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Determining Appropriate Preservation Conditions for Historical Mixed-Media Objects: a Risk-Based Approach

Willemien Anaf and Marjolijn Debulpaep

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Introduction

1 Within heritage conservation, historical mixed-media objects are unique remains from the past. They are objects that consist of a wide range of materials that can be organic or inorganic in nature. Examples are a headgear made of textile, leather, metal and feathers; an ethnographic object with wood, plant fibres, leather, shells and bone; or a wax Madonna with textile clothes under a glass dome, decorated with silk flowers. Their conservation state is often fragile due to the nature of the materials used, and their advanced stage of degradation. To safeguard historical mixed-media objects for future generations, their degradation rate should be slowed down. Apart from conservation and restoration treatments, this can be done by selecting well-considered environmental conditions. However, all materials have their own optimal conditions, influenced by the material specific properties, the conservation state of the artefact and the material-material interactions. This makes it challenging to give recommendations for historical mixed-media objects, and often compromises have to be made.

2 To support the decision making in determining well-considered preservation conditions for historical mixed-media objects, a risk-based approach is developed. Last decade, risk management approaches received a central position within preventive conservation in general. Well-known methods such as the ABC-method (Michalski and Pedersoli Jr. 2016), the Cultural Property Risk Analysis Model (Waller 2003) or the QuiskScan (Brokerhof and Bülow 2016) are applied to identify, analyse and evaluate the major risks for a collection. The method we propose uses the existing methods and risk terminology as a basis. It guides heritage guardians in estimating the relative importance of the different materials that make up a mixed-media object. It considers the material quantity, its value within the context of the object and its use, and the expected loss of value when exposed to a certain hazard. The outcome offers heritage guardians an objective basis to define compromises in preservation conditions for historical mixed-media objects. Moreover, it allows the comparison of different scenarios in order to select the most appropriate one.

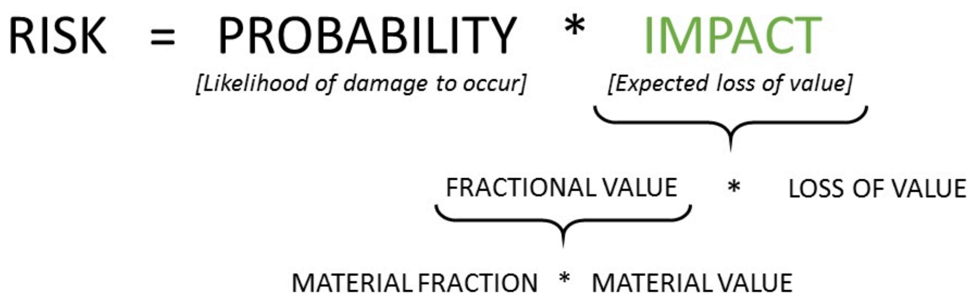
Materials and methods

Methodology

3 In the heritage field, risk is generally defined as probability times impact. 'Probability' can be described as the likelihood of occurrence of material damage or loss due to exposure to a certain hazard. It is quantified within the range of 0 (certainty that damage/loss will not occur) to 1 (certainty that damage/loss will occur). The environment is a controllable variable, i.e., the heritage guardian can adjust the environmental conditions in order to reduce the probability or the rate of damage/loss, and therefore the level of risk. The aim of the current study is to guide heritage guardians in selecting appropriate environmental conditions that will minimise risks to historical mixed-media objects.

4 The other risk factor 'impact' describes the expected loss of value to a mixed-media object if one or more of its components are affected by the environment in which it is kept. In the proposed methodology such components are defined as the different materials that make up a mixed-media object. Based on the expected loss of value in each of these materials, the impact on the mixed-media object can be determined. The latter can be quantified by (1) determining the fractional value of each constituent material, and (2) estimating the loss of value in these constituent materials over a pre-defined time horizon. The conceptual framework is depicted in Figure 1, and is discussed in detail below.

Fig.1. Conceptual framework



Conceptual framework for the risk-based approach

5 The fractional value corresponding to a constituent material is modelled as the product between its relative abundance (material fraction) and its value in relation to the other materials that make up the object (material value). Abundance can be defined in terms of volume fraction or surface area. The former has been used in this study. The sum of all material (volume) fractions equals 1. A ratio scale is used to quantify the volume of the different materials with respect to each other. E.g., if the most abundant material has a score of 0.8, and another material is 10 times less abundant, it receives a score of 0.08. The relative value of each material was quantified by several assessors using the same set of criteria. What is the historic, artistic, aesthetical, scientific, social or spiritual value of the object? What is the provenance, rareness or representativeness, condition or completeness, and the interpretation capacity (Russell and Winkworth 2009; Versloot 2013)? The material with the lowest value is given a value score of 1. Then, a ratio scale is used to quantify the relative value of the other materials. E.g., a material that is 10 times more valuable, receives a value score of 10. Subsequently, the fractional value of each constituent material is calculated by multiplying the material fraction with its respective value, and normalizing the sum of the resulting products to be equal to 1. In complex mixed-media objects, one material can occur in different parts of the object, each with its specific value. In such cases, each occurrence should be treated as a different type of material (with a different relative value). The overall material fractional value in the object should be calculated by aggregating the fractional values of each part containing that material.

