left: visualization of climate induced movement by matching the single pictures and marking the contours of the gilt layer (source: BSV). Right: T and RH during measurement (July 21st-22nd, 2014) with the 3D-microscope (marked with black crosses).

Climate analysis	Examination	Method
Short term fluctuations (daily – several days)	Examination of already damaged surfaces with regards to movement (swelling / shrinking)	SLR-Photography 3D-Microscopy Investigation of selected surfaces
	Comparison of the detail of a historic surface	Structured light scanner "1-shot-method"
Seasonal fluctuations	Comparison of the detail of a historic surface	Structured light scanner Investigation of selected surfaces

Table 1
Description of the different methods used to examine the reactions of the historic furnishings over varying periods. The selected surfaces were examined before and after the implementation of the ventilation system.

helped to define acceptable ranges for short term fluctuations. For this a 3D-microscope and SLR-photography were used (fig. 4). The structured light scanner was also used to examine the effects of short term fluctuations using the "1-shot-method." All examinations were conducted in different seasons and over the course of several days (see table 1).

Structured-Light-Scanning (SLS)

SLS is a combination of optical triangulation technology (optical distance measurement by angular measurement inside triangles) and interferometry (interaction of waves). The big advantage of this optical method is the fast recording of surfaces at a high resolution. For the measurements in Linderhof Palace the COMET L3D 5M structured light scanner by Steinbichler (now Carl Zeiss Optotechnik) was used (fig. 3). With this method it is possible to scan areas of varying sizes by changing the lenses. Using the 250 mm lens an area of 260 x 215 x 140 mm can be examined, and with the 75 mm lens the area is 74 x 62 x 45 mm. The distance between two measured points also depends on the lens: the smaller the image section the higher the resolution (250-mm-lens: 100 µm distance, 75-mm-lens: 30 µm). Using the Comet Plus 9.63 software, several scans are combined into a single data file. The scans were carried out in rows with a vertical and horizontal overlap of more than 50% between each single scan. This redundant data reduced the matching errors between the individual scans and guaranteed a higher geometrical accuracy for each monitoring area [Drewello *et al.*, 2011].

To examine the SLS data, two scans of the same surface are compared using the software Inspect Plus®. After a manual orientation using reference points, the software registers the scans to each other and calculates a "best fit orientation" (by specifying an error between 0.05 and 0.1 mm). Afterwards a comparison of the surfaces can be carried out. In order to demonstrate how much the two scans deviate from each other, the software creates a colour coded image illustrating the

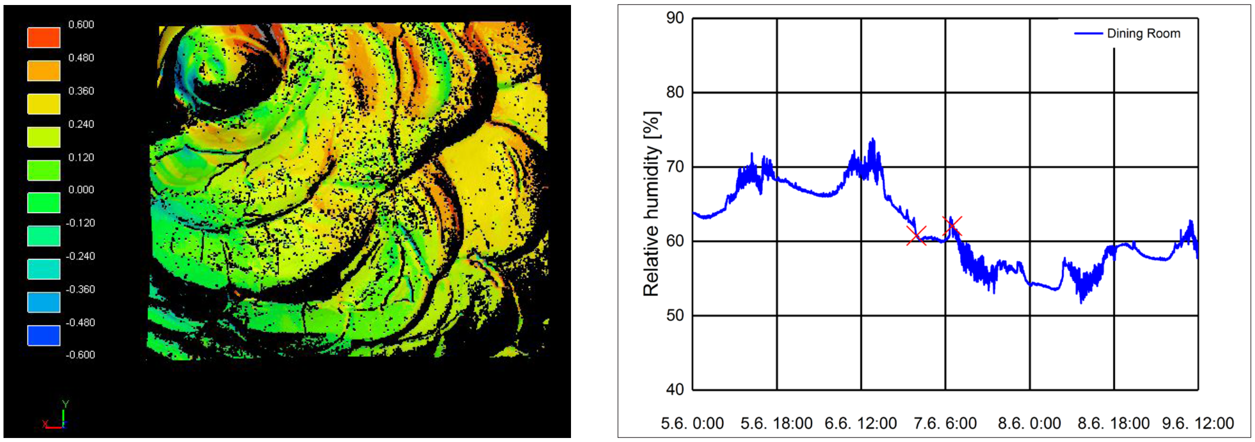


Fig. 6
Left: One-Shot Measurement: June 7th 2017, shows movements up to 1 mm (with ventilation system).
Right: RH during the whole measurement week. The time of the investigation with the SLS – 1shot-method (June 7th 2016) is marked with red crosses.

deviation. The scale of the false-colour illustration is manually selected. In this case, a dark green area means no change; areas which are coloured light green (minimum) to red (maximum) indicate a forward warping has taken place while colours from turquoise to dark blue indicate an increasing reverse warping (fig. 6).

The "1-shot-method" aims to minimise errors which can arise in the processing of the data. Two scans of the same area are taken at different times (last scan in the evening and first scan in the morning) without moving the measuring device. By this means it is possible to achieve a quantitative high resolution measure of the movement of the surface due to short-term climate fluctuations without the need to manually orient the scans via reference points (fig. 7).

3D-Microscopy and Time-Lapse Photography

For the examination of short-term fluctuations a single lens reflex camera (SLR) and a 3D-microscope were installed in front of the relevant area, focused on the damage, and left for the duration of the measurement campaign (fig. 5). The camera and microscope were programmed to take a picture every 20 minutes. Thus the impact of short term fluctuations could be examined micro- and macroscopically.

Unfortunately the analysis of the quantification of movement with the 3D-microscope didn't work on site as the motor used to focus on the object caused too many vibrations. Therefore, for both methods, an optical comparison was carried out by laying single images over each other using the graphical software Adobe Photoshop©. The change due to the mechanical response is made visible by tracing the contour of the flaking surface (fig. 5, left).

Results

As all recorded movements are caused by climate fluctuations it was necessary to correlate the results for all the deployed systems with the corresponding climate data. For that reason, a detailed record of climate data near the observed areas was carried out for the duration of the project.

Response of the Historic Furnishing to Short-Term Fluctuations

In the run-up to the implementation of the ventilation system, surfaces with existing damage (loosening of the surface or craquelure) were examined with the 3D microscope and SLR photography over several days during different seasons. As initially assumed, the movement of the loose parts was dependent on variations in the levels of moisture. In the summer months, for example, where daily fluctuations in RH could sometimes exceed 15%, the equipment showed a stronger movement than in winter when the room climate was more stable (see fig. 5). Figure 5, right, shows a graph of the T and RH next to the surface examined by 3D-microscopy. The green crosses mark the relevant climate at the time of examination. The evaluation of the investigation with the 3D-microscope is shown for the period of July 21st-22nd, 2014. The climate diagram indicates the most interesting times to be used for the graphical investigation. The method described here was also used for the evaluation of the data taken by the SLR-camera.

The investigations show that already loosened parts produced macroscopically visible movements caused by swelling / shrinking from a daily fluctuation of 10% RH. It was also seen that short term fluctuations do not affect the surface immediately, but occur after a short delay.

Compared to the results with the 3D-microscope, the loosened parts of the surface are seen less clearly with the SLR camera due to the reduced magnification. However, a mechanical response is still visible. Thus, examination with an SLR camera is sufficient for evaluating which short term fluctuations are acceptable.

With regard to the assessment of the reaction of the historical furniture to the changed indoor climate, the results of the "1-shot measurements" were particularly informative (fig. 6, left). The climate diagram (fig. 6, right) shows that the RH was very constant during the

Fig. 7
Combined illustration of photography and assessment of the structured light scanner (March-October 2015). The red lines mark the joints.

Fig. 8
Left: comparison March-July 2015. A clear shift of the panel is visible (blue: movement to the back, yellow/red: movement to the front). Right: comparison July-October 2015: the countermovement, although less distinctive, is visible. Both measurements were executed using the 250 mm lens. On both figures a movement of about ± 0.25 mm is visible.

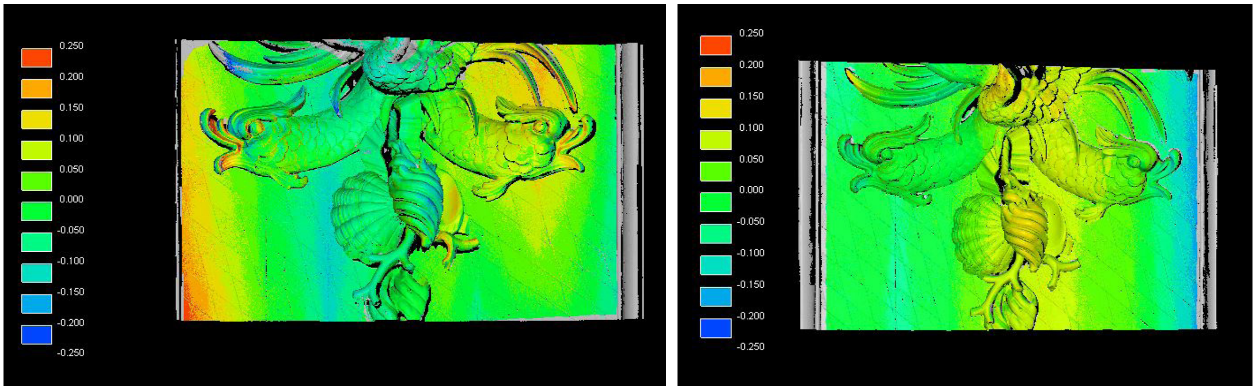
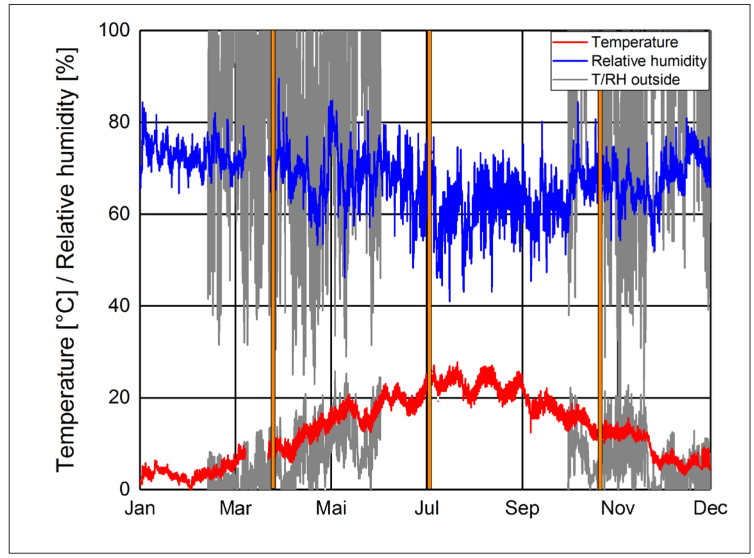


Fig. 9
Line diagram of RH and T in the dining room (blue and red) compared to the outdoor climate (grey) for the year 2015. The orange parts mark the times when the measurement campaigns were conducted.



time when the measurements took place (red crosses, Δ 2.9% RH), but as there were quite high fluctuations in the days before the documentation, it is clear that the changes in the historic furnishings recorded by the 1-shot measurements are caused by those previous climatic changes. Also, the commissioning of the ventilation system began a long-term process of dehumidifying the furnishings, which might be visible here as well. An investigation over a monthly cycle could give a better answer here.

