ARTICLE IN PRESS

Climate Risk Management xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm

Making sense of climate risk information: The case of future indoor climate risks in Swedish churches

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ARTICLE INFO

Article history:
Received 28 October 2015
Revised 23 April 2016
Accepted 3 May 2016
Available online xxxx

Keywords:
Risk communication
Cultural heritage management
Sensemaking
Adaptation

ABSTRACT

Organizations and institutions managing built heritage have to make use of increasingly detailed, elaborate and complex climate change impact assessments. It is a challenge to determine how, when and by whom climate predictions should be translated into risk estimates usable for decision-making. In this paper results from the Climate for Culture project are used to study how heritage decision-makers interpret future indoor climate-related risks to Swedish churches. Different sets of risk maps were presented to ten engineers, ten building conservators and five experts on indoor climate related risks. Interviews were used to understand how the interviewees made sense of the presented information and if they associated it with a perceived need for adaptation. The results show that the risks were interpreted and assessed largely dependent on their pre-understanding and familiarity with the individual risks. The magnitude of change and the lack of uncertainty estimates were subordinate to the overall impression of the information as being credible and salient. The major conclusion is that the dissemination of risk information, also from projects which at the outset have aimed at producing knowledge relevant for end-users, should be both customized and tested in collaborative efforts by stakeholders and scientists.

1. Introduction

In recent years there has been much effort invested to assess the impact of climate change to cultural collections and built heritage in Europe. The predominant approach has been to use top-down modelling where the outcome is predictions of how deterioration rates and patterns will change in the future. This is a necessary but not sufficient condition for the planning and implementation of adaptation and mitigation measures. In order for the risk assessments to have an effect they must be communicated to the end users. The overall problem addressed in this paper is how generic, complex and uncertain risk information should be disseminated to adaptation practitioners in the heritage sector.

The impacts of climate change on built heritage have been studied both for individual sites e.g. (Grossi et al., 2011) and for geographic areas e.g. (Sabbioni et al., 2010). The NOAH's ARK project (Sabbioni et al., 2010) assessed the effects of climate change to cultural heritage in Europe by applying damage functions to projections of the future climate. The main result of the project was a collection of maps over Europe, where key environmental variables were linked to potential damage for heritage materials. Recently, there have also been studies on how the indoor climate in selected historic buildings and the related risks will be affected by climate change (Bratasz et al., 2012; Brimblecombe and Lankester, 2012; Lankester and Brimblecombe, 2012b, 2012a). Huijbregts et al. (2012) showed how simplified building simulation of generic buildings

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http://dx.doi.org/10.1016/j.crm.2016.05.003
2212-0963/© 2016 Published by Elsevier B.V.

is a feasible methodology to produce maps of future indoor climates. The methodology was applied at a large scale in the recently finished project Climate for Culture (Leissner et al., 2014), which aimed to produce information useful for the management of historic buildings and cultural collections in Europe.

Organizations and institutions responsible for cultural heritage management now face the challenge of how to make use of increasingly detailed, elaborate and complex impact assessments in decision-making for climate change adaptation. It has been suggested that predictions of earth-system processes are most useful for decision making when they are related to near-term events and when predictive skill is known (Sarewitz et al., 2000). Predictions of climate change impacts are both highly uncertain and relate to events which, in a heritage management perspective at least, are located in the distant future. Despite this there is a demand from policy-makers and adaptation practitioners for more detailed and refined predictions about climate change impacts to cultural heritage, and a scientific community keen to supply this demand. However, to what extent existing predictions of impacts to cultural heritage have been useful for adaptation planning remains largely unknown. This situation calls for an urgent need to understand how researchers and stakeholders can collaborate to transform abstract and complex information about uncertain climate change impacts into actionable knowledge for adaptation decision-makers in the heritage sector.

The point of departure for this paper is the intersection between results from Climate for Culture (CfC), a research project supplying risk information, and the Church of Sweden, an organization in need of risk information for adaptation planning. In this intersection, concerns were raised about how the risk information should be selected, packaged, and assessed, and to what extent it actually was rendered as useful by decision-makers. To better understand the process of how the quantitative results of this and other climate change impact projects should be communicated, this exploratory study uses qualitative interviews to get a better understanding of how complex and uncertain risk information is subjectively interpreted by decision-makers.

The CfC project used climate modelling and building simulations to produce a set of European maps depicting future changes of deterioration for materials kept inside historic buildings. The project set out to produce results relevant for end-users by involving stakeholders throughout the research process. Dissemination of results was inscribed as a critical factor for reaching the project's aims. Questions about the identities of the end-users and the ways in which the results could be used received some attention in the initial phase of the project. A quite heterogeneous user group could be anticipated, ranging from policy makers at the national level to private owners of historic buildings. It was decided that the main strategy for dissemination should be to make results of the project easily accessible for decision-makers to choose based on their own needs (Leissner et al., 2014). There had been a process internal to the project where technical experts collaborated with stakeholders in the design of the maps. This kind of procedure is known to be insufficient to guarantee effective communication (Morgan et al., 2001, p. 19).