6 The expected loss of value is estimated for each material due to future exposure to the different agents of deterioration, i.e., incorrect temperature, incorrect relative humidity, light/UV, pollution, physical forces, pests, thieves and vandals, water, fire, and dissociation (Michalski 1990; Waller 1994). The expected degree of damage and loss can be deduced from literature data, from existing documentation and observations of the object itself or similar objects that have been exposed to the agents of deterioration in the past (under known conditions). The corresponding loss of value in the material should take into account its function and current condition as present in the mixed-media object. For quantification, a discrete scale with 5 options was selected, i.e., 0.05, 0.25, 0.5, 0.75 and 1, ranging from none/negligible (0.05) to extreme/total loss of value (1). The quantification considers either a fixed time horizon or a maximum possible loss due to exposure to a certain agent of deterioration.

7 Finally, the expected impact of risks to a mixed-media object is calculated by multiplying the fractional value represented by the affected constituent materials with the expected loss in value in each one of them upon exposure to each agent of deterioration. This results in a matrix including the constituent materials, the agents of deterioration, and the impact. Impact values range between 0 (no loss of value in the object) and 1 (total loss of value in the object), since all determining factors (fractional value affected and loss of value in the affected parts) are expressed by a number between 0 and 1.

8 By combining the probability of occurrence and expected impact for each risk, it is possible to evaluate which preservation scenarios result in the highest/lowest loss of value for the object within a given time horizon. In this way, the effect of environmental conditions can be objectively assessed, and the efficiency of mitigation actions quantitatively estimated. Multiplying the probability with the impact results in a quantified risk level for each material in relation to each agent of deterioration. The total risk for a certain scenario is defined by the sum of all risk levels per agent of deterioration and constituent material, divided by the variable number of materials.

Case study

9 The risk-based methodology was applied on an Enclosed Garden with the representation of the Calvary, Hunt of the Unicorn and the Immaculate Conception (Figure 2). It is part of a series of seven Enclosed Gardens that are conserved in the museum Court of Busleyden in Mechelen, Belgium. It is a 16^{th} century devotional wooden cabinet with polychromed wooden statues called ‘Poupées de Malines’, silk flowers with metal wire and parchment, paperolles wrapped in textile, relics, metal pilgrim badges, wax medallions, glass beads etc. It is one of the listed major art pieces of Belgium. Due to the different material combinations, it is a perfect example of a historical mixed-media object. The Enclosed Garden was meticulously restored between 2014 and 2017 by a multidisciplinary restorers’ team. The extremely fragile Enclosed Garden was fully dismantled during the restoration treatment. This increased the access to the small objects, and improved the documentation level.

10 From 2018 on, all seven Enclosed Gardens will be permanently exhibited in the attic of the renovated museum Court of Busleyden. The museum asked itself the question what the most appropriate exhibition format for the Enclosed Gardens should be. Four scenarios were suggested: in open display, with a protective glazing closing off the cabinet, or in a display case with passive or active humidity control. To support the museums decision, the risk-based approach was applied (1) to rank the impact level per material and per agent of deterioration in order to formulate preventive conservation recommendations, and (2) to compare the risk level of the four different scenarios in order to select the most appropriate exhibition format.

Fig. 2. ***Enclosed Garden***

Enclosed Garden with the representation of the Calvary, Hunt of the Unicorn and the Immaculate Conception, after the 2016 restoration.

Results

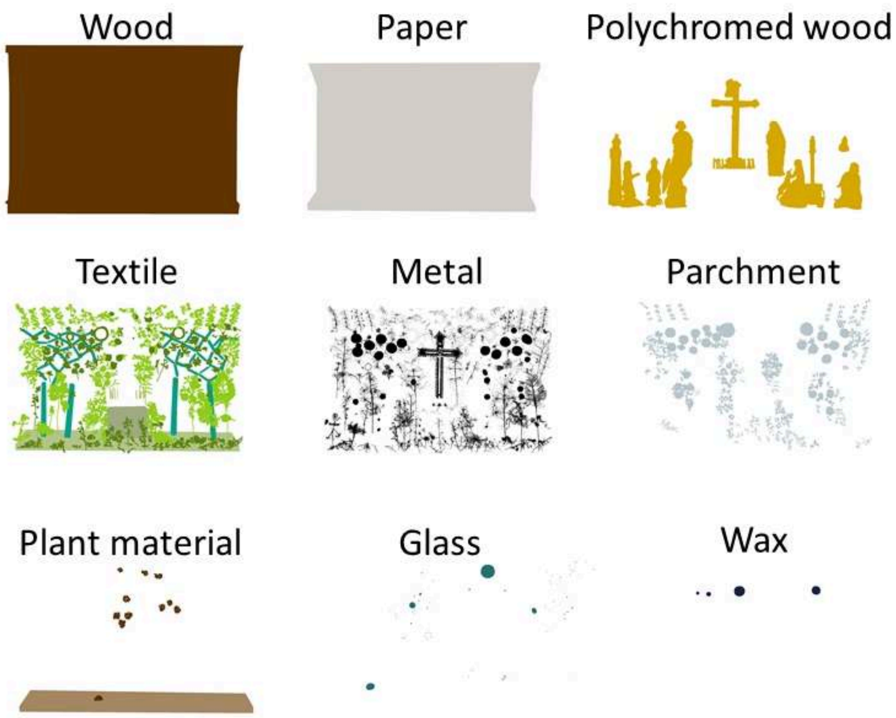
11 The results section is subdivided in three subsections. First, the fractional value has been determined for the Enclosed Garden. This fractional value is subsequently used to elaborate the two different but complementary applications: (1) the ranking of the impact level per material and per agent of deterioration, and (2) the comparison of different scenarios. The first application is useful when preservation recommendations have to be formulated for a historical mixed-media object. It makes a ranking of the importance of the constituent materials and indicates which agents of deterioration should be prioritized. This helps in the decision making to find compromises between the different 'optimal' conditions for each constituent material. The second application can be used when the mixed-media object will be conserved in a new or adapted setting. Several scenarios can be compared to each other to evaluate which one has the lowest magnitude of risk.