Response of the Historic Furnishing to Seasonal Fluctuations

The example described in this paper is a carved and gilded wooden panel dedicated to the art of fishing, situated in the dining room. Flaking and losses of gilt were found on the panel, especially on the left fish head (fig. 3). The joints have been partially repaired, which indicates large mechanical responses in the composite material (fig. 7). Before the installation of the ventilation system, the biggest and most frequent movement of the panel occurred between spring and autumn 2015 (fig. 8). During that period, various parts of the panel reacted differently. From March to July the left part of the surface warped to the front (fig. 8, left), whilst from July to October the right part warped to the back (fig. 8, right). The changes in T and RH over the course of 2015, as well as the times of data collection (marked in orange), are detailed in figure 9.

After the implementation of the ventilation system two measurement campaigns were conducted in June and July 2016. The results are shown in figure 10. The observed surface shows a movement of ± 0.2 mm, comparable to the previous measurements. We can see that the climate created by the ventilation system has so far not increased the movement in the historic furnishings. However, observations must

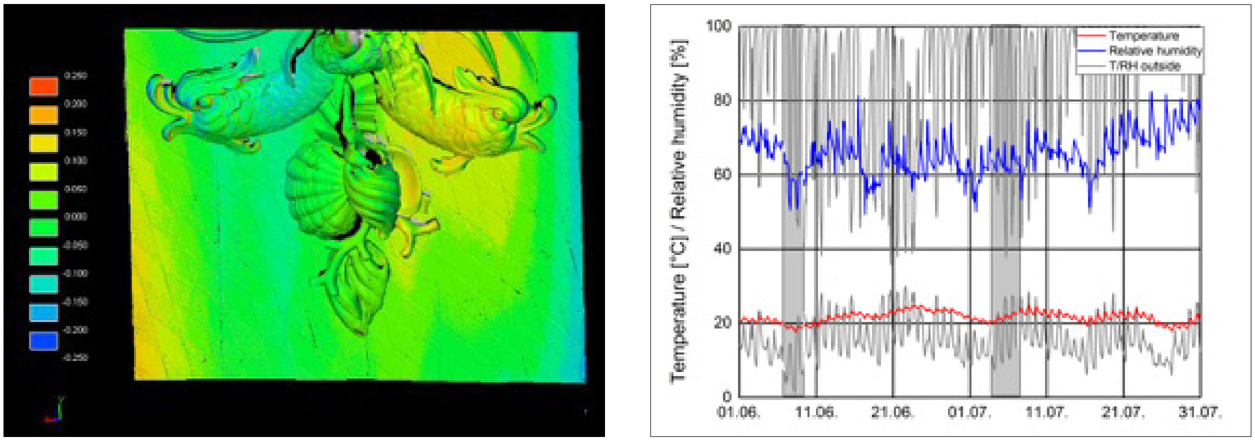


Fig. 10
Left: The comparison June-July 2017 with the 250 mm lens shows a movement of ± 0.2 mm.
Right: diagram of T and RH of the dining room (blue and red) compared to the outdoor climate (grey) from June 1st till July 31st. The time when the measurements where conducted are marked with grey areas.

be conducted over a longer time period before we can make a reliable statement.

In conclusion, the examined panels show a clear mechanical response to seasonal changes in the environment. Depending on the position of the objects in the palace, the response was most pronounced between either spring and summer or spring and autumn. The counter-movement, which correlates to the seasonal changes of climate, was noticeable between summer and autumn. The mechanical response in spring (fig. 8, left) and in autumn (fig. 8, right) clearly differed. This can be explained using the amplitude of two sine waves as an example: depending on the phase displacement the wave intensifies or decreases. In our case the mechanical response depends on the climate conditions. It should be pointed out that the measurements record just a single moment of the total environmental condition, therefore it is not surprising that the maximal mechanical response differs depending on the location and the equilibrium moisture content of the individual panels. Increasing the measurement intervals (for example, monthly) provides more detailed information on the movement and dimensional changes of the panels. In figure 10 the reaction of the surface to the “new climate” created by the ventilation system can be seen. The historic furnishings react to the decrease in average RH but the movement does not exceed the previous movement of ± 0.2 mm measured in June / July 2017.

Effects of the Ventilation System on the Indoor Climate – First Evaluation

As stated earlier, the indoor climate in Linderhof Palace is affected by strong daily fluctuations. These occur especially in the summer months due to the high number of visitors as an additional source of T and humidity. This forces the staff to open the windows for additional fresh air.

By implementing the ventilation system, the room climate is being gradually dehumidified as a fast change of the overall climate might stress and damage the historical surfaces. Therefore the RH will be reduced in small steps over several years. For the moment the value is around 67% RH, within the next few years it will be reduced to the target value of 62% RH.

Further monitoring campaigns will show how the ventilation system reduces short-term fluctuations, especially in the summer months.

Conclusion and Outlook

The comparison of the first measurements shows the great potential of MVM to answer questions of preventive conservation. Using this combination of techniques, the strengths and weaknesses of the individual technologies can be exploited optimally. Using SLS, three-dimensional measurement data of the historical surfaces are available in extremely high resolution. Here, even the smallest movements of the surfaces can be recorded and visualised, comparing measurement campaigns with sub millimetre accuracy over a long period of time. But during each campaign – except for the "1-shot measurements" – the test areas could only be documented once per measurement field (250 mm and 75 mm).

The 3D microscope is ideally suited for the detection of daily movements and allows for semi-automatic recording and visualisation. The comparatively complicated setup of the technique, however, only allows the recording of one or a maximum of two sample areas per campaign. Another restriction is that only data acquired over the course of a single campaign can be compared directly, because the camera position and the viewing angle must not be changed between measurements. Here the technique of digital image correlation might improve the evaluation of the data.

The SLR photography represents the third column of the MVM. Here, a very simple setup can be used to automatically record photosets of the test surfaces, and visualization of the results is also simple. This allows the short-term movements to be documented very well. However, only photos are taken and, as was the case with the 3D microscope, only the images from a single campaign can be compared directly.

Since for all the techniques, the recording time of the data is documented to the second, the results can be linked directly to one another and also correlated with the climatic measurements. This makes it possible to differentiate the effects of the short-term, daily climate fluctuations from the long-term movements, enabling further investigations.

Showing the movement due to changes in T and RH is an important step considering the potential for damage caused by fluctuations in climate. But in order to distinguish between periodic movements and actual damage, further investigations are necessary. The analysis of T- and humidity distribution inside an artwork via a hygrothermal simulation will help in evaluating the optical results.

Bibliography

BICHLMAIR S., HOLL K., KILIAN R., 'The Moving Fluctuation Range – A New Analytical Method for Evaluation of Climate Fluctuations in Historic Buildings,' in *Climate for Collections. Klima und Kulturgut – Wissen und Unwissen*, Munich, November 9th-11th 2012, London, 2013, pp. 429-440.

BICHLMAIR S., KILIAN R., KRUS M., 'Concept of a New Airing Strategy and Simulation of the Expected Indoor Climate in Linderhof Palace,' in *Clima 2013*, Prague, June 16th-19th 2013, Prague, 2013, pp. 2879-2889.

DIN EN 15757, *Conservation of Cultural Property – Specifications for Temperature and Relative Humidity to Limit Climate-Induced Mechanical Damage in Organic Hygroscopic Materials*, 2010-2012.

DREWELLO R., WETTER N., RAHRIG M., BELLENDORF P., '3D-Dokumentation mittelalterlicher Glasmalerei mit der Methode der 3D-Weißlicht-Streifenprojektion,' in Bornschein, Falko, *et al.*, *Konservierung mittelalterlicher Glasmalerei im Kontext spezieller materieller und umweltbedingter Gegebenheiten*, Stuttgart, 2011, pp. 142-154.

HOLL K., 'Comparison of the Indoor Climate Analysis According to Current Climate Guidelines with the Conservational Investigation Using the Example of Linderhof Palace' in *Climate for Collections. Klima und Kulturgut – Wissen und Unwissen*, Munich, November 9th-11th 2012, London, 2013, pp. 289-300.

HOLL K., BICHLMAIR S., JANIS K., NAUMOVIĆ T., KILIAN R., 'Konservierungswissenschaftliche Begleitung der Inbetriebnahme einer innovativen Lüftungsanlage in Schloss Linderhof,' in *Bausubstanz,* 4/2015, pp. 40-47.

HOLL K., *Der Einfluss von Klimaschwankungen auf Kunstwerke im historischen Kontext. Untersuchungen des Schadensrisikos anhand von restauratorischer Zustandsbewertung*, Laborversuchen und Simulation, Dissertation Munich, 2016.

MICHALSKI S., 'Quantified Risk Reduction in the Humidity Dilemma,' in APT Bulletin, 1996, vol. 27, no. 3, Museums in historic buildings, pp. 25-29.

MICHALSKI S., 'Relative Humidity: A Discussion of Correct/Incorrect Values,' in 10th Triennial Meeting, Washington, DC, August 22nd-27th 1993, Paris, 1993, pp. 624-629.

Acoustic Emission Monitoring of Baroque Furniture as a Diagnostic Tool for the Introduction of Environmental Control to an Historic House

Nigel Blades
National Trust for England, Wales and Northern Ireland
nigel.blades@nationaltrust.org.uk

Katy Lithgow
Former Head Conservator, National Trust for England, Wales and Northern Ireland
katy@perry-lithgow.co.uk

Martha Infray
National Trust for England, Wales and Northern Ireland
Martha.Infray@nationaltrust.org.uk

Lisa O'Hagan
National Trust for England, Wales and Northern Ireland
Lisa.OHagan@nationaltrust.org.uk

Marcin Strojecki
Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences
ncstroje@cyf-kr.edu.pl

Abstract
Knole, in Kent, England, houses one of the National Trust's most internationally significant collections of late 17th/early 18th century furniture in equally important early 17th century interiors. Many objects have remained on open display in the same rooms for 300 years, subject to the naturally humid climate of an unheated UK building. Conservation heating is being introduced to lower relative humidity and provide a safer environment for the collections. In order to avoid drying or desiccation during the transition to this drier environment, acoustic emission (AE) monitoring is being used to assess the environmental response of painted and gilded furniture as relative humidity is lowered. AE monitoring of pieces of Baroque furniture showed their response to be very low in the existing high RH environment with only small increases in response as environmental control was introduced.

Keywords
Baroque furniture, relative humidity, conservation heating, acoustic emission.

Knole, in Kent, England, is one of the largest and most important historic houses owned by the National Trust (fig. 1). Knole is home to an internationally significant collection of late 17th/early 18th century royal Stuart furniture, acquired by the Sackville family through their royal and diplomatic connections. A former archiepiscopal palace built by Thomas Bourchier, Archbishop of Canterbury (1454-1486), Knole was given to Henry VIII in 1538. Acquired from the Crown by Sir Thomas Sackville (1536-1608) in 1570, the interiors were remodelled in the height of Northern Renaissance taste between 1605 and 1608, shortly after his elevation to the peerage as 1st Earl of Dorset in 1604 by James I. The Royal Stuart furniture was acquired by the 6th Earl, Chares Sackville, as a "perquisite" of his role as Lord Chamberlain to William and Mary. He introduced it to Knole in 1701 to replace the 1st Earl's moveable contents which had been seized and sold by the Commonwealth in retribution for the 4th Earl's, Charles Sackville's (1591-1652), support for King Charles I.

These antiquarian charms have drawn visitors to Knole since the

Fig. 1
The west front of Knole House. (© National Trust Images/Robert Morris)

late eighteenth century. By 1874 Reginald Mortimer, 1st Lord Sackville, found that the thousands of visitors now visiting the house meant "people strayed away from their parties, broke into our rooms, tore the fringe off the chairs and couches, and did all manner of things, whereupon I felt obliged to shut up the place" [Sackville-West, 2010]. Although visiting resumed on his death in 1888 at reduced levels and the collections were repaired, often by recycling indigenous textiles, the enormous cost of maintenance and increase in taxes in the twentieth century led to the house being transferred to the National Trust for England Wales and Northern Ireland (NT) in 1946, with subsequent gifts of contents in lieu of tax.

