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

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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.

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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.

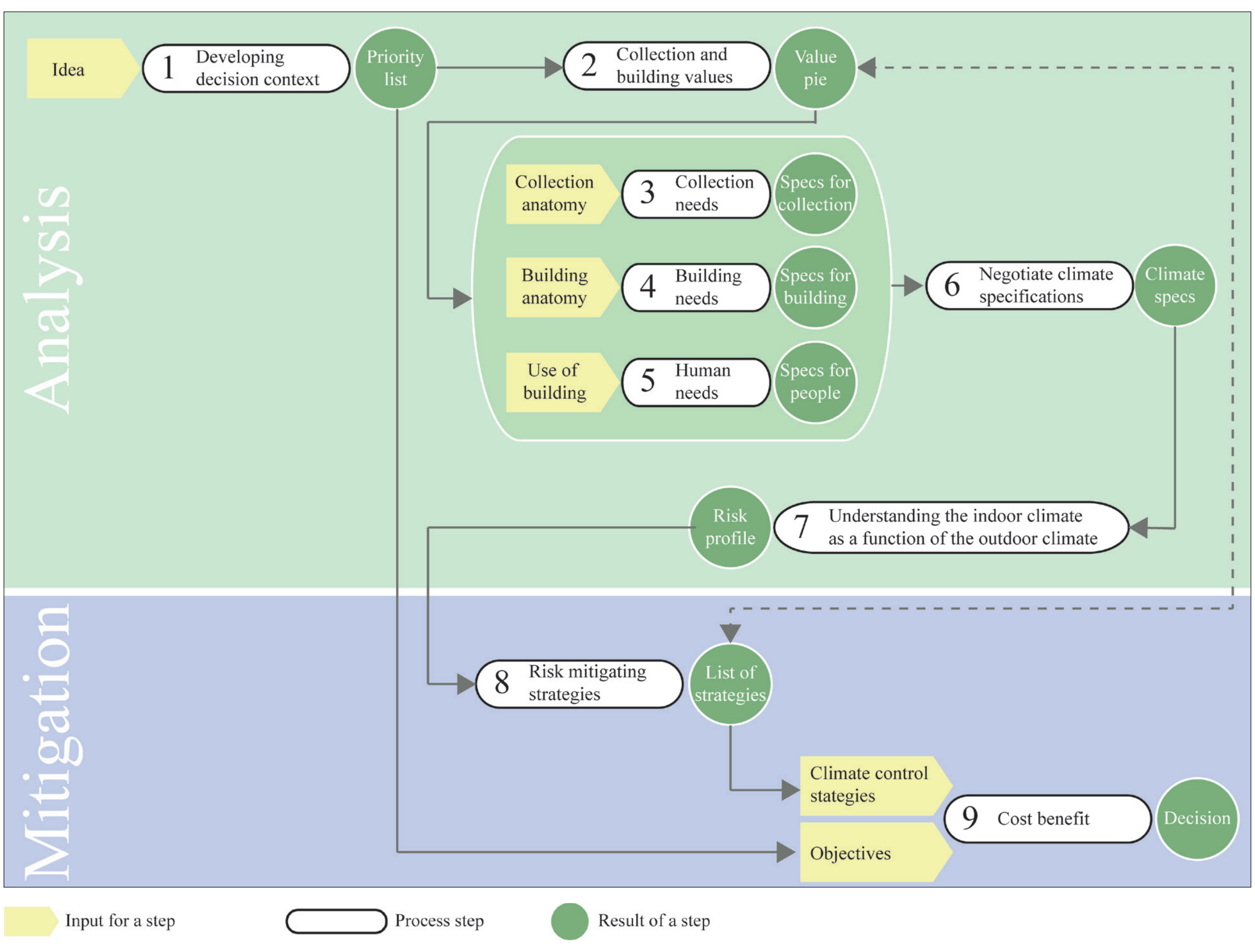
The main building of the castle has several so-called museum spaces. These are seen as the most valuable rooms in the castle and contain many important moveable objects of high cultural value. In figure 1 an aerial overview of the castle and two museum rooms are presented. In figure 5 the museum rooms 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