Determining the fractional value

12 The Enclosed Garden is composed of multiple materials present in different items in the object: wood, polychromed wood, textile, wax, glass, vegetable materials (e.g., peat, cherry kernels), paper, parchment and metal. The relative abundance of each material is estimated in terms of its volume fraction. First, for each material present, a 2D projection is prepared based on a high resolution photograph of the front sight of the Enclosed Garden (Figure 3). The coverage area is then determined based on the amount of pixels using an open-access image processing software (GIMP 2). The volume fraction is subsequently estimated by multiplying the coverage area with a well-considered 3D-factor. This factor is arbitrarily defined based on the formulas for volume calculation. In case of different types of items made of the same material, each type is considered separately. For many items, the 3D-factor simply reflects their thickness. Consider for example the metal wire used in the silk flowers. An average thickness of the metal wire of around 0.3 cm is determined based on microscopic images. This wire thickness is

implemented as the 3D-factor. Therefore, the volume of the metal wire derives from the coverage area multiplied by 0.3. For other items, volume formulas are used that best reflect their shape. Consider the example of the polychromed wooden statues. For these, the formula for volume calculation of a cylinder is applied ($V_{cylinder}=\pi r^2 h$; where r is the radius and h is the height). The coverage area of the polychromed statues corresponds to dh, where d is the diameter and equals $2r$. The formula is therefore adjusted to $(\pi d^2 h)/4$. After subtracting the coverage area, a 3D-factor of $(\pi d)/2$ is used. The diameter d is estimated to be 6 cm. This results in a 3D-factor of 4.7. Figure 4 a) shows the result of the material fractions for the Enclosed Garden.

Fig. 3. 2D-projections of the different materials used in the Enclosed Garden



The 2D-projections are based on a high resolution photograph of the front side of the Enclosed Garden.

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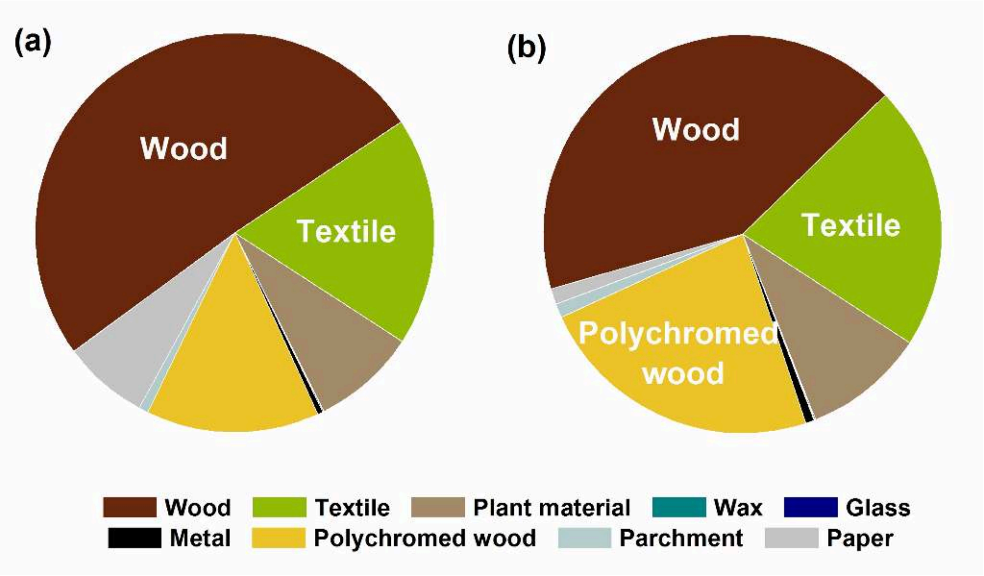
13 To calculate the fractional value of each constituent material, a value assessment is performed. The relative importance of the different items in the Enclosed Garden were - independent of their material type – scored using a ratio scale. Such scale indicates how many times more or less important an item is in relation to another. The item with the lowest value received a value of 1. All other items were scored relative to it. Several relevant persons individually performed the value assessment using the same criteria as described by Russell and Winkworth (Russell and Winkworth 2009). The average value score is used. As an example, the paper at the back of the inner cabinet received a value score of 2. This paper is probably a late 19th-early 20th century 'redecoration' (Baert and Iterbeke 2017; Baert, Iterbeke, and Watteeuw 2015). Nevertheless, the paper gives the Enclosed Garden an experiential value. The polychromed wooden statues, on the other hand, were given a value score of 10. This higher value is related to the important figurative value of the so-called 'Poupées de Malines'. Such 'Poupées de