The Church of Sweden is responsible for the majority of historic churches in Sweden. During 2014, the organization investigated potential ways of re-organizing their building management. An assessment of climate change impacts to churches was considered necessary in order to understand the future need of adaptation. The results of the recently finished CfC project became a timely opportunity for delivering the kind of information sought by the Church of Sweden.

In the researcher-stakeholder dialogue that followed, a key question was identified: how the quantitative information produced by CfC should be transformed into statements about risk usable for adaptation planning. The results from CfC are meant to be used by heritage professionals whom have the necessary knowledge about local circumstances to judge the relevancy of the information in relation to specific cases. Building management expertise from within the Church of Sweden had to be involved in the risk assessment process to contribute with the necessary local knowledge – but it was uncertain how this should be carried out. Therefore, it remained a challenge to determine how, when and by whom the predictions made by CfC should be translated into risk estimates usable for the decision-making process.

How scientific information successfully translates into action has been described as a key question for climate risk management (Travis and Bates, 2014, p. 1). Empirical research has shown how the use of information in decision making can be dependent of a range of factors, such as institutional barriers, resolution of the information, level of skill among users, trust between producers and users, etc. (Kirchhoff et al., 2013). It has been suggested that to create actionable knowledge, information about climate change must fit into existing contexts to close the usability gap between what scientists understand as useful information and what users recognize as usable in their decision-making (Lemos et al., 2012). To achieve this, there is a need to tailor climate information through sustained interactions between researchers and decision-makers (Lemos et al., 2012, p. 789; Moss et al., 2013, p. 697). Previous studies addressing the usefulness of climate risk information for heritage practitioners have pointed out the necessity to contextualize climate change information in order to make it relevant for practical management (Cassar and Pender, 2005; Haugen and Mattsson, 2011).

There is no shortage of advice for how to communicate risk and uncertainty effectively e.g. (Morgan et al., 2001, p. 19; Renn, 2008; CCSP, 2009; Fischhoff, 2011; Mastrandrea et al., 2011; Fischhoff and Davis, 2014). One thing that different strategies have in common is that risk communication should focus on issues that are relevant for the target audience. Another commonality is the importance of testing communications before final dissemination. Despite the abundance of advice, there is little empirical evidence on the efficacy of different strategies for climate communication (Pidgeon and Fischhoff, 2011). Furthermore, there are competing understandings of what constitutes good risk communication and different ends will require different sets of best practices (Demeritt and Nobert, 2014).

It has often been argued that uncertainties in climate change impacts should be characterized, quantified (based on historic data or expert judgment) and communicated to the end user in order to improve decision-making e.g. (Mastrandrea et al., 2011), although the procedures, scope and purpose of this enterprise is debated (Adler and Hirsch Hadorn, 2014). Most impact studies on indoor climate risks to buildings have been of a deterministic nature, despite calls for probabilistic approaches where at least some of the uncertainties are quantified (de Wilde and Tian, 2011). Uncertainties in one modelling step will propagate to the subsequent step. As an example, Nik (2012) shows how uncertainties in global climate models have substantial impact on building simulations. The prediction of future indoor climate-induced damage in buildings introduces an additional layer of uncertainty (Leijonhufvud et al., 2013). The functions used for modelling damage to cultural heritage are rarely probabilistic (Strlič et al., 2013). As an example, a recent review concluded that all mould growth models are deterministic (Vereecken and Roels, 2012). There remains the possibility to address other (known) uncertainties. Of interest for this paper is a study by Nik et al. (2012), which takes into account the uncertainty of future emissions when predicting future mould growth in ventilated attics in Sweden. The study by Lankester and Brimblecombe (Lankester and Brimblecombe, 2012b) on the impact on future climates on historic interiors also compared different emission scenarios.

While addressing known uncertainties is considered good practice, it will always increase the amount of modelling and analysis needed. In the already complex CfC-project it was considered unfeasible to introduce more modelling parameters. Consequently, the CfC-project produced single point estimates of future damage (with the exception that two actually quite similar forcing scenarios were used). In practice, the results can be said to be based on a "series of best guesses", which means that there is no uncertainty range coupled to the final result (Schneider and Kuntz-Duriseti, 2002, p. 68). This is problematic as a decision-maker might interpret the information as representing the most likely future scenario. Furthermore, the high resolution of the result might lead to false reductionism, i.e. that a more detailed model creates an illusion of realism (Dessai et al., 2009). There is also a risk that the map format in itself adds to a sense of precision and legitimacy obscuring uncertainty (Preston et al., 2011).