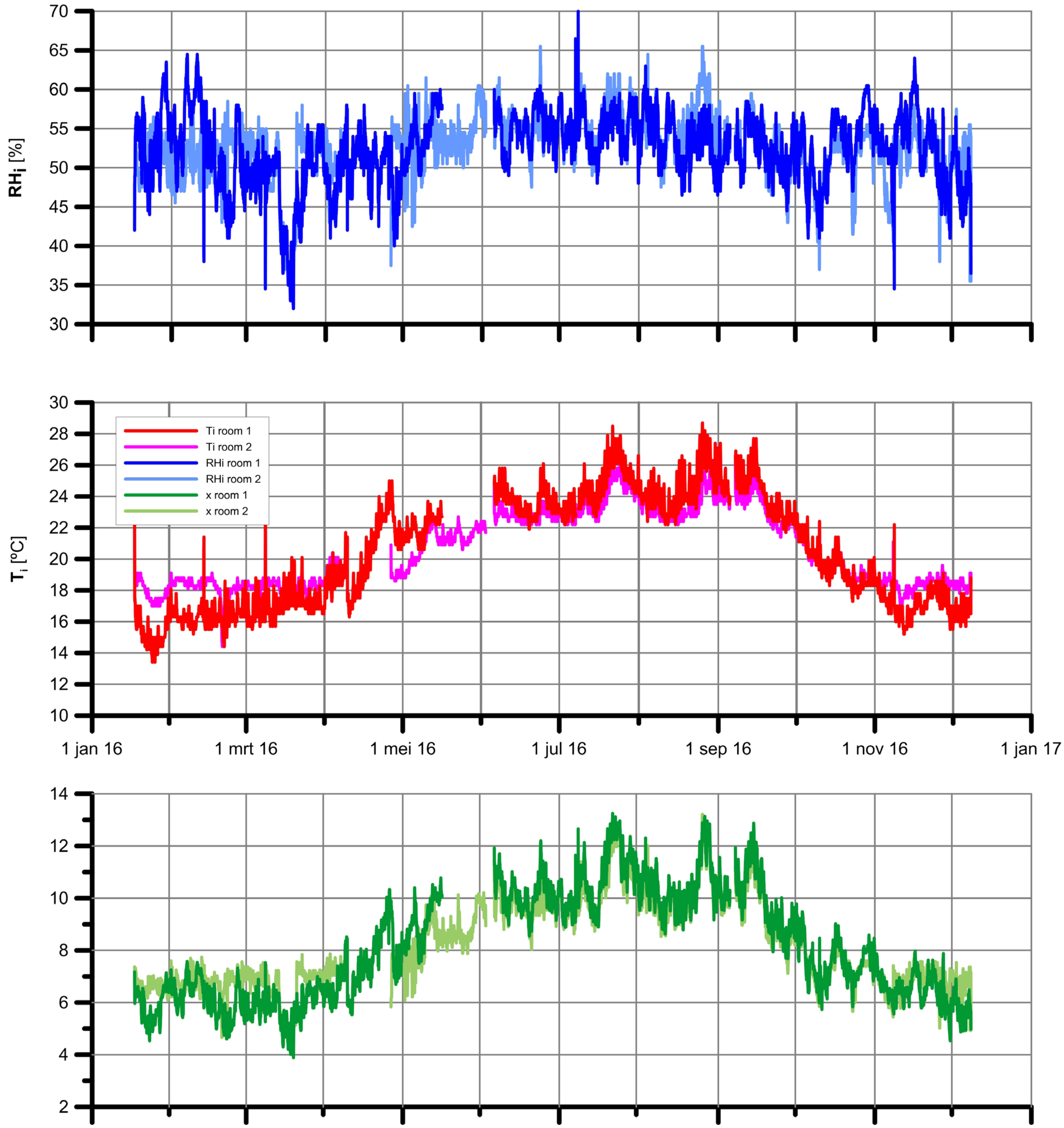
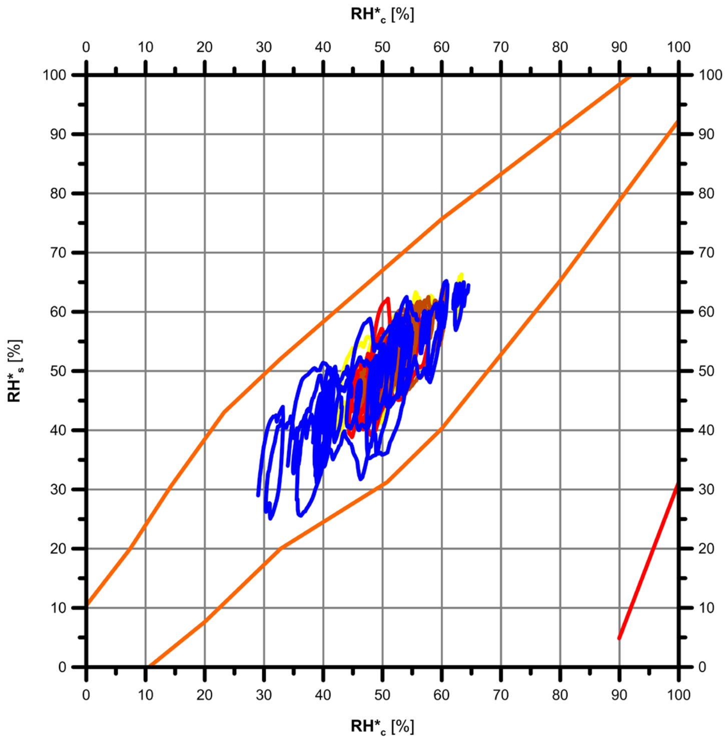