Malines' are collector items throughout the world, and many publications and monographs are dedicated to these type of statues. This makes them interesting study objects since a large volume of comparative material is present.

14 The fractional value is now calculated by multiplying the material fractions and their respective value scores. If one material is present in different items with each their own value score, only the material fraction corresponding to that specific item is used to be multiplied with the corresponding value score. Finally, the multiplication results are summed up per material with the sum normalized to 1. The result is visualized in Figure 4 b).

Fig. 4. Pie chart



a) Pie chart of the material fractions (by volume); b) pie chart of the fractional value of materials (obtained by multiplying the material fractions with their corresponding relative value in the Enclosed Garden).

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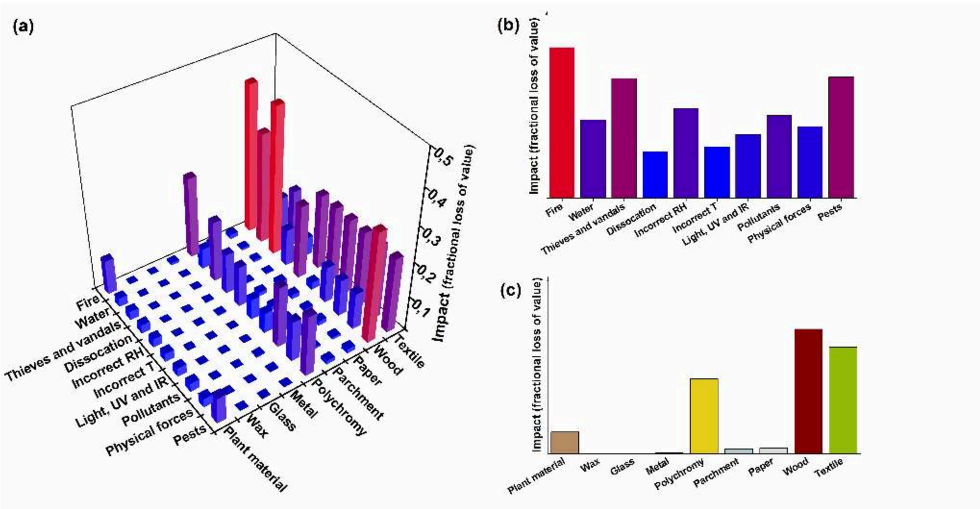
Ranking the impact level per material and per agent of deterioration

15 The loss of value per constituent material due to exposure to each agent of deterioration is determined, considering the current conservation state of each material. Table 1 gives an overview of the actual effects that are considered per agent of deterioration. For cumulative deterioration processes such as light damage, the loss of value is estimated as the maximum possible loss due to exposure, i.e., a worst case scenario. Finally, the expected loss of value in the entire object (impact) is calculated by multiplying the fractional value of each constituent material with the fractional loss of value they are expected to suffer if exposed to each agent of deterioration. Figure 5 a) visualizes the resulting three dimensional diagram. For the 'sudden' agents of deterioration such as fire and water, wood experiences the highest impact. In contrast, textile experiences a higher impact for the slow (i.e., cumulative) agents of deterioration. The total impact per agent of deterioration (Figure 5 b), and per material (Figure 5 c) are assessed by summing up the respective impacts. For the Enclosed Garden as a whole, fire has the highest impact, due to an expected total loss of value

(Figure 5 b). For the cumulative processes, incorrect relative humidity has the highest impact. From the material point of view (Figure 5 c), wood, textile and polychromy are the materials for which the highest fractional loss of value in the Enclosed Garden could be expected. The importance of these three materials already became clear in the pie charts of the material fractions, and their values (Figure 4).

Fig. 5. Overview of the impact (fractional loss of value in the *Enclosed Garden*)



(a) Three dimensional visualization per constituent material if exposed to each agent of deterioration (considering a ‘worst case scenario’ for cumulative processes); (b) total impact per agent of deterioration; (c) total impact per material.