The deterministic approach used by CfC does not preclude the results from being usable for decision-making – but who should do the necessary transformations from point estimates to risk assessments, and under which circumstances? On the one hand it has been suggested to let those with most knowledge make subjective estimates of risk instead of passing uncertainty on to lay-people (Schneider and Kuntz-Duriseti, 2002). On the other hand scientists should refrain from summarizing complex and uncertain information on behalf of policy makers (Stirling, 2010). The risk information produced by CfC integrates expertise from several fields (i.e. climate science, building physics, conservation) and both scientists and stakeholders have collaboratively contributed to determine the procedures for establishing the end result in the form of European maps. Consequently, the lines between producers and users, experts and lay-people are not easily drawn in this case.

Much of the literature on best practices in risk communication is based on an understanding where the overall goal of risk communication is to transmit "risk messages" without distortion to inform, and not influence, decisions (Demeritt and Nobert, 2014, p. 315). As an example, risk communication has been described as intended to help decision-makers to make informed, independent judgments about risks (Morgan et al., 2001). It is common that psychological factors such as cognition and emotion are used to explain how risk messages are misunderstood and biased, while the cultural and social nature of risk is downplayed (Boholm and Corvellec, 2010; Granderson, 2014). Conceptualizations of risk as a transferable message correspond to objectivist approaches to knowledge, in which knowledge is unproblematically separable from the scientist who produced it and the practitioner who may use it and where communication is essentially one-way and linear (Greenhalgh and Wieringa, 2011).

The risk message model fits into more overarching ideas of governance as a matter of "predict-then-act" (Adler and Hirsch Hadorn, 2014). However, practical risk governance tends to deviate from the prescriptions and ideas conveyed in formal risk management protocols (Boholm et al., 2011). Boholm et al. (2011) show the importance of sense-making processes when planners deal with risk, and how scientific assessment procedures advocated in risk management guidelines are substituted by social processes of negotiation.

The lack of uncertainty estimates in the CfC maps, the complexity of the modelled processes and the blurred line between producers and users make it difficult to test how well the information, understood as a risk message, is transferred to a user. It is impossible to examine to what extent the information is "biased" as there is no objective yardstick to compare with. This ambiguity inherent in the information does not imply that there is no use in trying to understand how it is interpreted and understood by users. On the contrary, it could be argued that it is even more important than if there was consensus among experts about the magnitude of the risk.

To better understand the processes involved in the communication of the risk maps there is a need for an exploratory and qualitative way of inquiry, and the Church of Sweden serves as a relevant case study for this aim. Hence, the major objective of the paper is to explore and understand how the generic, ambiguous and complex climate risk information produced in the CfC-project is interpreted by decision-makers in the Swedish church. A secondary objective is to develop a methodology for how to select adaptation-relevant parts of the risk information produced by CfC and pre-test its dissemination to a specific target audience (see Fig. 1).

2. The Climate for Culture project

The Climate for Culture project (CfC) was a five year Large Scale Integrated Project within the EU Seventh Framework Program completed in 2014. The general objectives of the project were to quantitatively assess the effects of climate change on cultural heritage in Europe and to discuss mitigation strategies in connection to this. One main outcome of the project was a

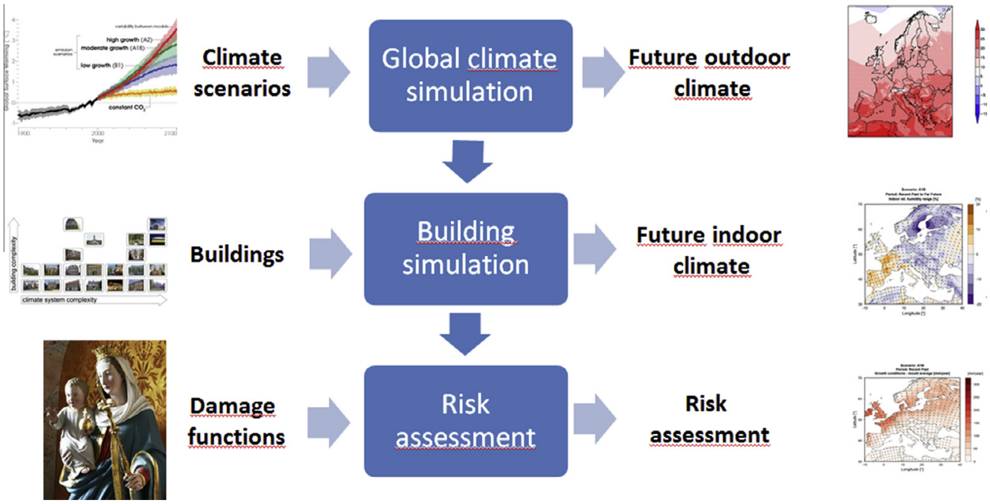


Fig. 1. The method to produce risk maps developed in the Climate for Culture-project (Leissner et al., 2014).

method to produce risk maps for Europe. A brief introduction to the method is given below, more details can be found in Leissner et al. (2014) and Leissner et al. (2015).