Whilst conservation work on high priority pieces such as the King's Bed, and running repairs on other objects, was undertaken in the latter half of the 20th century, by the present century it was apparent that the house and its internationally significant collection were in rapid decline – a leaky building and roof, and no environmental control in historic showrooms had resulted in the building and contents becoming unstable and in poor condition. Physical and aesthetic damage was being caused by insect pests such as the larvae of *anobium punctatum* (woodworm), mould growth, and the cementation of dust into "mud packs" by the formation of calcite and sticky exopolymers produced by bacteria under high RH conditions [Brimblecombe *et al.,* 2009; Tarnowski *et al.,* 2004].

Although there was a great need for remedial conservation, the constraints of time, money and the need to develop a bespoke conservation

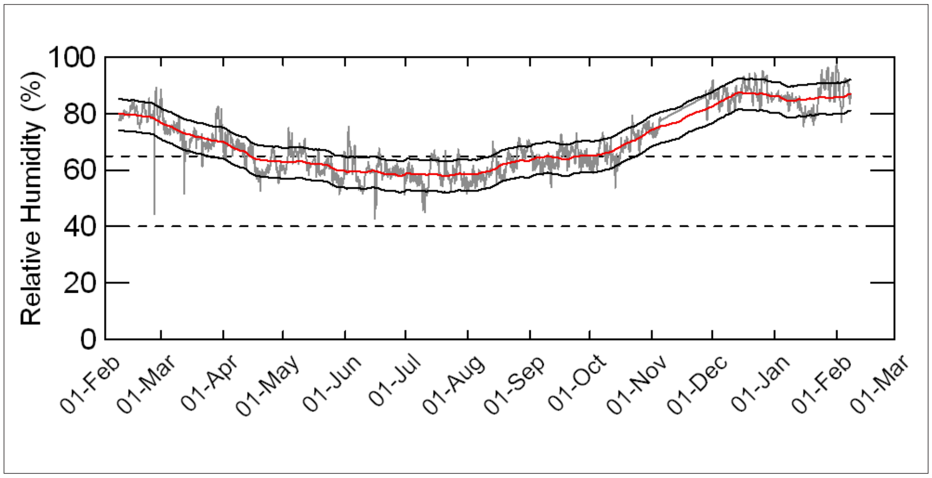


Fig. 2
RH in the Knole Spangled Bedroom, 2015-2016. The measured RH is shown in grey with the 30-day moving average in red. Solid black lines denote the 7th and 93rd percentiles, taken to represent the safe range of RH variation as defined in EN15757. The dotted lines define the National Trust RH 40-65% control band.

approach to prolong the life of such important but fragile collections constrained the speed with which such work could be carried out. The National Trust aims to present collections in "original" condition on open display as much as possible to retain an evocative spirit of place. Therefore, the approach to collection conservation prioritised preventive conservation, and minimal intervention until the funding of the major project "Inspired by Knole" which began in 2012 and was completed in March 2019 [Barratt 2012]. This is the most complex project undertaken by the National Trust, and one of its most expensive, costing just under £20 million, part funded by the Heritage Lottery Fund. Although the scope of the work is broad, from improving visitor facilities to introducing a new electricity sub-main and opening new areas to the public, conservation has always remained at the heart of the project, manifested in the construction of a Conservation Studio in the restored medieval Tythe barn, where conservators carried out light touch treatments in front of the public as part of the visitor offer, to gently lift the appearance and stabilize the condition of the collection, whilst more complex work was outsourced to freelance conservators studios with more sophisticated equipment. In the showrooms, preventive conservation is being enhanced through the provision of environmental control through conservation heating, enhanced light control and use of case covers to protect vulnerable textiles.

The Environment

Knole is distinctive amongst National Trust houses in that, since the early 18th century, most of the showrooms were set up to display the most important furniture and paintings rather than for living or domestic occupancy. These rooms have remained largely unchanged for 300 years, with the collections on open display and subject to a naturally humid climate as the showrooms have largely been unheated throughout this time and into the modern era.

Fig. 3
Left: frass from anobium punctatum emergences on a table leg in a piece of Baroque furniture from Knole. Right: mould growth on surface of a painting. (© National Trust)

As such, the collections have become accustomed to a high relative humidity (RH) environment where the annual RH typically ranges 55 to 90% with an annual average of about 70%. Research in the last two decades has greatly advanced our understanding of the climatic response of hygroscopic materials and it is no longer assumed that controlling to a museum RH standard, such as 55±5% is the correct approach for the care of such a collection. Modern preventive conservation thinking takes far greater account of the historic climate of the objects, and the concept of long-term acclimatization is at the heart of the European Standard EN15757, *Specifications for Temperature and Relative Humidity to Limit Climate-Induced Mechanical Damage in Organic Hygroscopic Materials*. Applying the EN15757 method to determine safe climate for mechanical damage to the conditions at Knole, suggests, a winter RH range of 75-90% (fig. 2). Indeed, the Knole collection appears to be stable mechanically at the current high RH conditions. However the high RH also promotes wood-boring insect attack, which is evident on much of the furniture and regular and persistent mould growth on textiles and paintings (fig. 3).

It was our goal therefore to lower the average RH to prevent these biological damage processes whilst at the same time avoiding the risk of increased mechanical damage as the RH is reduced. Over the last 25 year the National Trust has developed conservation heating [Staniforth *et al.,* 1994; Bullock, 2009] as its main method for controlling and reducing RH. When conservation heating has been introduced at other properties a gradual lowering of RH set points over several months and years has been adopted to allow collections to acclimatize. The fragility and significance of the furniture at Knole was felt to warrant close monitoring of the acclimatization process from a high RH environment to levels considered to lower the risk of mould and insect pests. The method chosen to monitor the environmental response of

Object type	Materials	Description
Gole Suite Side Table	Oak, possibly lime, gilding layers, tin and brass	Carved, gilded and silvered table with a top of pewter inlaid with elaborate scroll foliage of engraved brass Believed to have been made in the workshop of Pierre Gole (1620-84), Paris
Gole Suite Torchère	Oak and possibly lime, gilding layers	One of a pair of carved gilt-wood torchères, in the form of putti on tripod bases, possibly representing Summer and Autumn from a set of four seasons. Thought to have been made in the workshop of Pierre Gole (1620-84), Paris, around 1671.
Jensen Suite Side table	Japanned and ebonized pine and possibly beech	A black and gold japanned pier table with one long drawer, the top with raised gesso and gilded border, on ebonized scroll legs, parcel gilt shaped stretchers and bun feet. The set is attributed to William III's cabinetmaker Gerrit Jensen, who is recorded to have charged the 3rd Earl of Dorset £18 for 'a Table, Stands and Glass Japan' on 21st December 1691.
Jensen Suite Torchère	Ebonized and japanned wood with brass mounts	One of a pair of elaborate black, gold and japanned torchères with octagonal tops with raised gesso and gilded borders, on baluster supports with scroll tripod bases, decorated in the so-called Chinese style.

Table 1
Knole Furniture selected for AE monitoring.

the Knole furniture was acoustic emission (AE). The monitoring was carried out in collaboration with the Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences, who have developed acoustic emission as a method for understanding the mechanical response of hygroscopic cultural heritage objects to changing RH [Lukomski *et al.,* 2017].

Acoustic Emission Monitoring Programme

Four objects from two suites of furniture were selected for the AE study, chosen for their high significance and fragile decorative finishes: a table and one torchère by Gerrit Jensen, and a table and one torchère by Pierre Gole. Taking analogies from demographic studies, it was hypothesized that if these "canary objects" did not respond adversely to environmental change, then the majority of the collections at Knole would also be safe. Additionally, the AE technique required objects to be monitored in pairs so it made sense to choose two items from each suite of furniture.

Acoustic emission monitoring uses small acoustic sensors or microphones, working in and above the frequency range audible to humans, to detect acoustic events caused by mechanical changes in the wood. Acoustic emission is defined as the energy released due to micro-displacements in a structure undergoing deformation. The energy passes through the material as ultrasound and sound waves, and is detected on the surface of an object using a piezoelectric transducer which converts the surface vibration to an electrical signal. The AE sensors

Fig. 4
Attachment of AE sensor to the Jensen Suite table, March 2016. Left: tissue pasted to bracing bar of Jensen table with sensor mount ready for attachment. Right: completed sensor mount with cylindrical steel sensor in the acrylic moulding (© National Trust).

need to be physically attached to the objects in order to detect sounds correctly. A reversible method of attachment was devised in consultation with, and applied in March 2016 by, the Trust's specialist furniture conservation adviser John Hartley. Japanese tissue was first glued to the object surface using starch paste and then the acrylic AE sensor mount was adhered to the tissue using Paraloid B72 adhesive (fig. 4). In the case of the Gole table the AE sensor, located between table leg and support, was wedged in place using plastazote.

The AE experimental setup consisted of: a multi-resonant wideband differential AE sensor (Phys. Acoust. Corp.), an acoustic amplifier (EA System), a simultaneous-sampling analogue input card PCI-9812 (Adlink Technology Inc.) and a laptop computer. AE signal data sets were recorded within 100 ms time-windows with a 1 MHz sampling rate, whilst the duration of a typical AE event was of the order of hundreds of μs. Sets of row data recorded during each monitoring phase were post-processed with the help of a computer program searching for individual AE events, extracting them and calculating the most important AE features i.e. amplitude, energy, duration and frequency distribution. The laptop computers were fitted with 3G mobile data connection, enabling the researchers to interrogate the AE equipment and download data remotely. In parallel with the AE monitoring, T and RH data for each of the monitoring locations was collected using Knole's Hanwell radiotelemetric monitoring system.

A detailed description of the absolute energy calibration and data processing has been presented elsewhere [Strojecki *et al.,* 2014; Lukomski *et al.,* 2017]. AE data were analysed in search for possible correlations with RH, indicating deterioration of objects induced by variation of environmental conditions.

Fig. 5
Gole Suite table and torchère in Cartoon Gallery with AE monitoring equipment. AE sensors connect to the amplifier (right), which is linked by the PCI interface (left) to the laptop (rear centre). Hanwell T and RH sensor temporarily located in the foreground. (© National Trust)

The first phase of monitoring investigated the AE response in the existing room environments at Knole compared to changes, if any, in when the furniture was moved to different storage environments during the course of the project, before returning to the showroom locations. Table 2 summarizes the movements of the furniture and the different environmental conditions experienced at each location. The monitoring had to fit around the phasing of the project and the various moves between showrooms and stores as the project progressed. Nonetheless, data were collected for each item in the unheated, uncontrolled Knole environment enabling comparison with the conservation heated controlled environment.

Results

The processed and filtered acoustic emission data are shown for the Jensen Suite (fig. 6) and Gole Suite (fig. 7). Each graph shows the acoustic energy of AE events from each object after interference has been filtered out, as green or black spikes, plotted in parallel with the temperature and RH at the monitoring location. In figure 6 the AE spikes appear fairly randomly distributed and there is little evidence of correlation with RH, or difference between the two monitoring locations.