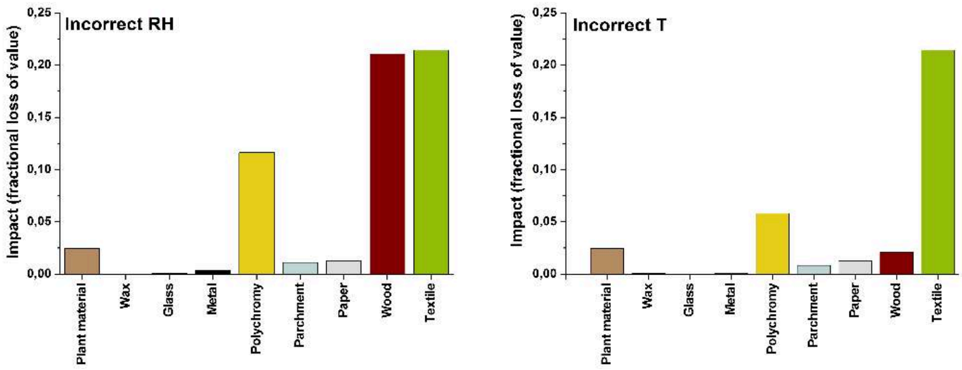
Table 1. Overview of the effects considered per agent of deterioration in the quantification of the loss of value. The last column indicates whether an agent of deterioration is considered as a cumulative process (●) or not (empty)

Agent of deterioration	Effects considered	Cumulative
Fire	Post-flashover stage (fully developed fire whereby all objects and the building are threatened) with an (almost) total combustion (for combustible materials); heat deformation, collapse, sooting (for non-combustible materials)	
Water	Damage by leakage: deformation, staining, dissolution/migration of water-soluble materials, mold growth (in organic materials if remain wet for too long), etc.	
Thieves and vandals	Theft of object items	
Dissociation	Loss of small parts	
Incorrect RH	Mechanical damage due to fluctuations (e.g., deformation, cracking etc.), mold and corrosion due to elevated RH levels, embrittlement due to dry conditions	●
Incorrect T	Fragilization and embrittlement due to faster chemical deterioration by hydrolysis/oxidation (elevated temperatures)	●
Light, UV and IR	Color fading and loss in strength due to photochemical degradation processes	●
Pollutants	Accumulation of dust, enhanced chemical degradation due to pollutant gases	●
Physical forces	Mechanical damage due to vibrations and air flow (detachment or movement of small items, loss of materials due to fraction etc.)	●
Pests	Insect attack (perforation, weakening, losses etc.)	

16 The results of the impact assessment help heritage guardians to make decisions concerning the (environmental) conditions in which a historical mixed-media object should be conserved. Defining set points is most difficult for temperature and relative humidity, since these parameters cannot be eliminated from the environment as is the case for light, pollution etc. Therefore, the expected fractional loss of value in the Enclosed Garden is plotted for both incorrect relative humidity and incorrect temperature (Figure 6). The highest expected fractional loss for incorrect RH is due to the expected damage caused in textile, wood and polychromy. Therefore, the most appropriate conditions for these three materials are considered. Textile (mainly silk) has the most critical recommendations. A low RH decreases (chemical) degradation, but increases brittleness (Reilly and al. 1995; Hansen and Sobel 1992; Luxford, Thickett, and Wyeth 2010; CCI 2013). However, due to the high impact of physical forces such as vibrations on the highly deteriorated textile, brittleness should be avoided. Therefore, a relative humidity in the intermediate range is recommended, i.e., 45%. This value is acceptable for most other materials in the Enclosed Garden. Daily fluctuations are recommended to be maximum ±2.5%, and seasonal fluctuations of ±5% are allowed. For incorrect temperature, the expected loss of value is by far the highest for the textile. Elevated temperatures hasten its chemical degradation reactions (CCI 2013; Michalski 2002). Therefore, a constant and as low as possible temperature is advised, with a maximum of 20°C. In the exhibition areas, also human comfort is considered and often determines the lower temperature threshold. It should be noticed that for textile, wood and polychromed wood, the impact of incorrect temperatures is lower compared to the impact of an incorrect relative humidity. However, for silk for example, the

degradation rate at an RH of 50% is 1.5 times higher at 20°C compared to 16°C (Luxford, Thickett, and Wyeth 2009).

Fig. 6. Expected fractional loss of value in the entire *Enclosed Garden*



Loss due to exposure of the different constituent materials to (a) incorrect relative humidity; and (b) incorrect temperature.

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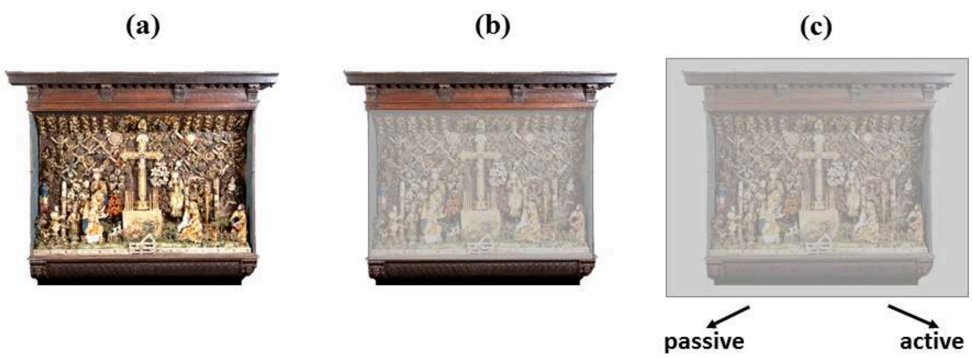
17 As a conclusion, we get insights in the most harmful agents of deterioration for a historical mixed-media object and the materials with the highest impact score. This information is based on a 'worst case scenario' by considering the highest possible loss of value when exposed to a certain agent of deterioration.