The climate model REMO, developed at the Max Planck Institute of Meteorology, was used to produce regional simulations of the climate on a grid of about 11 km. Two global circulation models were applied as driving force (ECHAM5-MPIOM and MPI-ESM) (Leissner et al., 2014). The simulations were carried out for three 30-year periods: 1961–1990 (recent past), 2021–2050 (near future) and 2071–2100 (far future). The simulations for the future were forced with two different emission scenarios (A1B and RCP 4.5), while the simulations of the recent past was forced with observed greenhouse gas emissions. Past and future climate data in the form of hourly values for the whole 30-year periods were produced on a European grid with more than 900 locations. The modelled climate data sets were verified with observational data sets to check their applicability for building simulation. Systematic deviations and other issues related to the use of modelled climate data were identified.

Indoor climates in 16 different generic buildings were simulated in a subset of these locations by the use of a simplified hygrothermal building model. A state-space model was used comprising a mathematical function, derived from a statistical analysis of measurements, that calculates the indoor climate from the outdoor climate. The model has been validated by Kramer et al. (2013).

Changes in future damage were assessed based on damage functions, i.e. equations or algorithms that relates quantifiable factors in the environment to quantifiable changes within the object. The damage functions that were used by CfC include:

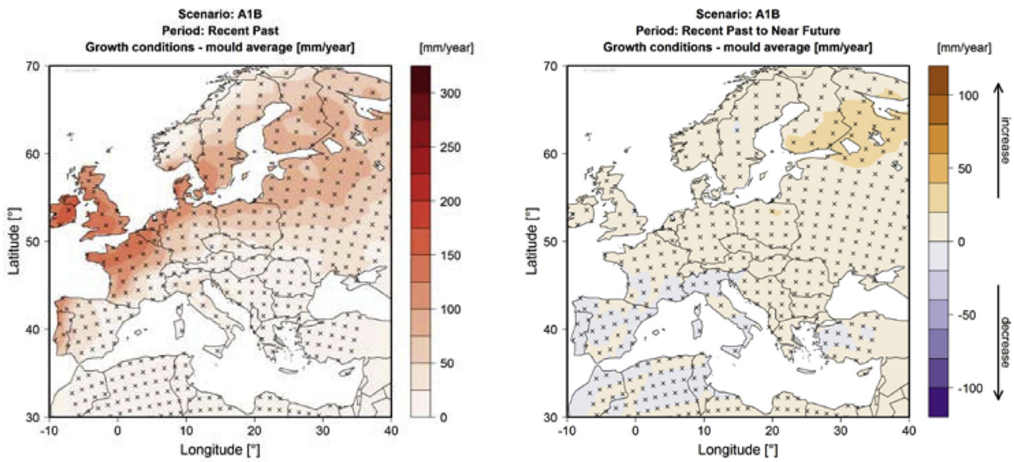
- Mechanical damage: wood, painted wood.
- Chemical damage: paper, textiles, photographic material.
- Biological damage: mould growth, insects.

Finally these changes were presented as maps over Europe either showing the absolute values for the three time periods or the change in damage in relation to the recent past (see Fig. 2).

3. Method

The methodology used in the present paper consisted of two steps. The first step was to roughly identify the subset of the risk information produced by CfC that was relevant for adaptation planning of historic churches in Sweden. The combination of two emission scenarios, different timescales, 16 building types used for building simulation and a range of damage functions had resulted in a total of 55,650 risk maps. Only a limited number of these were relevant for the Church of Sweden. The selection was made in a collaborative workshop with researchers from CfC and stakeholders from the Church of Sweden. The constitution of the stakeholder group was chosen by the Church of Sweden and comprised both top-level management and engineering and conservation professionals directly involved in management. Based on the discussions in the workshop, a set of risk maps was chosen by the researchers from CfC.

After the selection of risk maps made in the workshop, the next step was to study how adaptation decision-makers interpreted the selected maps, how the information fitted into their existing decision context and if it translated into a perceived need for adaptation. Based partly on the stakeholder experience of knowledge acquisition within the Church of Sweden, it



Mould growth. The picture to the left shows the reference period and the figure to the right the difference between the reference period and the near future. The mould growth has been calculated on the basis of temperature and relative humidity. Scale: mm/year. One example: In Gothenburg there is in the reference scenario a mould growth of 100-125 mm/year in the building. The growth is expected to increase with between 0-20 mm/year in the near future. Observe that there is expected mould growth already today in this type of building, except in the northwest of Sweden.

a) how do you assess the changed risk level? (negligible, small, substantial, serious, unable to assess)
b) should this information lead to any adaptation measure? (yes, no, unable to assess)
c) what kind of measure would that be?