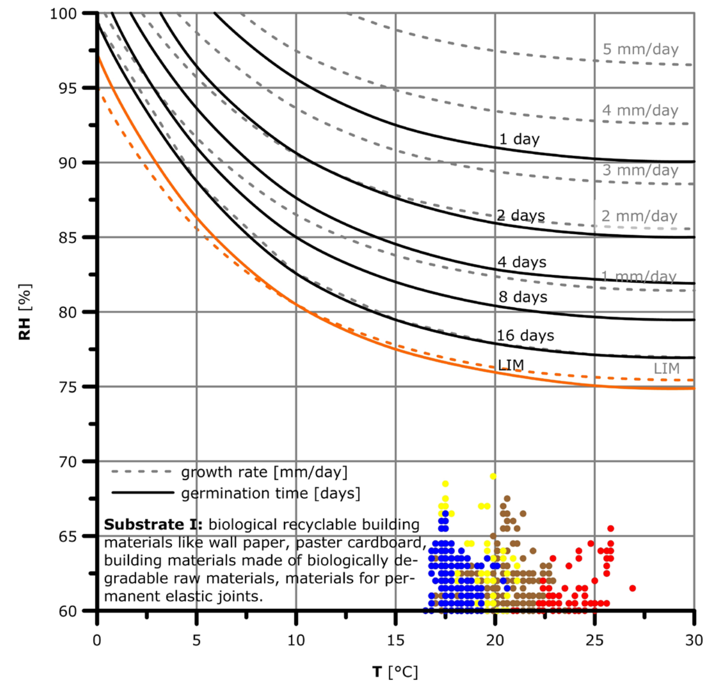
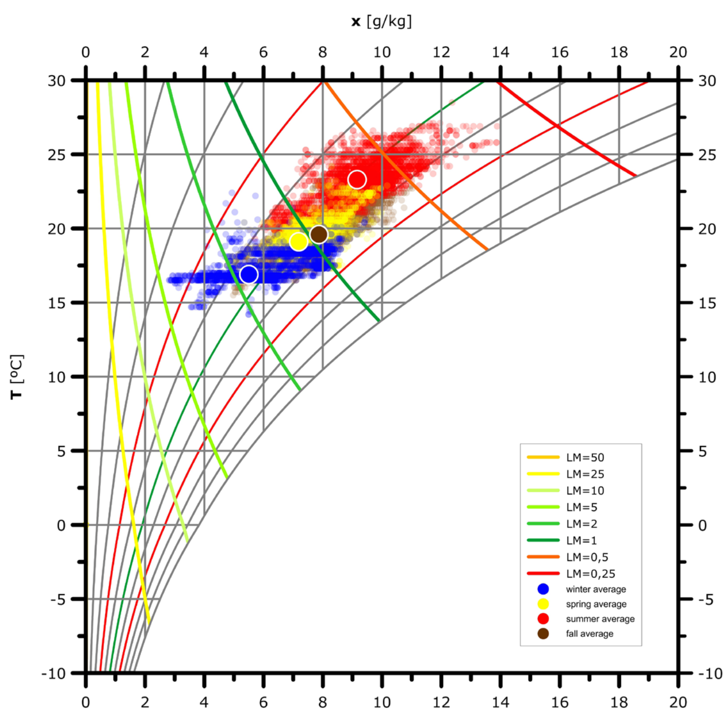