Comparison of different scenarios

18 In the previous section, the ranking of the impact per material and per agent of deterioration is performed based on the highest possible loss of value. When considering specific scenarios, the loss of value depends on the scenario itself. In this study, four risk scenarios concerning the presentation of the Enclosed Garden were compared to each other, each with an increase in degree of protection: an open display, a protective glass pane closing off the cabinet, a showcase with passive humidity control, and a showcase with active humidity control (Figure 7).

Fig. 7. Different scenarios for the permanent exhibition of the *Enclosed Gardens*



a) open display; b) protective glass pane closing off the cabinet; c) showcase with passive or active humidity control.

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19 The use of scenarios requires a detailed description of each scenario. Several general conditions are considered for the four scenarios. The Enclosed Garden will be exhibited in the attic of the renovated Court of Busleyden. An active climatization system will condition the room. An ASHRAE climate class B or better will be obtained (i.e., temperature between 15-25°C with short fluctuations of ±5°C and seasonal adjustments of ±10°C but < 30°C; relative humidity between 40-60% with short fluctuations of ±10% and seasonal adjustment of ±10%) (ASHRAE 2011). An up-to-date fire detection system will be installed. No water pipes will be present near the Enclosed Garden. All direct sun radiation will be blocked. The Enclosed Garden will be exhibited at low lux levels of 50 lux without UV radiation during the opening hours of the museum. Some guiding illumination for the public will be present in the room, also at low lux levels.

20 Specific boundary conditions are set for each scenario. For the open display and the protective glass, a spacer is provided to ensure that visitors cannot touch the Enclosed Garden. The protective glass generates an air tightness of 1.5 air changes per day inside the cabinet. For the showcase an air tightness of 0.4 air changes per day is considered. One showcase is passively climatized using silica gel, the other one has an active climatization system for humidity. For both showcases the outer showcase is designed separated from the pedestal to prevent shock from direct visitor contact. Moreover, passive shock dampers are installed to dampen vibrations below 100 Hz. The showcases are manufactured with low emitting materials.

21 In the following paragraph, the level of protection for each agent of deterioration in each scenario is discussed. The level of protection impacts the quantification of the probability and the 'loss in value' for the different scenarios.

- Incorrect temperature: The temperature to which the Enclosed Garden will be exposed, will be the one of the climatized surrounding room. A protective glass or showcase hardly influence the temperature, and cannot buffer temperature fluctuations.
- Incorrect RH: The relative humidity in the attic will be controlled with an HVAC-system. Such system is most of the time reliable, but technical problems could cause sudden changes in RH. When in open display, the Enclosed Garden would directly be exposed to the - often drastic - RH-changes due to a malfunctioning system. A protective glazing will partially buffer such RH-fluctuations. Both showcases are expected to buffer RH-fluctuations due to their high air tightness in combination with their passive and active RH-control. This RH-control additionally allows to maintain a certain RH-level. The passive controlled showcase will favour from a constant room temperature. Active climatization in a showcase also relies on technology, and could fail. Such failure could result in a higher loss of value.
- Radiation: Light radiation will be set at 50 lux in all scenarios. Therefore, the probability of light damage and the loss of value is equal for all situations.
- Pollution: Dust accumulation is considered as a major problem for the Enclosed Garden. An open display will not protect the Enclosed Garden from dust accumulation and other pollutant gases. A protective glass will partially block (large) dust particles and lower the concentration of external pollutant gases. Due to the high air tightness of the showcases, they will efficiently block outside generated pollution, both gases and particulates (Thickett, David, and Luxford 2005). Since the indoor generated pollution in the showcase is negligible, the loss of value due to pollution is much lower compared to the first two scenarios.
- Physical forces: When permanently exhibited, physical damage mainly entails vibrations and shocks when visitors walk on the floor, or touch the (pedestal of) the Enclosed Garden. Increased air turbulence could also cause physical damage due to the movement of the

fragile parts within the Enclosed Garden. The open display is most prone to such physical forces. The showcase design with its vibration dampers should limit the exposure to vibrations. The separate pedestal blocks the shocks that visitors cause by walking or tapping against the showcase.