Fig. 2. Excerpt from the questionnaire. Question on mould growth (translated from Swedish).

was decided that the most efficient way to elicit information was to use telephone interviews. The interviews were semi-structured, revolving around a questionnaire that was sent to the interviewees beforehand.

The questionnaire was divided in three sections. The first section described the aim of the study and gave background information about the CfC-project and the production of risk maps.

The second section contained pairs of maps, depicting climate change impacts for the generic building type representing an unheated small stone church (Fig. 2). The pairs consisted of one map showing the recent past, and one map showing the difference between the recent past and the near future. For each pair of maps there were three identical questions. The first question considered risk assessment. The rationale for using an ordinal scale is that such scales are commonly used in practical risk assessments, for example when doing environmental impact assessments (Boholm, 2010). The two other questions were about the need for adaptation measures and what kinds of adaptation measures that were considered relevant for the risk in question. The pairs of maps (mould growth, insects and salt damage) were chosen to represent different degrees of severity and uncertainty.

The third section consisted of questions about indoor climate control and indoor climate-related risks in churches today. They were constructed to reveal problems and opportunities with existing management processes as well as identification of both technical and non-technical barriers to improved indoor climate control in churches. There were both questions with predefined answers and open-ended questions.

The rationale for the chosen format of the interview (a combination of qualitative interview and survey) was the qualitative and exploratory character of the research question. The aim was to understand how the risk information conveyed in the survey-like questions was interpreted by decision-makers. The risk assessments are interesting on their own but the focus is here on sensemaking: the process in which the interviewees renders the information as intelligible and relate to it (Weick, 1995). The interviewees were therefore instructed to "think aloud" and explain the rationale for all answers, a method often used for pre-testing surveys (Collins, 2003). In cases where the interviewer felt that the verbal accounts didn't reveal enough information, interviewees were probed with cues such as "explain how you came up with that answer", "what are your thoughts on...?".

A category of key actors regarding adaptation planning in the Church of Sweden were identified at the workshop. At the Diocese level there are engineering and heritage professionals employed to support parishes with all aspects of the management of churches. Typically, there is one engineer and one building conservator employed by each of the thirteen Swedish Dioceses. These professionals give support to the often layman-led management of the individual churches, both regarding daily operation and renovation projects. They have good, aggregated, knowledge of risks to churches in their geographic region because of their strategic position and tight collaboration with individual parishes. However, they are not specialized in indoor climate-related problems. Interviews were made with ten engineers and ten building conservators. In the rest of the paper these are referred to as "decision-makers".

To compare the assessments made by decision-makers, five experts regarding indoor climate risks were also interviewed. Two mycologists, one entomologist and two engineers specialized in climate-related damages in buildings were interviewed regarding the pairs of maps that were within their area of expertise.

The interviews were made over telephone in August-September 2014. Each interview lasted between 30 and 80 min with an average of 45 min. The interviews were recorded and notes were taken. All quotes have been transcribed verbatim and translated into English by the author.

4. Results and analysis of the interviews

The following analysis begins with some general reflections on the perception and interpretation of the risk information as a whole, and continues with a more in-depth analysis regarding how two specific questions in the questionnaire were interpreted.

Most interviewees seemed to have read the material carefully and tried to answer the questions with care, despite a low degree of familiarity with the technical details. All but one of the 21 decision-makers that were contacted for the interviews were able to participate with short notice, which indicates that they had an interest in the subject matter. There was consensus among decision-makers and experts that the presented risk information was relevant. They could all relate to the content and found it interesting. Despite perceiving the information as relevant, two of the experts did not perceive the information as reliable enough to be of any use.

Most of the interviewees expressed that it was relatively easy to understand what the risk maps showed. However, as discussed in more detail below, the way they referred to the maps indicated that their technical comprehension sometimes was flawed. Most interviewees were hesitant to make any kind of risk assessment, as they perceived the information to be too abstract, unspecific and uncertain. However, in the end only a minority chose to use the "unable to assess" option. One building conservator expresses her concerns about assessing the maps in this way:

> *It is difficult to interpret, expert knowledge is needed... difficult to relate to the numbers. I understand that all this is dependent on a lot of hypothesizing at the drawing table... there is a need of a pre-interpretation.*

The main objectives of the interviews were to understand how the interviewees interpreted the different pairs of maps, how they assessed the risks and if they related the information to a need for adaptation measures. The questions regarding mould growth (Fig. 2) and salt damage (Fig. 4), will be used here as examples. These questions were chosen because of their differences regarding the familiarity of the type of damage and the strength of the climate change signal. Mould growth is a common problem in Swedish churches, with a cause-effect relationship assumed to be well known to decision-makers. Salt damage, on the other hand, is not as common, and the understanding among decision-makers of the cause-effect relationship was assumed to be lower. Furthermore, while the predicted climate change impact on mould growth is significant, the impact on salt damage is negligible.