Fig. 3
On the left the temperature, relative and specific humidity plots of 2016 of the Tin room (1) and White room (2) are presented. On the right the three plots show the climate risks for chemical degradation (top right), mould (middle right) and mechanical degradation (bottom right) using the climate 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

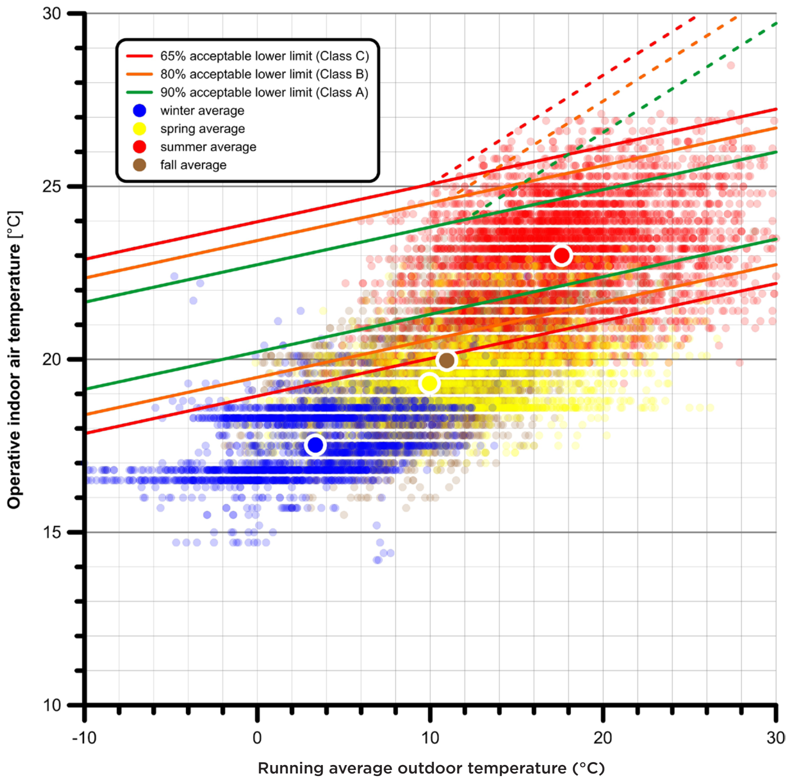


Fig. 4
Collected indoor temperatures measured in 2009, 2010, 2013, 2014, 2015 and 2016 in the Salon as a function of outdoor temperatures. The comfort limits for an "alpha" building in which the user has limited control over the indoor temperature by e.g. opening windows, is presented using the so-called Adaptive Thermal Model, extracted from Van der Linden et al [2006].