- Fire: In case of fire, it will be hard to quickly evacuate the Enclosed Gardens due to the location in the building (attic). However, proper fire compartments are provided in the building. An open display would make it easier to evacuate the object, but a showcase, on the other hand, will better protect the object from 'side damage' in case of fire, i.e., soot accumulation, water damage, etc.
- Thieves and vandals: An open display is most tempting to take out small but valuable objects from the Enclosed Garden. A protective glazing and a showcase protects the object for this agent of deterioration. However, once thieves access the Enclosed Garden, a total loss in value for the stolen objects should be considered. Thus, the probability of an event related to thieves or vandals differs in the different scenarios, but the loss of value is considered to be equal.
- Water: Water damage could occur due to water leakages in the roof. The structure of the roof was controlled during the renovation works. The open display and the protective glazing do not protect the entire object from water damage, as does a showcase. Therefore, the probability of damage to occur is highly reduced for the latter.
- Pests: Insects, mould spores etc. enter the museum by small openings, or could be brought in by visitors. In open display, they have free access to the object. Therefore, the highest probability of damage to occur is to be expected for that scenario. The protective glass already reduces the probability for pests. However, small openings between the glass and the cabinet still allow small insects and mould spores to enter. Moreover, the wooden cabinet itself is not protected from the outside, and wood should be considered as an attractive material for insects and mould. Both showcases will highly reduce the probability for pests. Once accessed the object, insects and other pests are expected to cause a similar loss of value for the different scenarios.
- Dissociation: A higher probability for dissociation has been assigned to the open display in comparison with the other scenarios, since the likelihood of a small object to get lost is expected to be higher.

22 For each scenario and each agent of deterioration probabilities of damage to occur are now defined. The probabilities are quantified with values between 0 to 1, representing a negligible to a significant likelihood of damage to occur, respectively. A time horizon of 100 years is considered. The quantification is shown in Table II. Several agents of deterioration can be considered to affect heritage items through cumulative processes, i.e., incorrect T, incorrect RH, radiation, pollution and physical forces (vibrations). These agents have received a probability of 1 for all scenarios. This means that a certain degree of damage will accumulate in the historical mixed-media object – even if very small - over the course of a 100-year period. The other agents of deterioration can be considered as events. This means that they could occur once or more in the predetermined period of 100 years. The probability of the so-called 'sudden' agents of deterioration has been determined by the Poisson process (Waller 2003), assuming that the likelihood of damage equals the likelihood of an event taking place. Event frequencies were converted to probabilities with the formula $P(t)_{(event)} = 1\text{-}e^{-\lambda t}$ in which $P(t)_{(event)}$ is the probability of an event to occur in time t, λ the frequency and t the time span. For example, a fire affecting the Enclosed Gardens is expected to occur about once every 500 years. This is estimated based on the number of house fires in Belgium

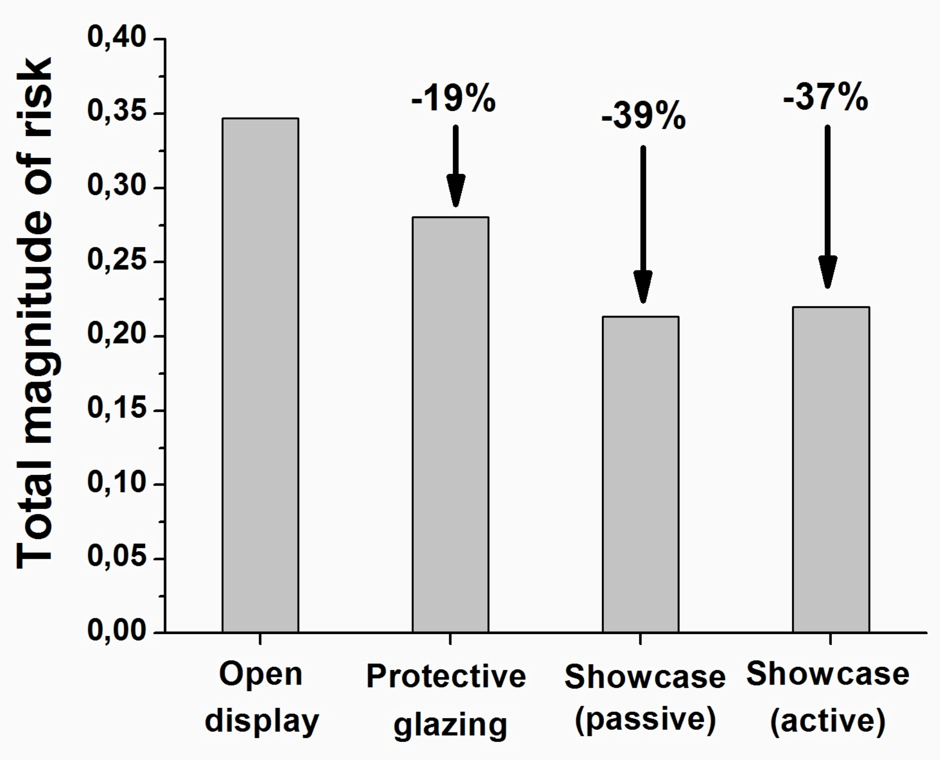
(www.statbel.be; www.belgium.be). This equals a probability of 0.18 (or 18%) for a 100-year period. Since the degree of protection in the different scenarios has no or minor influence on the likelihood of a fire to breakout, this fast agent has the same probability for all scenarios. For the other sudden agents, the probabilities vary over the different scenarios.