Using the same format, figure 7 shows the AE response of the Gole Suite Table. The AE response in the Great Store was small and no activity at all was detected during the Brown Gallery storage phase; however there is a considerable change when the table moved back into the Cartoon Gallery, with more frequent and pronounced AE spikes. It is believed that the high activity levels are due to wood-boring insect

Objets	Date	Location	Environment
Gole Suite Table and Torchère	Mar 2016 – Dec 2016	Great Hall temporary store	Conservation heated to 65-70% RH
	Dec 2016 – Mar 2017	Brown Gallery temporary store	Uncontrolled, unheated
	Mar 2017 – July 2018	Cartoon Gallery	Initially uncontrolled, then conservation heated to 65%
Jensen Suite Table and Torchère	Mar 2016 – Nov 2016	Spangled Bedroom	Uncontrolled, unheated
	Dec 2016 – Oct 2017 (monitoring then discontinued for object conservation)	Conservation Studio Store	Conservation heated to 65% RH

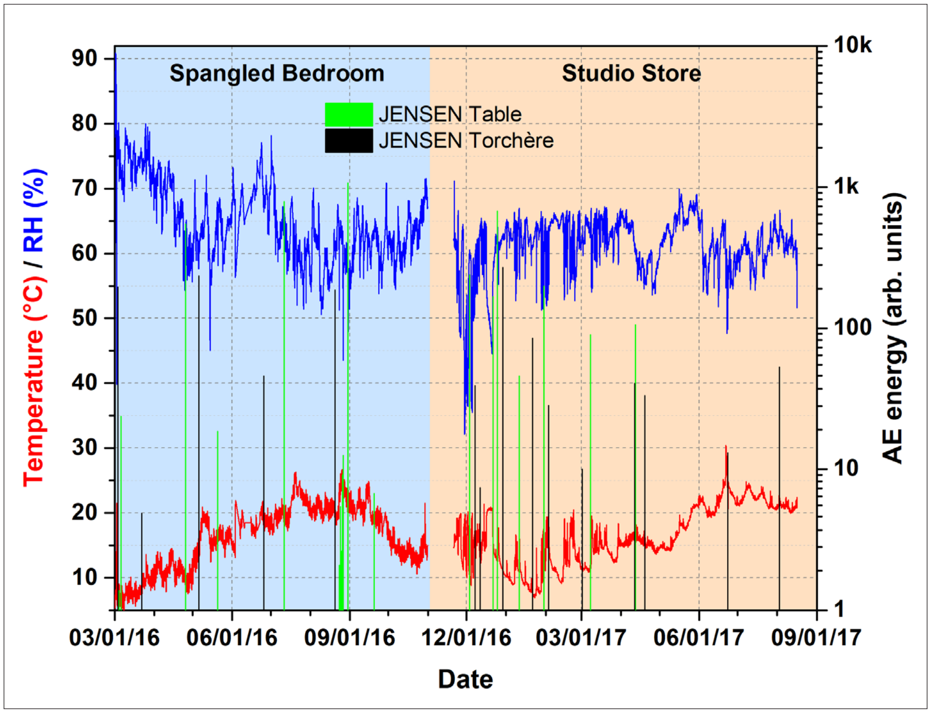
Table 2
Object locations and environmental conditions during Knole acoustic emission monitoring programme.

larvae in the Gole Suite table – AE has been used in the construction industry to detect wood-boring larvae activity in timber [Nasswettrová *et al.*, 2016]. The Gole Suite torchère showed similarly large AE activity, far in excess of what would be expected from a mechanical response to RH change. House staff and the property's conservator had previously found evidence of insect activity in the Gole objects and the AE measurements appear to confirm this. Whilst an interesting observation in itself, this finding does confound the use of the torchère data for illustrating mechanical object response, because the AE activity due to woodworm masks the smaller mechanical RH response.

To understand better the AE response from each object in the different environments, tables 3 and 4 summarize the data from each monitoring phase and express the AE response as crack length propagation in a reference wood sample, so the degree of object response and damage can clearly be visualized.

The Jensen Suite table and torchère responses from the unheated Spangled Bedroom and Studio Store controlled to 65% RH are both negligible. Interestingly, the wardrobe AE response from the much drier National Museum in Kraków, considered to be a small value by the researchers on the basis of the total length of existing cracks [Strojecki *et al.*, 2014], is 40 times greater the highest response from the Jensen Suite.

The Gole Suite table gave a tiny AE response in the Great Store and negligible response during the winter in the Brown Gallery, but developed significant woodworm activity during the spring and summer of 2017. The Gole Suite torchère had significant woodworm activity



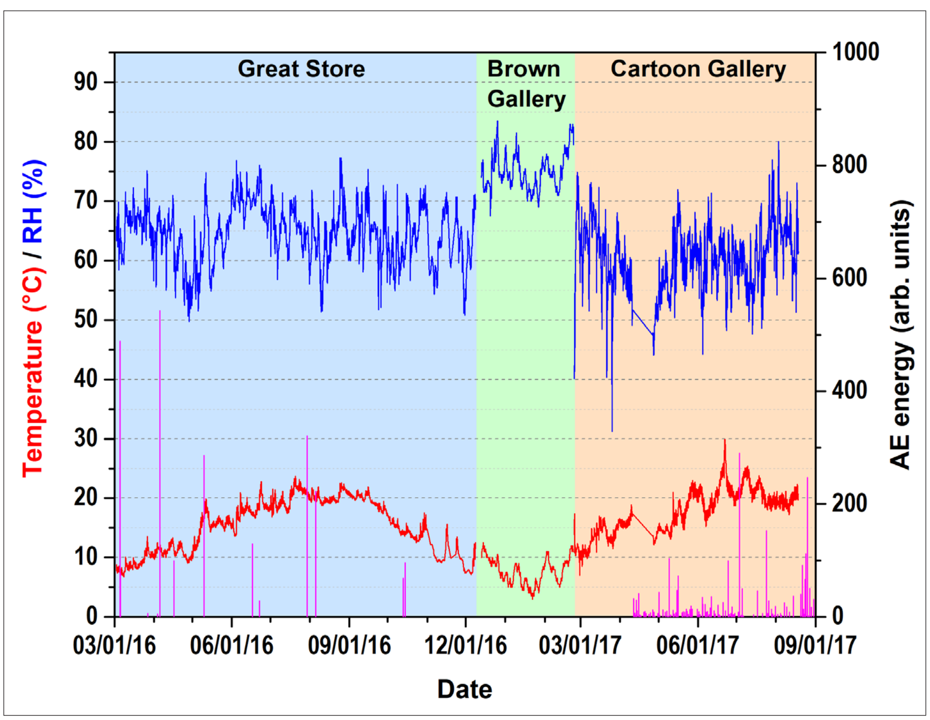


Fig. 6
Acoustic emission response of Jensen Suite table and torchère (vertical spikes, right axis) overlaid with T and RH data from each monitoring location.

Fig. 7
Acoustic emission response of Gole Suite table (vertical spikes, right axis) overlaid with T and RH data from each monitoring location.

Location	Seasonal range (30 day moving average)	Object	Number of AE events	Total AE energy (arbitrary units)	Theoretical crack propagation
Spangled Bedroom, March – Oct 2016	57–74% RH	Table	122	3,054	0.008
		Torchère	48	5,201	0.014
Studio Store, Dec 2016 – Aug 2017	59–66% RH	Table	61	1,964	0.002
		Torchère	19	580	0.001
National Museum of Kraków	32–47% RH	Wardrobe		350,000 per year	0.6

Location	Seasonal range (30 day moving average)	Object	Number of AE events	Total AE energy (arbitrary units)	Theoretical crack propagation
Great Store Mar – Dec 2016	8.8 – 20.5 °C 59 – 71% RH	Table	48	3,713	0.009
		Torchère	18 045	424,697	Woodworm activity
Brown Gallery, Dec 2016 – Mar 2017	5.6 – 8.9 °C 75 – 77% RH	Table	negligible	negligible	negligible
		Torchère	506	67,846	Woodworm activity
Cartoon Gallery, Mar – Aug 2017	13.7 – 22.3 °C 56 – 64 % RH	Table	367	10,543	Woodworm activity
		Torchère	1 098	419,309	Woodworm activity

Table 3
Summary of Jensen Suite AE response and environmental conditions during two different monitoring phases, and in comparison with furniture monitored at the National Museum in Kraków [Strojecki *et al.,* 2014]. To compare all the monitoring results the last column presents the theoretical wood crack length propagation per year.

Table 4
Summary of Gole Suite AE response and environmental conditions during three monitoring phases, same basis as table 3.

during all monitoring periods, with the highest activity during the summer and a significant falling off in the winter.

Conclusions

The AE monitoring clearly indicated that, for the four objects tested, the mechanical changes in wooden objects induced by moving from the existing 60-85% RH environment at Knole to a moderately controlled conservation heated environment with 65% RH set point, are small, if not negligible. To date, this accords with visual assessments of the objects' condition at Knole in the first phase of the house, which was re-serviced and has been open to visitors since spring 2017.

It was interesting that woodworm activity could be detected by AE even though this confounded the use of AE to understand the mechanical response of the Gole Suite torchère. The Gole Suite table and torchères have since been treated using the Thermolignum controlled heating process to kill the woodworm infestation [Beiner and Ogilvie, 2005/6]. Monitoring is continuing on these objects and has found that the high AE response stopped after treatment, supporting the hypothesis that it was due to woodworm activity.

The AE results give confidence that the climate changes instigated at Knole are safe for the furniture and other collections at Knole, providing better conditions for their preventive conservation in the long term, by reducing the risk of mould growth and wood-boring insect infestations. In practical terms AE is very much a research technique, requiring a high level of technical expertise to set up the equipment, keep it in reliable operation and interpret the data. However as acoustic emission becomes more widely used and protocols established for monitoring it may become part of the preventive conservation arsenal of techniques for understanding direct object response rather than inferring response from measuring RH.

Bibliography

BARRATT S., 'Inspired by Knole,' in *The Artifact, their Context and their Narrative: Multidisciplinary Conservation in Historic House Museums*, The Getty Research Institute, Los Angeles, November 6-9, 2012. ICOM DEMHIST / ICOM-CC.

BEINER G.G, OGILVIE M. A., 'Thermal Methods of Pest Eradication; Their Effect on Museum Objects,' in *The Conservator* 29, 2005/6, pp. 5-18.

BRIMBLECOMBE P., THICKETT D., YOON Y. H., 'The Cementation of Coarse Dust to Indoor Surfaces,' *Journal of Cultural Heritage,* 10 (3), 2009, pp. 410-414.

BS EN 15757:2010 *Conservation of Cultural Property – Specifications for Temperature and Relative Humidity to Limit Climate-Induced Mechanical Damage in Organic Hygroscopic Materials*, British Standards Institute, London.

BULLOCK L., 'Environmental Control in National Trust Properties,' in *Journal of Architectural Conservation*, March 2009, pp. 83-98.

ŁUKOMSKI M., STROJECKI M., PRETZEL B., BLADES N., BELTRAN V. L., FREEMAN A., 'Acoustic Emission Monitoring of Micro-Damage in Wooden Art Objects to Assess Climate Management Strategies,' *Insight* 59 (5), 2017, pp. 256-264.

NASSWETTROVÁ A., KŘIVÁNKOVÁ S., ŠMÍRA P., ŠTĚPÁNEK J., 'Acoustic Detection of Wood-Destroying Insects,' in *Wood Research*, 61 (5), 2016, pp. 755-766.

SACKVILLE-WEST R., *Inheritance: The Story of Knole and the Sackvilles,* Bloomsbury, London, 2010.