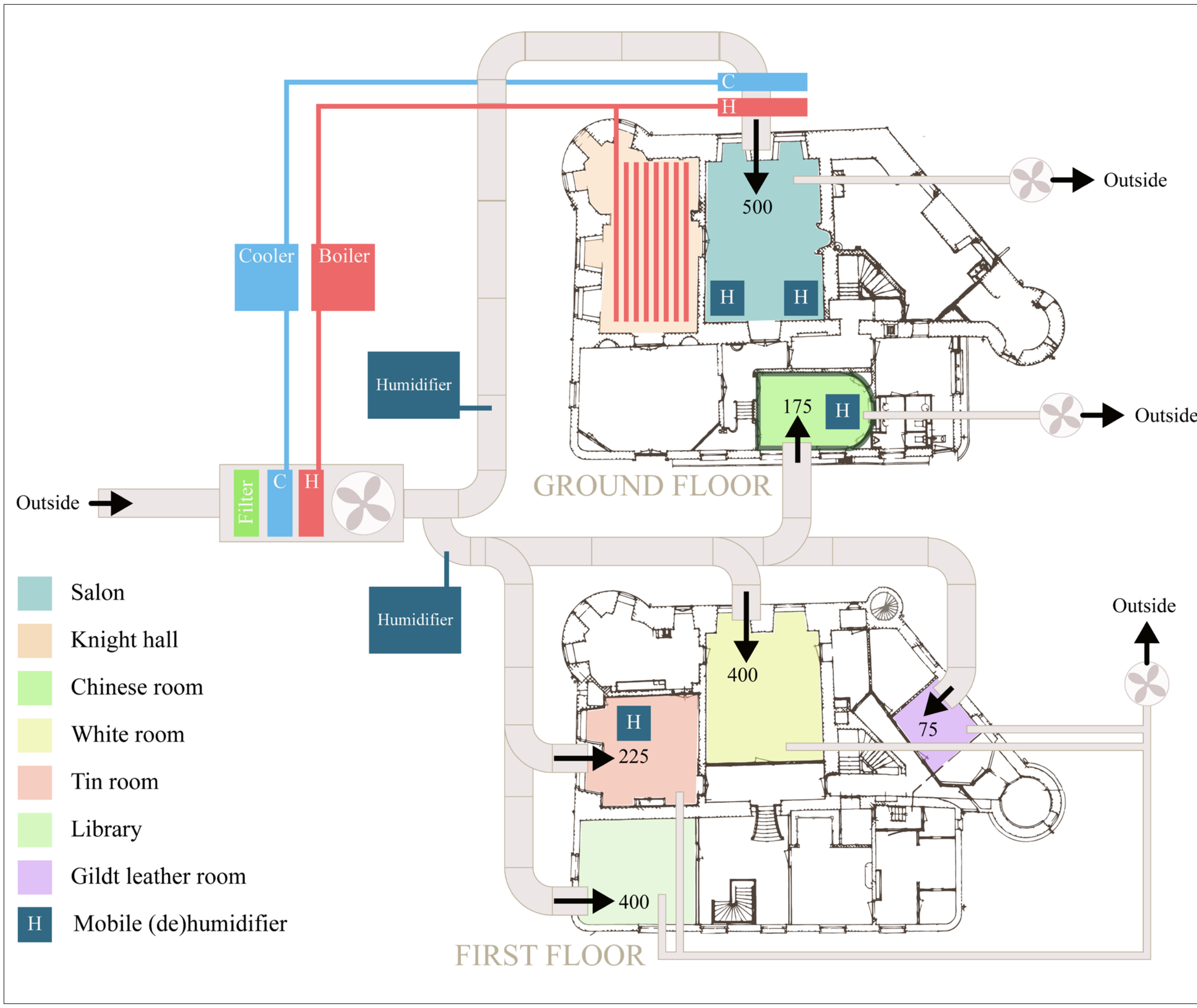
Fig. 5
Climate control of Heeswijk Castle in 2017. The museum rooms are indicated by a colour. Outside air is brought to a specific temperature by a system with cooling, resulting in dehumidification and heating capacity. The air is subsequently split into 2 main air flows that are both humidified by 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 (50^{th} 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

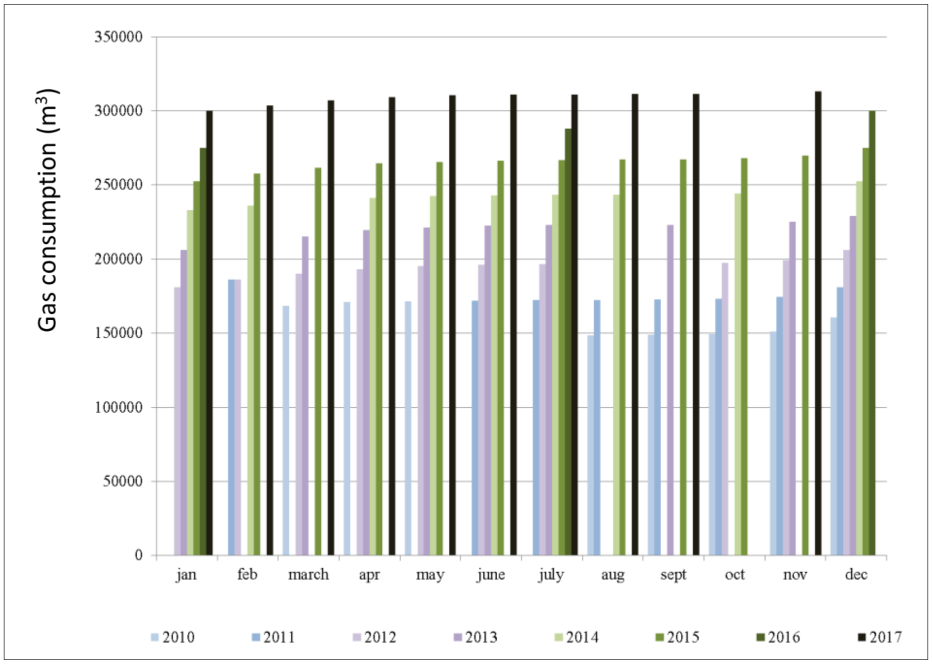


Fig. 6
Monthly gas consumption of Heeswijk Castle between 2010 and 2017.

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.

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