Table 2. Quantification of the probability of material damage or loss to occur for the different scenarios and in function of the ten agents of deterioration. 0 indicates a negligible probability, while 1 represents a high probability, i.e., damage is expected to occur within a 100 year time horizon

Scenario	Incorrect T	Incorrect RH	Radiation	Pollution	Physical forces	Fire	Thieves and vandals	Water	Pests	Dissociation
Open display	1	1	1	1	1	0.18	0.63	0.63	0.86	0.63
Protective glass	1	1	1	1	1	0.18	0.18	0.63	0.63	0.18
Showcase (passive)	1	1	1	1	1	0.18	0.18	0.18	0.39	0.18
Showcase (active)	1	1	1	1	1	0.18	0.18	0.18	0.39	0.18

23 Subsequently, the loss in value is defined for each scenario per agent of deterioration and material. As discussed in the methodology, a discrete scale with 5 options was used. Finally, to quantitatively evaluate the different scenarios, the probability values are multiplied with the quantified values for the fractional value and the loss in value. To define the total magnitude of risk, all values of the resulting matrix were summed up, and divided by a factor 9 (number of material types considered) in order to obtain values from 0 to 1. The result for the four discussed scenarios is shown in Figure 8. As intuitively expected, the open display entails the highest magnitude of risk, while the showcase with passive climatization entails the lowest magnitude of risk. The use of such showcase decreases the magnitude of risk with 39 per cent compared to an open display. An actively climatized showcase results in a risk reduction of 37 per cent, while a protective front glazing has a risk reduction of 19 per cent. Based on these results, the museum Court of Busleyden decided to realize a permanent exhibition of the seven Enclosed Gardens in passively climatized showcases.

Fig. 8. Risk magnitude



Total risk magnitude for the four different scenarios with indication of the percentage risk reduction compared to the scenario with the highest risk magnitude (i.e., the open display).

Discussion

24 The developed methodology is a semi-quantitative approach. It allows a substantiated argumentation to define preservation recommendations for historical mixed-media objects with a wide range of materials. Moreover, it allows the objective comparison of different scenarios in order to evaluate the most appropriate scenario. The case study demonstrates the application of both options.

25 Although the method compares scenarios in a rather objective way, one should also be aware of the uncertainties the method incorporates. The different quantified factors all have their own uncertainties which are hard to quantify. However, the core of the method is to compare the different factors and the total outcome. This creates a ranking of the impact and risks. Even with incorrect quantifications, the end result will still be valuable as long as the ranking within each factor (e.g., material fraction, value, loss in value) is correct.

26 In the treated case study, the determination of the material fraction is based on volume calculations. However, it is mainly the surface area that counts for material-environment interactions. The determination of surface areas is, however, rather complex due to the numerous small fragments, separate silk wires, etc. In order to simplify the method, volume calculations could be considered as a good indicator to estimate the material fraction.

Conclusion

27 A risk-based methodology is developed to support the decision making regarding the preservation conditions of historical mixed-media objects. The methodology allows two main applications. In a first application the impact level is ranked per material and per agent of deterioration. This helps in prioritizing the agents of deterioration that will affect the mixed-media object the most, and detects the most sensitive materials towards each agent of deterioration. This creates an objective basis to define compromises in the preservation conditions for historical mixed-media objects. A second application is the comparison of the risk magnitude for different well-defined scenarios. This allows to select the most appropriate scenario for the preservation of historical mixed-media objects within the possibilities of the objects' owners.

28 The case study of an Enclosed Garden well demonstrates the usefulness of the method. An Enclosed Garden can be considered as an extremely complex historical mixed-media object due to the wide variety of materials used and its fragile state. Based on the results of this study, recommendations regarding preservation conditions were provided to the museum Court of Busleyden. Moreover, the museum selected the scenario with the lowest risk magnitude for the permanent exhibition of all seven Enclosed Gardens in their collection.

ABSTRACTS

Historical mixed-media objects consist of a wide range of materials that can be organic and inorganic in nature. They are often fragile due to the nature of the materials used, and their advanced state of degradation. Well-considered preservation conditions are needed to slow down their degradation. Since each material has its specific requirements, it is challenging to give preventive conservation recommendations. To support the decision making, a risk-based approach is developed. The proposed methodology (1) offers an objective basis to define compromises in preservation conditions, and (2) allows the comparison of different scenarios in order to select the most appropriate one. The methodology is first explained theoretically. Subsequently, its two application aspects are illustrated on the basis of a case study regarding the preventive conservation of a medieval Enclosed Garden.

Les objets composites historiques sont constitués d'une large série de matériaux organiques et/ou inorganiques. Ils sont souvent fragiles en raison de la nature des matériaux utilisés et de leur état de dégradation avancé. Leurs conditions de conservation doivent faire l'objet d'un choix réfléchi afin de ralentir leur dégradation. Chaque matériau ayant ses exigences spécifiques, il est difficile de donner des recommandations de conservation préventive. Pour appuyer la décision, une approche basée sur la gestion des risques est développée. La méthodologie proposée (1) offre une base objective pour dégager des compromis concernant les conditions de préservation et (2) permet la comparaison de différents scénarios afin de sélectionner le plus approprié. Dans un premier temps, la méthodologie est expliquée de manière théorique. Une étude de cas sur un jardin clos médiéval permet ensuite d'illustrer ces deux aspects.

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