STANIFORTH S., HAYES B., BULLOCK L., 'Appropriate Technologies for Relative Humidity Control for Museum Collections Housed in Historic Buildings,' in Roy A., *Preventive Conservation Practice, Theory and Research, Preprints of the Contributions to the Ottawa Congress,* 12-16 September 1994, International Institute for Conservation of Historic and Artistic Works, London, 1994, pp. 123-128.

STROJECKI M., ŁUKOMSKI M., KRZEMIEŃ L., SOBCZYK J., BRATASZ Ł., 'Acoustic Emission Monitoring of an Eighteenth-Century Wardrobe to Support a Strategy for Indoor Climate Management,' *Studies in Conservation,* 59 (4), 2014, pp. 225-232.

TARNOWSKI A., MCNAMARA C., BEARCE K. AND MITCHELL R., 'Sticky Microbes and Dust on Objects in Historic Houses,' in *AIC: Objects Specialty Group Postprints*, The American Institute for Conservation of Historic & Artistic Works, Washington DC, 2004, pp. 11-28.

Experimental “Patrimex” Workshop at the Château de Fontainebleau

Abstract

The Foundation for Heritage Sciences ensures the scientific management of the Equipex Patrimex, it is a financed project within the framework of the investments for the future which constitutes a socio-technical network for the characterisation, the conservation and the restoration of material heritage in all its forms (monuments, statues, paintings, manuscripts, archives, old instruments). It brings together study tools using wave-matter interactions, distributed around four poles. The “mobile platform” pole has enabled the development and the acquisition of a certain number of analytical tools during the years 2013 to 2016. The project has arrived at the end of a first development phase, an experimental workshop was set up from April 24th to 28th, 2017. Its purpose was to bring to the site, in this case, the Château de Fontainebleau, the various mobile analyses techniques from the mobile platform to implement them on the same support. This made it possible to establish comparisons between the produced data, to show their complementarity in order to allow future users to better understand the use of these tools.

Emmanuel Poirault
Head of the Fondation des Sciences du Patrimoine
emmanuel.poirault@u-cergy.fr

Christine Andraud
Professor,
Centre de Recherche sur la Conservation (CRC),
Muséum national d’Histoire naturelle, CNRS, Ministère de la Culture
christine.andraud@mnhn.fr

The Foundation of Heritage Sciences (FSP) is a partnership foundation created by the universities of Cergy-Pontoise and Versailles-Saint-Quentin en Yvelines, the Louvre museum, the Palace of Versailles and the Bibliothèque Nationale de France.

Placed under the patronage of the ministry of Culture and Communication, it also includes several cultural institutions (National Archives, the Quai de Branly Museum, Pompidou Centre), training institutions (Institut National du Patrimoine) or research structures (Laboratoire de Recherche des Monuments Historiques – LRMH, the Museums of France Research and Restoration Centre – C2RMF, the Research Centre on Conservation – CRC…).

The FSP’s ambition is to structure and finance research around tangible cultural heritage, in several fields: knowledge, improvement of conservation and restoration methods, finally, dissemination and sharing of knowledge.

The Foundation ensures the scientific management of the Patrimex Equipment of Excellence, a project financed under the investments for the future, which constitutes a socio-technical network for the characterisation, conservation and restoration of tangible heritage in all its forms (monuments, statues, paintings, manuscripts, archives, old instruments). It brings together study tools using wave-matter interactions, distributed around four poles.

On the Neuville site of the University of Cergy-Pontoise, new laser tools are developed to meet the challenges of characterisation and restoration of material heritage. The results obtained will promote a much detailed knowledge of tangible heritage, suggesting, for example, new restoration techniques.

Embedded versions in a mobile platform supervised by the LRMH (Laboratoire de Recherche des Monuments Historiques) allows on-site analysis, for all historical monuments and heritage works that cannot be moved.

As part of IPANEMA, a new light line of (PUMA) dedicated to the study of heritage materials is located within the prestigious SOLEIL synchrotron. This instrument makes it possible to explore in a non-destructive way the heart of the matter thanks to the radiation produced by the circulation of electrons at a speed close to that of light.

All information collected will be digitally preserved and accessible to the involved laboratories through the creation of an innovative database, a real information system dedicated to the study of tangible heritage and the transmission of the associated knowledge.

Having reached the end of the first phase of development (acquisition, adjustment and installation of equipment), the continuation of the project required the organisation of an event to put in the situation of various techniques present in Patrimex. Thus was born the idea of setting up an experimental workshop.

The Château de Fontainebleau conservation team has agreed to host the event held from April 24th to 28th, 2017. Various study supports were discussed. The final choice fell on two of the castle's spaces:

– The Saint-Louis vestibule: not open to the public, this room is located in the dungeon, the oldest part of the castle. Under Louis-Philippe, this space benefited from a painted neo-Gothic style decor. Today attacked by the presence of salt and capillary rise, this decor requires an analysis to prepare for its eventual restoration, especially for the "Louis-Philippe in Fontainebleau" exhibition which is in preparation.
– The salon known as the King of Rome: This space is located at the end of the gallery of Diana. This gallery built under Henri IV included a wooden ceiling with wooden framed walls whose plaster was painted with scenes from the history of Diana and Apollo. The walls included panelled woodwork surmounted by battles of the king and

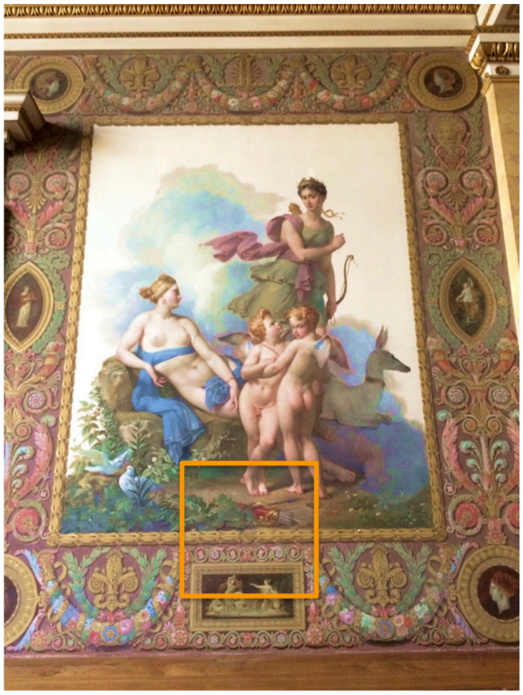


Fig. 1
Wall painting concerned by the analysis, the salon of the King of Rome, Château de Fontainebleau.

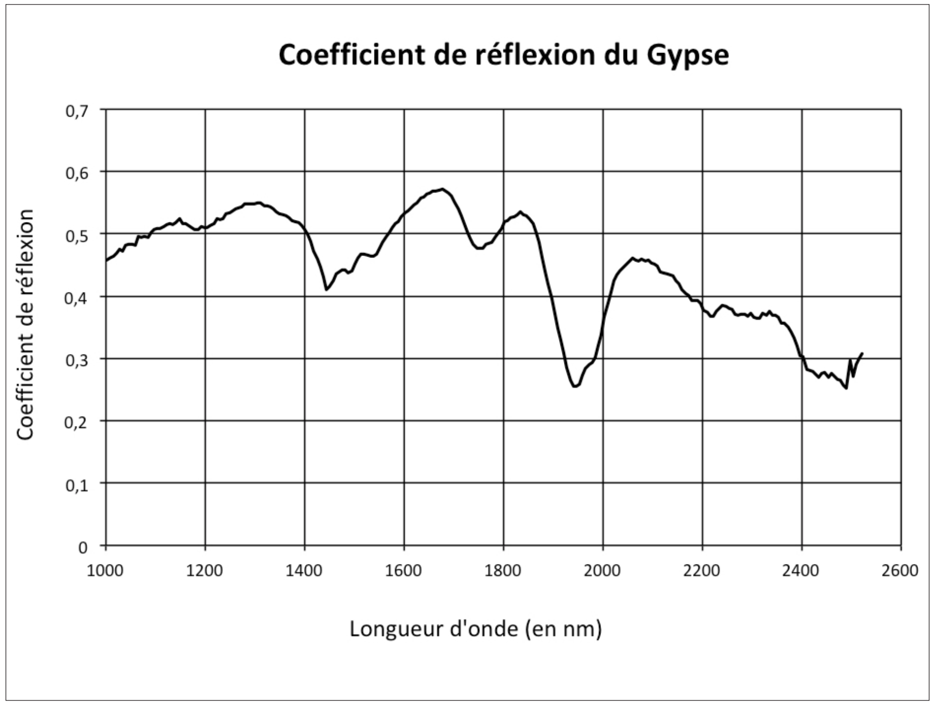
Fig. 2
Visualisation of the analysed area in the bands corresponding to wavelengths 1200 nm.

Fig. 3
Visualisation of the analysed zone in the bands corresponding to the wavelengths 2000 nm.

deities. Very ruined at the end of the Ancien Régime, the gallery underwent a general restoration in 1810. Napoleon then projected a new decor evoking the actions of his reign. The Restoration completed the project, which was replaced by a set of paintings representing the history of the monarchy. Under the Second Empire, the gallery was transformed into a library. The space that hosted the experimental workshop has retained its decor of the First Empire. Currently very under-studied, this set of plaster and painted stucco raises questions about its composition.

The defined objectives were the following: to bring on the same site different analysis techniques in order to implement them on the same medium, to make comparisons between the produced data and

Fig. 4
Spectrum of reflection highlighting the uniform presence of gypsum.



especially to allow future users to better understand their use. The duration and the constraints related to the setting up of such an operation within fragile spaces did not make it possible to proceed to the delivery of data directly exploitable by the conservation team and the restorers of the site. Only reflections and information on the relevance of certain techniques in relation to certain mediums could be presented.

A certain number of mobile techniques have been put in place, which can provide information on the structure of the studied materials (Raman spectroscopy and mid-infrared, X-ray fluorescence, etc.). We will only detail here the techniques which gave directly exploitable results.

Hyperspectral Imaging in the Near-Infrared

Hyperspectral imaging is an optical analysis technique (non-destructive and contactless) which allows the acquisition of images containing, not three (as in conventional digital imaging – RGB) but several hundred channels covering a wide range of wavelengths, from visible to far infrared. Initially developed for teledetection (mining), these techniques are now extended to other fields of application: industrial, biomedical and more recently for the study and conservation of heritage objects. The processing of the information contained in these cubes of data can lead to the characterisation and identification of materials, and then to their mapping. The hyperspectral imager financed by Equipex Patrimex works in the near infrared, at energies just below

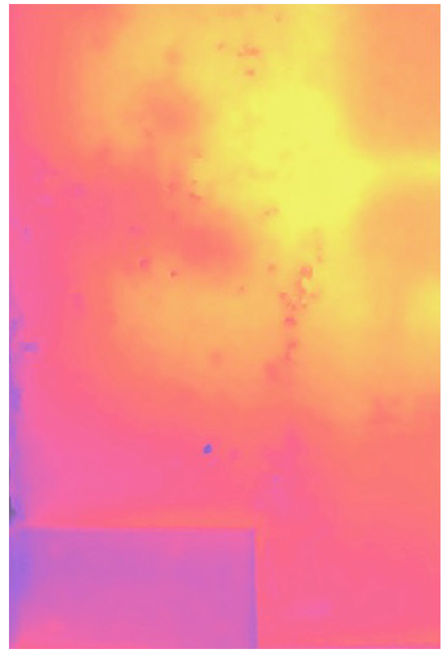


Fig. 5
West wall of the Saint-Louis vestibule, Château de Fontainebleau, detail.