The quantitative distribution of answers is to illustrate the variety of responses. An analysis of how individuals explained their reasoning behind their answers, in some instances after being cued to do so, is used to interpret the quantitative results.

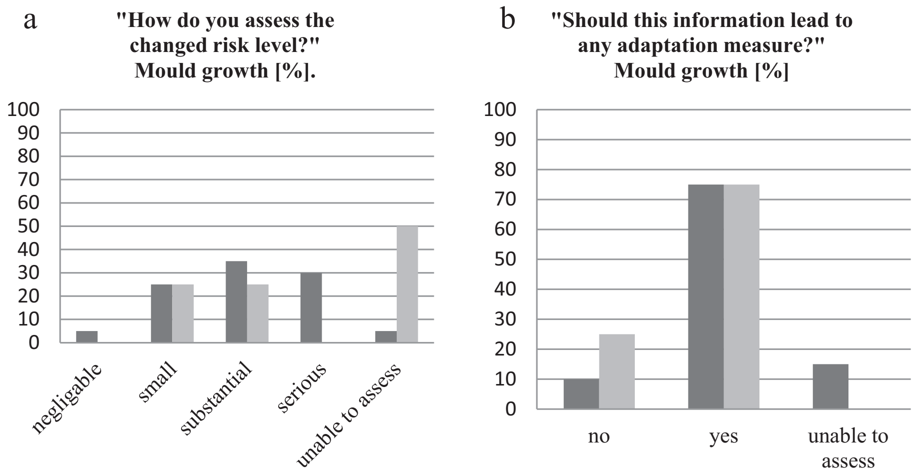
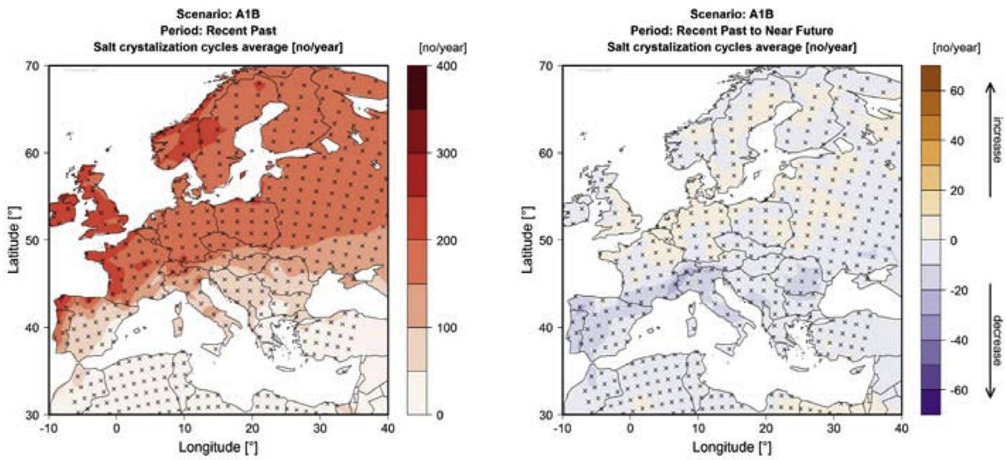


Fig. 3. (a and b) Mould growth. Decision-makers (n = 20) in dark grey, experts (n = 4) in light grey.



Salt damage: Number of occurrences when the relative humidity passes 75 % (NaCl crystallizes). The picture to the left shows the reference period and the figure to the right the difference between the reference period and the near future. An example: In Gothenburg the 75 % relative humidity threshold will be passed 150-200 times per year. In the near future this number is expected to increase with 0-10 times per year.

a) how do you assess the changed risk level? (negligible, small, substantial, serious, unable to assess)
b) should this information lead to any adaptation measure? (yes, no, unable to assess)
c) what kind of measure would that be?

Fig. 4. Excerpt from the questionnaire. Question on salt damage (translated from Swedish).

The mould growth maps (Fig. 2) show predicted mould growth for the A1B emission scenario for the recent past (left) and the change between recent past and near future (right). Mould germination and mycelium growth were calculated on hourly values for the 30-year periods, using RH and T isolines from Sedlbauer (2002). The maps show the average growth per year for the whole 30-year period. For the recent past, the map shows a predicted mould growth between 0 and 125 mm over Sweden, with the lowest values in the northwest, and highest in the southwest. The change map shows an increase with 0–20 mm over the whole country, implying a possible maximum relative increase in the southwest of about 20%. However, the change can also be zero as the value can be anywhere in the range between 0 and 20 mm.