Fig. 6
Infrared image of a portion of the west wall of the Saint-Louis vestibule highlighting a cold spot (blue area).

the visible energies. The measurements taken at the Château de Fontainebleau were made in the salon known as the King of Rome, located on the murals at the end of the gallery of Diana. The image area was relatively limited so as to minimise exposure and measurement time. Figure 1 illustrates the concerned wall painting and the analysed area. Figures 2 and 3 show the visualisation of the analysed area in the strips corresponding to the 1200 nm and 2000 nm wavelengths. In this area, no underlying amendment or outline could be detected. The data cube also makes it possible to extract for each of the present pixels their spectrum of reflection, it has made possible to highlight the uniform presence of gypsum, as illustrated in figure 4. The further identification of the various constituents could be considered by coupling these analyses in the near-infrared to those in the visible field, but also with an elementary identification such as X-ray fluorescence.

Stimulated Infrared Thermography

Stimulated infrared thermography is based on the analysis with a thermal camera of the temperature response of a previously excited sample using a controlled light source. The presence of defects results in the appearance over time of localised heating zones. The analysis of the kinetics of heating and cooling of these anomaly zones makes it possible to characterise these defects (depth of the defects, etc.). This technique was put in place on the West wall of the Saint Louis vestibule (fig. 5). This wall showed, following its deterioration, a visible stratigraphy with several layers, including one seeming to contain metal. The infrared image of this same wall has made it possible to highlight a cold spot (blue zone on fig. 6), showing of the presence of a conductive material (i.e., metal). This hypothesis was subsequently corroborated by the optical microscopy study of a swab.

Conclusion

The experimental Patrimex workshop made it possible to implement a set of analysis techniques all in one place and in the presence of specialists of these techniques, which could show the complementarity of the different techniques. It also helped to understand the complexity of a multi-analysis campaign for the specialists but also for the conservators. Finally, certain research paths for conservation and restoration have been proposed. These can be considered in the framework of the next Patrimex call for projects, allowing the financing of cooperations between scientific actors and heritage institutions.[1]

Notes

[1] Patrimex's partners wish to thank Vincent Droguet, Oriane Beaufils and Jehanne Lazaj, conservators, as well as all the teams from the Château de Fontainebleau.
The organisation of the workshop benefited from the patronage of the Credit Mutuel Enseignant of Ile-de-France.

Assessment of the Risks of Mechanical Degradation of Paintings

Alain Roche
Engineer, conservator-restorer,
LARCROA
a.roche@larcroa.fr
www.larcroa.fr

Abstract
In this article, we present an assessment method for the mechanical degradation risk of paintings or "risk indicators." It is based on two of painting's fundamental properties, on one hand, the sensitivity to humidity and temperature, represented by the sensitivity diagrams, and on the other hand, the mechanical fatigue endurance limit defined by the minimum tension variation ($V_{mini}t$). This method relies essentially on the relationships that exist between these two properties.

When knowing the work's climatic environment, the mechanical behaviour towards humidity and temperature and the minimum tension variation, we are able to transform the climatic data – humidity or temperature – into mechanical data of force or tension and to assess using the $V_{mini}t$, the tolerance zone which suits each painting.

The risk indicator is an assessment tool which is easy to use, it is constituted of an Excel calculation module and an overview where the results are gathered together.

This risk indicator allows to:

– analyse the mechanical degradation risks of a painting during transport, during a loan for a temporary exhibition.

– to determine the capacity of a room, according to its environmental conditions, prior to an exhibition of painted works of different techniques.

– to determine the climatic tolerance zone of each type of painting.

Keywords
Preventive conservation, risk assessment, humidity-temperature, mechanical fatigue, sensitivity diagram, tolerance zone.

Introduction

Preventive conservation in museums and in collections has been the subject of numerous books, guides and manuals on risk management. The complexity of managing the risks of heritage and collections' encourages us to evolve in stages to achieve the objectives. The difficulty most often encountered in risk management comes from their assessment. Whatever the method used, risk assessment raises a number of questions. How to get a fair and objective score not diverted by a subjective appreciation? How is it calculated? What are the used parameters?

Our experience has showed us through numerous climatic studies, carried out in the framework of museums, funds, galleries, historic dwellings and exhibition halls, that despite the presence of an air-conditioning system, climate stability is far from being perfect. The humidity and temperature regulation in a building depends on many parameters: exterior climate, the building's sanitary design and state, technical facilities and their functioning state, the attendance and the management of the public's flow, etc.

So the probability that the climate is perfectly stable is very low if not unlikely. It will, in any case, have an impact on the present objects and specially the painted works. Moreover, aware of these limitations, the authors of the various studies that have been conducted to define the best climatic conditions, offer humidity differences that, according to the sources, range from 45 to 55%, from 50 to 60% RH, [Thomson, 1978] or from 40 to 60% [CCI, Note10/4, 1993]. The normative values proposed by the ICOM – RH = 55% ± 5% or 50% ± 5% and T = 20°C ± 2°C – are the most followed instructions by the museums. Knowing that the paintings' sensitivity to humidity and temperature are different from each other, these recommendations are not valid for the whole spectrum of pictorial techniques.

In the context of preventive conservation we have developed an assessment tool that measures the impact of environment climate on the conservation of painted work on canvas or paper. It is a risk indicator. This risk indicator is based on 2 fundamental properties for paintings:

– their sensitivity to humidity and temperature represented by the sensitivity diagrams;
– their endurance limit in mechanical fatigue defined by the minimum tension variation.

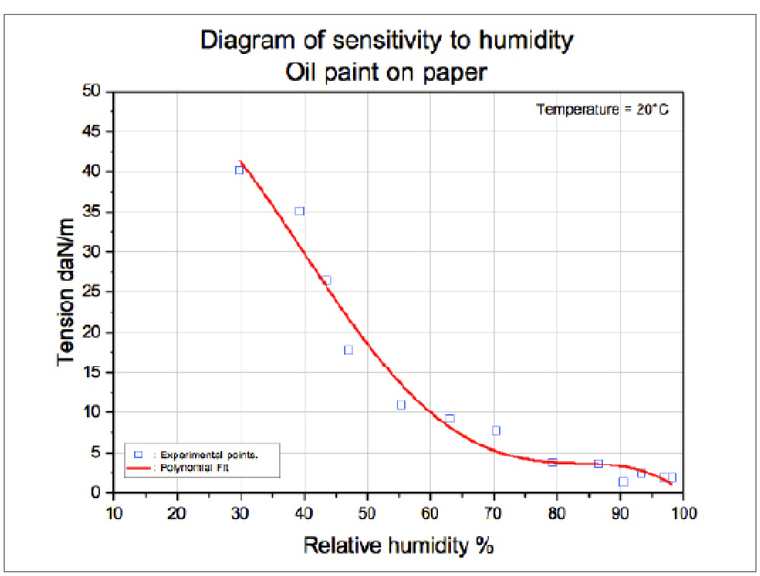


Fig. 1
Experimental construction of a sensitivity diagram.

What is a Temperature and Humidity Sensitivity Diagram?

They are curves specific to each pictorial technique. It is a curve that describes the variation of the tension in a painting according to the humidity or the temperature. They can be built experimentally or theoretically [Roche, 2016].

Experimental Construction: paint samples, mounted on an "Extensiometric Frame" or a "Universal Test Machine (UTM)," enclosed in a climatic chamber, are solicited in humidity or temperature. The experimental measures give a series of points that can be represented by a polynomial degree n. The curve thus obtained is mathematically described by its polynomial function (fig. 1).

Theoretical construction: the mechanical behaviour of a pictorial technique is obtained according to the law of additivity. By adding the mechanical behaviour of each constituent, it is possible to produce a theoretical diagram of sensitivity to humidity or to temperature (fig. 2).

In all the cases the curves can be mathematically described with a polynomial function of order 4.

$$Y = a + bX + cX^2 + dX^3 + eX^4 \quad (1)$$

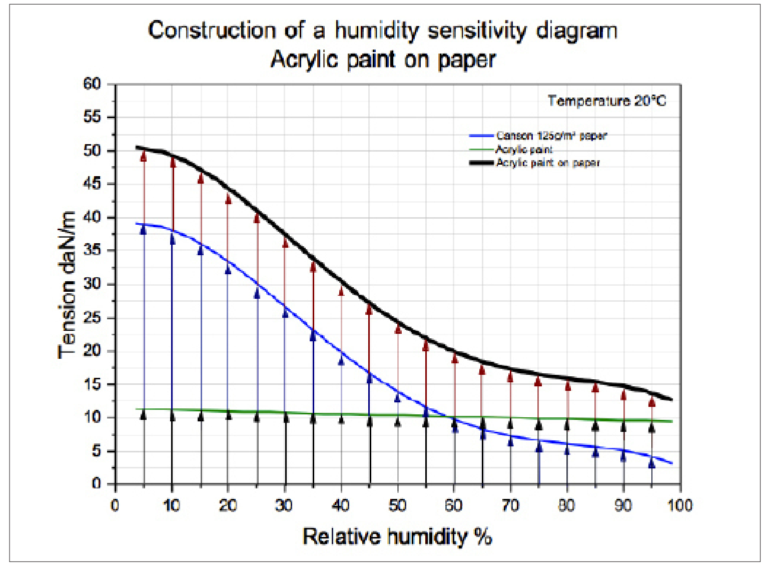


Fig. 2
Theoretical construction of a sensitivity diagram.

The Endurance Limit of a Film of Paint

In mechanical fatigue, it is said that it is the maximum variation of stresses that a film of paint can withstand without breaking, regardless of the number of cycles. If we accept that the endurance limit of a painting is linked to both the breaking stress and to the stress concentration factor *Kt*, we can write that the ratio between σ_{rupt} and *Kt* is equivalent to the endurance limit of a film of paint.

By validating the value of the stress concentration factor at a constant value of *Kt*=100[1] [Roche, 2016], the simplified expression of the endurance limit of a painting is expressed by the following relation:

$$\varsigma Dp = \frac{\sigma_{rupt}}{100} \quad (2)$$

The endurance limit of a film of paint can be expressed through the minimum variation of tension ($V_{mini}t$) which is equal to the product of the endurance limit and the thickness (σDp) of the film of paint (e):

$$V_{mini}t = \frac{\sigma_{rupt}}{100} \times e \quad (3)$$

In any case if:

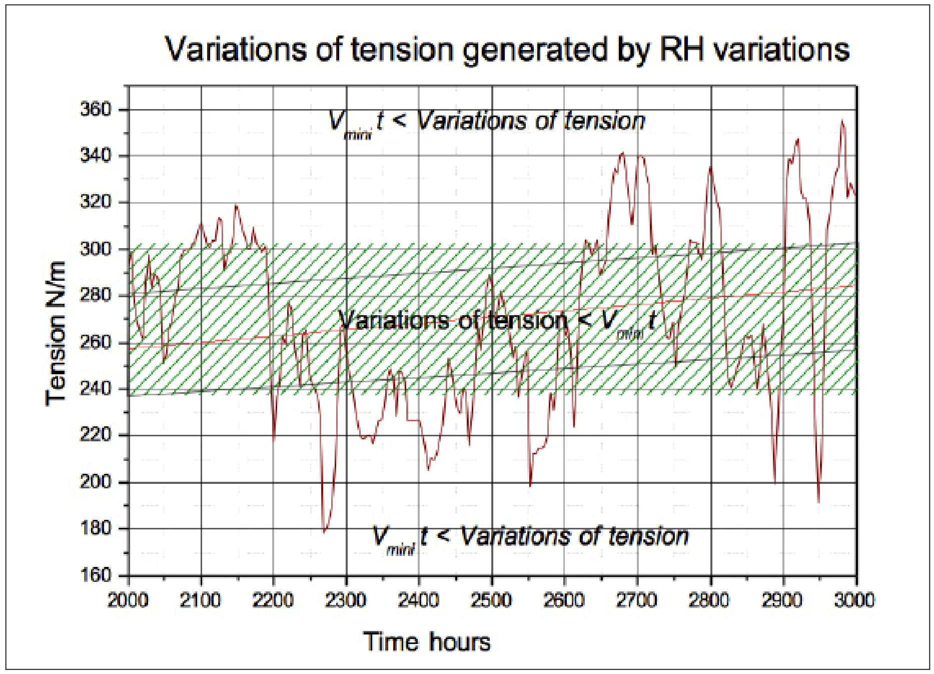
$\sigma Dp > \Delta s_{max}$	ou $V_{mini}t > \Delta t_{max}$	risk of mechanical degradation = 0
$\sigma Dp = \Delta s_{max}$	ou $V_{mini}t = \Delta t_{max}$	risk of mechanical degradation – limited
$\sigma Dp < \Delta s_{max}$	ou $V_{mini}t < \Delta t_{max}$	risk of mechanical degradation – significant

Assessment Principle of the Risk Indicator (RI)

This “risk indicator” tool relies essentially on the relationships that exist between:

– the mechanical properties of paintings vis-a-vis of the environment;
– the mechanical fatigue endurance of the paintings.

Fig. 3
Tracings of the tension curve and the tolerance zone.



By knowing the climatic environment of the artwork, either by placing a mini recorder on the reverse of the artwork or by collecting the climatic data from a recorder close to the artwork, by knowing the mechanical behaviour of the artwork vis-a-vis climatic variations by choosing the appropriate relative humidity and temperature sensitivity diagram and by knowing the minimum tension variation obtained from the thickness of the film of paint and the break stress, one is able to:

– transform the climatic data – humidity or temperature – into mechanical force (N) or tension (daN/m) data;
– compute and plot with the $V_{mini}t$, the upper and lower limits of the tolerance zone appropriate for each painting (fig. 3).

By knowing that the tension values within the zone correspond to tension variations below the endurance limit and that all outside values correspond to variations greater than the endurance limit of the painting, it is possible to calculate the risk index to determine climate impact on the conservation of the artwork. For this we have created a calculation module that converts the climate data into tension in the painting, from one of the 40 polynomial functions and the thickness of the paint.

The risk index can be timed as a time function (duration of exposure or transport) by applying depreciation coefficients.

Presentation of the Risk Indicator (RI)

Calculation Module

The risk indicator on Excel consists of a calculation module in which you enter all the necessary parameters: time/date, relative humidity, temperature, polynomial function associated to the selected diagram, duration in months. The tension calculation results are displayed in a column as are the values of the upper and lower limits of the tolerance zone. By comparing the obtained tension values with the endurance limit $V_{mini}t$ of the studied painting, the module calculates the risk index noted from 0 to 100%. The results are automatically displayed in the overview of the calculation module.

Overview

The overview contains 2 graphic windows in which will be displayed on the left hand side the curves, the relative humidity and the temperature, framed by the tolerance zone recommended by the ICOM and on the right hand side the tension variation curve framed by the tolerance zone determined by the $V_{mini}t$.

There are also 3 charts displaying on the left hand side statistical climate data, in the centre statistical data of tension values and on the right hand side the paintings' characteristics.

The risk indicator values are presented, in the centre of the overview, by a numerical value in % in a box and a graphic representation in the form of a dial and a moving needle.

Under this part of the overview, there is, on the one hand, a text box allowing the input of comments or the interpretation of the results and on the other hand, the tabs allowing to access the calculation module, the tolerance zone and various humidity and temperature sensitivity diagrams (fig. 4).

The risk indicator dial is divided into 5 zones of appreciation:

– in the "negligible" risk zone (0 to 20%), the formation of a few internal micro-cracks, at the defect level, is likely when the limit value

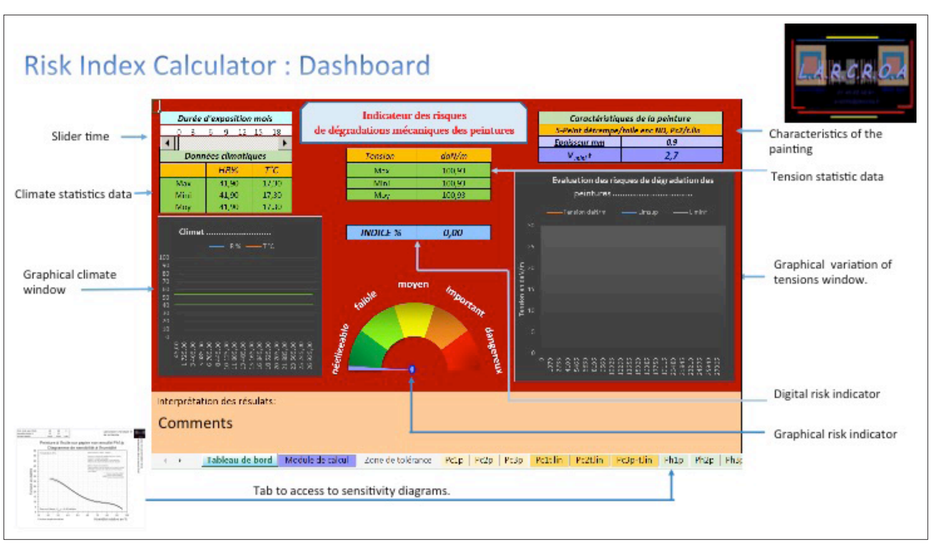


Fig. 4
Presentation of the risk indicator overview.

of 20% is approached. These micro-degradations are not visible on the surface.

– In the "weak" risk zone (20 to 40%), the micro-cracks are going to progress towards the formation of fine cracks, visible on the surface. Their spread increases with the value of the index.

– In the "medium" risk zone (40 to 60%), cracks are intensified with the birth of a network, which will be more or less extended depending on the value of the index.

– In the "significant" risk zone (60 to 80%), the densification of the cracks network intensifies with the emergence of raises in the pictorial material.

– In the "dangerous" zone (80 to 100%), the development of the densification of the cracks network and the raises, jeopardises the integrity of the collection piece.

What are the Applications for this Risk Indicator?

1-6 month loan of an 18th century painting for an exhibition in a museum.

Analysis of the conditions during transport (fig. 5).

If we examine the climatic data during the trip, we can find that the humidity values are completely outside the recommendations. However the calculation of the risk index of 0.2% is very low and the risks are negligible, no degradation of a mechanical nature will appear on this artwork during the trip.

Analysis of the conditions during 6 months of the exhibition (fig. 6).

The humidity conditions during the exhibition period fluctuate. The hygrometry went from a 45% average during the first 2 months to 35% during the last three months. In spite of a certain climate instability, we can see that the tension variations follow the slope of the tolerance zone. The risk index does not exceed 16.45% and stays in the negligible risk zone. During this exhibition period the humidity didn't have a direct impact on the conservation state of this artwork.

Determination of the exhibition hall's capacity to reception, according to its environmental conditions, painted artworks with different techniques.

A library manager has the intention to organise in one of its exhibition halls an exhibition of painted artworks with different techniques:

– oil paint on pasted paper;
– oil paint on paper mounted on canvas;
– painting on unprimed canvas;
– tempera on paper;
– tempera on pasted canvas;
– vinyl paint on pasted paper.

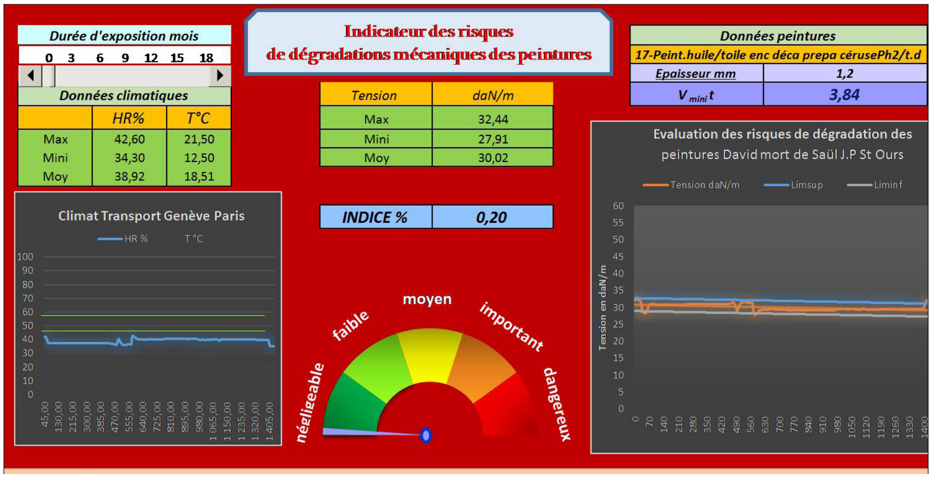


Fig. 5
Analysis of transport conditions of oil painting of Versailles.

Results interpretation:
Risk Index Calculator is 0.2% "insignificant," no degradation is to be expected during transport. If we examine the climatic data during the trip, we can find that the humidity values are completely outside the recommendations. However the calculation of the risk index of 0.2% is very low and the risks are negligible, no degradation of a mechanical nature will appear on this artwork during the trip.

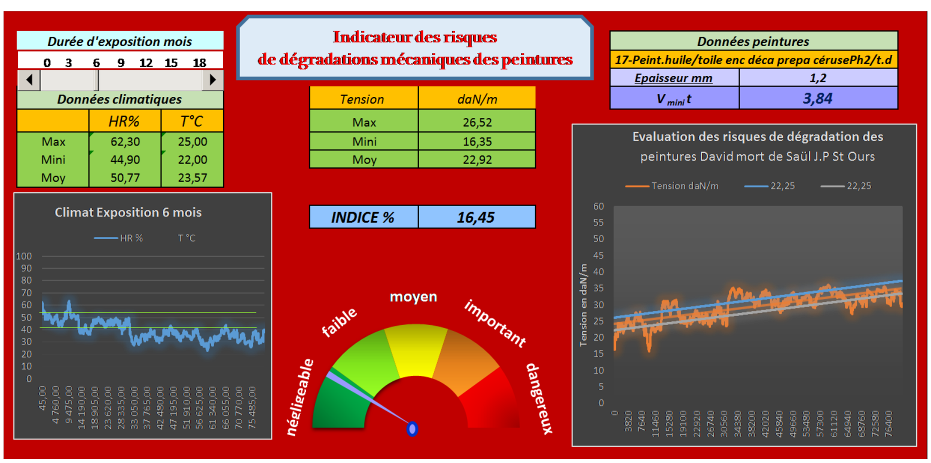


Fig. 6
Analysis of exhibition conditions of oil painting in museum.

Results interpretation:
Risk Index Calculator is 19.84% "between insignificant/weak." Risks of formation and development of internal fissures. Weakness of cohesion. These mechanical degradations are not visible on the painting surface.
The humidity conditions during the exhibition period fluctuate. The hygrometry went from a 45% average during the first 2 months to 35% during the last three months. In spite of a certain climate instability, we can see that the tension variations follow the slope of the tolerance zone. The risk index does not exceed 16.45% and stays in the negligible risk zone. During this exhibition period the humidity didn't have a direct impact on the conservation state of this artwork.