The risk assessments for this pair of maps varied considerably (Fig. 3a). Only one of the decision-makers assessed the risk as negligible, while the other answers were about evenly distributed between small, substantial and serious risk. One decision-maker was unable to assess the risk. The assessments from the experts, in this case two mycologists and two engineers working with moisture problems in historic buildings, were quite varying in that the mycologists considered themselves unable to assess the risks, and the engineers assessed the risk as small and substantial, respectively. The question if the information on mould growth should lead to an adaptation measure was answered affirmatively by 75% of both decision-makers and experts (Fig. 3b).

The results show that the level of assessed risk for the mould growth maps varied both within and between the groups of decision-makers and experts. In the following, a number of individual accounts are used to illustrate how the same information is interpreted in different ways within the groups.

The reasoning of one of the decision-makers shows how the combination of a perceived weak signal, high uncertainty and a skeptical attitude toward the method results in an outlier assessment. This decision-maker assessed the increased risk level for mould growth as small and answered the question of the need for adaptation measures negatively. He reportedly had a long experience with mould problems in churches. On the basis of his experiences, he suggests that the link between mould problems and climate change is weak compared to the influence of other factors:

> *...we see changes [of the extent of mould growth] already today but it is nothing that worries me, there are much bigger problems concerning other aspects [that affects the risk for mould problems in churches].*

He expressed an overall skepticism regarding the possibility to doing these kinds of predictions at all, claiming them to be "too general" and "too uncertain". At the same time, he seemed to be able to interpret the maps in a technically correct way and paid attention to technical details. In sum, this individual seemed to perceive the information as lacking in saliency (the change being too small) and credibility (too much uncertainty), and therefore did not consider it as usable.

In contrast to the technical and rather critical approach represented by the former example, there were several decision-makers whose risk assessments seemed to be biased by a preconceived impression of a negative development. Hence, the details of the information regarding the specific question were downplayed in relation to the overall impression. An example was one decision-maker, also with long experience of mould problems in churches, who assessed the mould risk as serious and answered affirmatively on the need for adaptation measures. This engineer seemed to make his assessment without paying attention to the actual details of the maps. Rather, he reasoned that mould problems already today was a significant problem, and that any change in the direction to a warmer and more humid climate would be a serious problem. In a way, then, the conveyed information strengthened his already internalized impression of the negative impacts of climate change. He explained his reasoning by referencing to general phenomena only loosely coupled to the presented information. In his case, the risk information was perceived as both salient and credible.

The assessments of the experts were quite diverging. One of them, a mycologist, was skeptical to the usefulness of the information, claiming the underlying science to be too uncertain. Consequently, he had a negative stance towards the methodological approach taken by CfC, grounded in skepticism towards the possibility to predict mould growth in buildings as a function of the outdoor climate:

I consider the uncertainties too large for making an assessment of the risk possible. Furthermore, I do not think that small differences in the outdoor climate have an impact as the differences which are specific for each building are much more critical [for mould growth].

This verdict did not seem to be due to skepticism about climate change in general, but rather due to a lack of faith in the overall research approach. Hence, he did not perceive the information as credible and refrained from making any assessments based on the information.

This can be contrasted to the views of another expert, an engineer specialized in indoor climate-related risks in churches. This expert was more positive of the usability of the results and assessed the predicted increase in mould growth as substantial. As a reference point for his assessment, he explained that many churches in the southern parts of the country were close to a threshold for developing mould problems, and that even a small change could have major consequences. Interestingly, he commented on his own assessment that it was biased by his experience of an increase in mould problems in churches during the last 5–10 years, according to him likely due to a changed outdoor climate. His thoughts about this illustrate how all risk assessments are based on personal experience:

Expert: The way in which I make my assessment is affected by my personal experience. If I didn't know anything [about problems today] I wouldn't be worried over these numbers. Actually, the best would be to find someone without preconceived notions.
Interviewer: It is difficult to find an expert on mould growth in buildings lacking experience with mould problems.
Expert: Yes, it is a dilemma.

The salt damage maps (Fig. 4) show the predicted number of NaCl salt transitions for the A1B emission scenario for the recent past (left) and the change between recent past and near future (right). The number of transitions over 75% RH (the equilibrium RH for NaCl) were calculated on the hourly values and averaged for the whole 30-year period. For the recent past, the map shows a predicted number of 150–200 transitions per year for most of Sweden. The change map shows an increase of 0–10 transitions in the south and northeast, and a decrease of 0–10 transitions in the rest of the country. These changes are very small in relation to the overall uncertainty of the simulations.