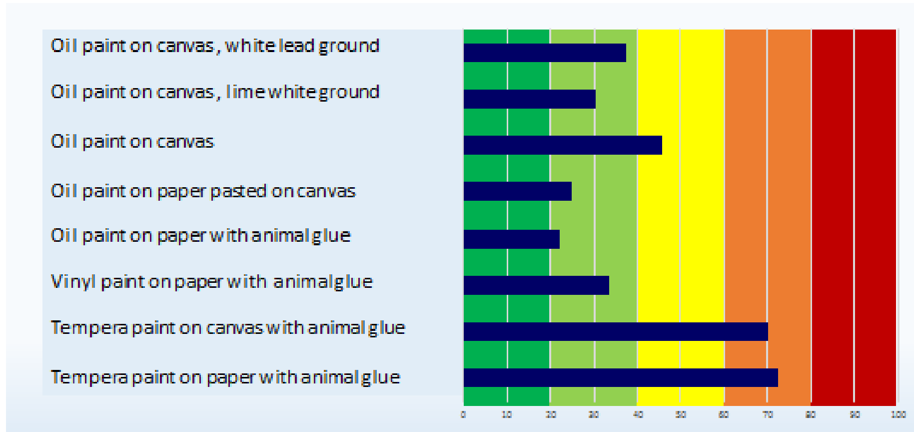


Fig. 7
RI results for the 8 paintings.

Before exhibiting the collection, he wonders if the climatic conditions of the exhibition hall meet the conservation requirements. As a precautionary measure, an evaluation of mechanical deterioration risks for each technique is made from the library exhibition hall's climatic records. The index results obtained are grouped in the following graph (fig. 7).

The results show that tempera paint on paper (IR=72.3%) or on canvas (IR=70.1%) are the most sensitive and vulnerable to the exhibition hall's unstable climate.

Consequently, from the conservation point of view of this kind of painting, it is strongly discouraged to exhibit these artworks in this hall, otherwise the networks of cracks will spread rapidly with the appearance of rises in the pictorial material. Nevertheless, the historical interest of these artworks is such, that they must be exhibited. In order to find a suitable solution, we must look for the optimal conservation of these artworks by determining its zone of climatic tolerance.

Determination of the paintings' climatic tolerance zone in humidity

It is possible to quickly determine the climatic tolerance zone by using the humidity sensitivity diagram and the mechanical fatigue endurance limit $V_{mini}t$ of the painting in question (fig. 8).

For tempera paint on paper, at 55% RH the tension is 16.24 daN/m. Knowing that the $V_{mini}t$ is 1.2 daN/m, adding and subtracting half of the minimum tension variations from the tension value of 55% gives 2 tension values. By projecting their intersection points with the curve, on the X axis, we obtain 2 humidity values. This difference corresponds to the humidity variation that meets the optimal conservation conditions.

The graphic representation shows that the humidity difference must be between 53% and 57% to ensure the best conservation conditions for this painting. In the case that the mechanical degradation

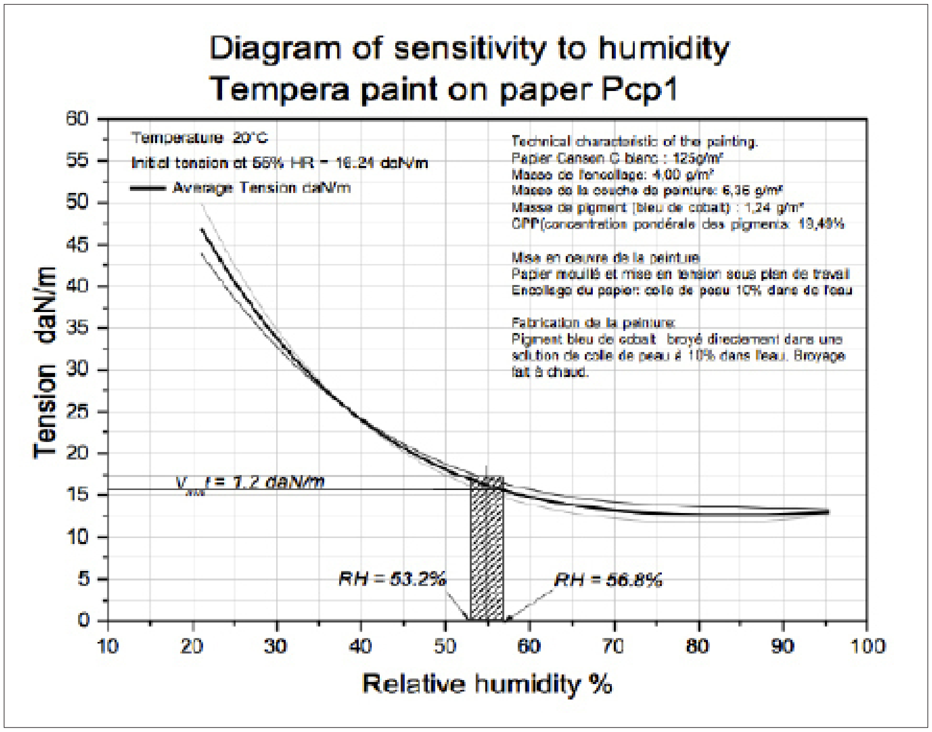


Fig. 8
Search for the tolerance zone on a sensitivity diagram.

risks are null then the two most sensitive paintings can be exhibited. Otherwise there are alternative solutions.

Conclusion

In the field of assessing the degradation risk of painted artworks, we often resort to a subjective assessment of the fragility and the sensitivity of the collection. It is due to a lack of expert tools, essential for this evaluation. It is reflected most of the time by the very different opinions between specialists.

By exploiting, as we have seen, two of the fundamental mechanical properties of the paintings, behaviour towards humidity/temperature and the endurance limit to mechanical fatigue, we are able to obtain a risk value in a specific climatic context which is based on scientific data. This tool gives us a new dimension to this expertise. It will be able to erase any contradiction that may appear in a subjective assessment.

In the context of museums, historic dwellings and funds, climate as a risk factor is very important. Its stability, depending on many parameters, is difficult to manage and master. Ubiquitous, its instability can very quickly lead to a loss in heritage value of the collection.

In addition, cultural policy has for several decades encouraged people to visit museums, historical dwellings and exhibitions. It is responsible for a massive arrival of visitors. This high concentration of people in the permanent and temporary exhibition halls is causing significant climate disruptions. The impact of the public on the climatic environment can be reduced by improving the management of the flow in the halls or by limiting the access to a smaller number of people. Some institutions have already put in place preventive conservation measures of this kind. In this honourable context of cultural development, to feed the temporary exhibitions in France and abroad, the loaned collections circulate enormously. Transport, handling, climate shocks are all risk factors that must be managed and anticipated. In these conditions we must be vigilant and adapt to changing practices, always bearing in mind that artwork conservation is a priority. We must therefore react accordingly, by giving ourselves the financial and material means to acquire and use the risk assessment tools at our disposal.

Within LARCROA, the quest for humidity and temperature sensitivity diagrams continues. We have developed a new experimental setup with an instrumentation that performs better, to obtain more accurate humidity and temperature sensitivity diagrams. We work on both pictorial techniques that we reproduce from documentation and samples of real paintings from artists. Our goal is to enrich our diagram collection, in order to get closer to reality and to serve the conservation of the collections.

Endnotes

[1] COM-CC Paintings, Preventive Conservation and Documentation Working Groups in association with the Institut National du Patrimoine (INP) and the University of Paris Panthéon-Sorbonne 29 and 30 of September 2016, unpublished. Problématiques physiques dans la conservation des Peintures: Surveiller, documenter et atténuer.

Bibliography

Environmental and Display Guidelines for Paintings, Canadian Conservation Institute (CCI) Notes 10/4, 1993. http://canada.pch.gc.ca/eng/1439925170465 (accessed on 18 September 2017).

Roche A., 'La conservation des peintures modernes et contemporaines,' CNRS Editions, pp. 69-75.

Roche A., 'Limite d'endurance d'un film de peinture,' paper presented at the ICOM CC joint interim meeting, Physical Issues in the Conservation of Painting, Paris 29-30 September 2016.

Thomson G., *The Museum Environment. 2nd edition,* Butterworth-Heinemann, London, 1978.

Mechanical Research Applied to Preventive Conservation – What Next?

Łukasz Bratasz
Head of the Sustainable Conservation Lab, Institute for the Preservation of Cultural Heritage, Yale Universitylukasz.bratasz@yale.edu

Abstract

Despite indisputable developments in the understanding of the mechanical behavior of heritage objects in response to their environment, several significant gaps in this knowledge still exist. This article aims to identify some of these gaps and suggest future applications of mechanical research to optimize preventive conservation approach with pragmatic risk assessment. The presentation focuses on gaps in knowledge that create barriers in the development of meaningful models for risk assessment and risk management of heritage collections. There is a lack of adequate models to assess the risk of mechanical damage caused by extreme but rare climate variations and to predict the rate of mechanical damage caused by a large number of moderate RH cycles. Also, more research needs to be done to understand crack saturation process in paint layers which might give new insight into common observation of curators and conservators-restorers that objects survived remarkably well in environments far from ideal museum conditions.

The absence of these models and thorough understanding of crack saturation have impeded progress towards a consensus on museum standards with wider RH variations. It also creates a significant barrier in communication with decision makers when designing strategies for climate control in new museum buildings or when retrofitting existing ones. This limits the implementation of more energy efficient strategies of collection care in museums, libraries and archives.

Field Experiment to Study Responses of Objects to Variations in Climate

Michal Lukomski
Head of Preventive Conservation research at the Getty Conservation Institute, Los Angeles
MLukomski@getty.edu

Abstract

Object deterioration is affected by climate, but also a variety of object-related factors, such as the type of construction and existing damage. Investigations using new material and mock-ups are limited in their applicability to characterize in-situ damage of real objects. This means that making preservation decisions remains a complex and uncertain task.

In order to deepen understanding of damage to collections, a selection of real, non-accessioned objects were exposed to different climatic conditions over time. This allowed observed or recorded changes to be directly related to climatic conditions, providing greater insight into deterioration and preservation management.

The environments were controlled, but developed to simulate in-situ conditions with increasing intensity. This approach narrows the gap between laboratory research and the practicalities of display environments. The objects were housed in a room with precise climatic control, so each object was exposed to the same ambient climate (as they would be on open display).

The climatic conditions were adjusted, moving from object equilibrium at 20 °C and 50% RH to periods at 65% RH, 40%, 30% and 20%. Each time the conditions were held until equilibrium was reached (approx. 4 weeks), and each time returning to 50% RH (until equilibrium was reached) before moving again.

Objects were chosen to represent a variety of object types and assemblies. Their responses were monitored with high precision dimensional measurements and photography (14 objects), and acoustic emission (6 objects) allowing for direct tracing of micro-damage development. This provided the opportunity to examine how these approaches could be used in cultural institutions, and the extent to which their data could be linked.

Although the sample of objects was small, the study has provided insight into responses of historic objects to changes in relative humidity that have implications to possible broadening the acceptable range of climate fluctuations for museum collections.

Silvana Editoriale

Direction
Dario Cimorelli

Art Director
Giacomo Merli

Editorial Coordinator
Sergio Di Stefano

Copy Editor
Clia Menici

Layout
Letizia Abbate

Production Coordinator
Antonio Micelli

Editorial Assistant
Ondina Granato

Photo Editors
Alessandra Olivari, Silvia Sala

Press Office
Lidia Masolini, press@silvanaeditoriale.it

Silvana Editoriale S.p.A.
via dei Lavoratori, 78
20092 Cinisello Balsamo, Milan
tel. 02 453 951 01
fax 02 453 951 51
www.silvanaeditoriale.it

Cover
© EPV Thomas Garnier