The salt damage maps are different from the mould growth maps in that it is difficult to determine if salt damage will decrease or increase in the near future. Despite this difficulty, 55% of the decision-makers made the assessment that the information implied a small or substantial level of risk. On the question if the information on salt damage should lead to any adaptation measure, 25% of decision-makers answered no, 30% yes and 45% unable to assess (see Fig. 5).

How can it be explained that a map which objectively shows a negligible impact of climate change is assessed as depicting a substantial risk? One of the decision-makers gives a hint: he argues that it is difficult to estimate a risk as the indicated change is very small, but as the uncertainty is high he still think the risk is substantial. Another reason might be that several interviewees had difficulties in understanding the difference between the baseline map and the change map. The information shown in the reference scenario seems to be used as the dominating basis for the risk assessment and little attention was paid to the expected change. Related to this, it was clear that several interviewees based their risk assessments on how problems were experienced today, ignoring the information in the maps. One decision-maker argued in this way when explaining the difficulty in using the information for risk assessments:

all questions are intertwined /.../ it is like this that you have to base your interpretation on the situation today, when there is such a wide scope for interpretation.

Both experts assessed the changed risk level as negligible, referring to the small change as well as the uncertainty inherent in the damage function.

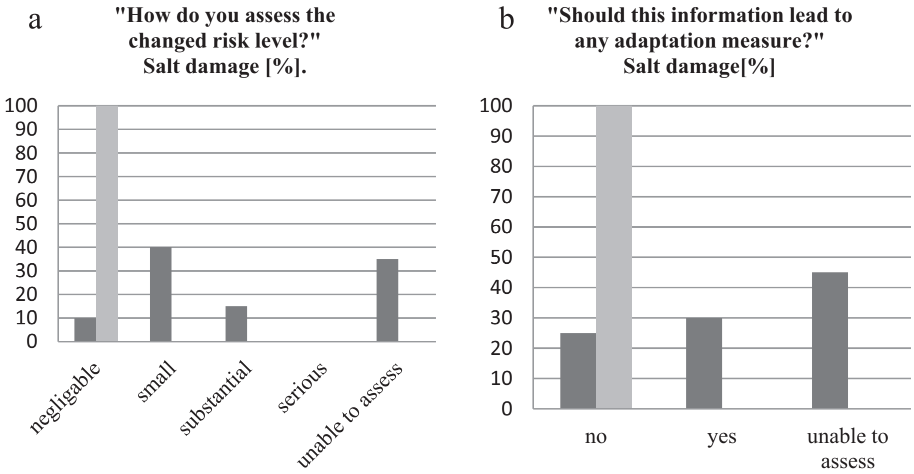


Fig. 5. (a and b) Salt damage. Decision-makers (n = 20) in dark grey, experts (n = 2) in light grey.

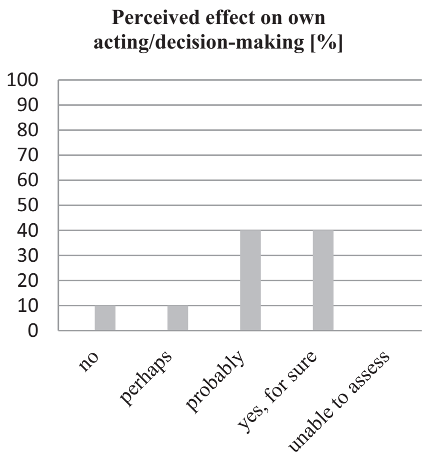


Fig. 6. Answers from decision-makers (n = 20) to the question "Do you estimate that the aggregated information about risks for mould/insects/salt damage will affect your own acting/decision-making?".

Fig. 6 shows that most of the decision-makers thought that the presented information was likely to affect their own acting/decision-making. The overall impression was that the information was perceived as strengthening the need for already existing ways of adapting to climate change:

> *We already have these problems, but this shows that it is likely going to become even worse. This gives us a stronger argument for continuing with what we already do [to reduce indoor climate-related risks]. (decision-maker)*

The notions of risk that emerged in the interviews diverged from the common technical definition of risk as a product of likelihood and expected outcome. The way the interviewees reasoned revealed how the term risk was used in different ways by different individuals and how ideas of risk, consequence, probability, uncertainty and vulnerability were intermingled. Risk was for example referred to as dominated by expected outcome: "the risk might become serious in rare cases" (decision-maker), or the other way around, emphasizing likelihood: "big consequences but small risk" (decision-maker).

A confounding factor for making risk assessments was the difference in the potential for risk reduction for different kinds of risk. This can be exemplified with that mould growth potentially can lead to big damages, but it is relatively inexpensive and simple to reduce the risk with preventive measures, e.g. dehumidification. Then, in a case where effective risk reduction measures are already in place, it is intelligible to assess the risk as low.

Finally, and related to the definition of risk, there were few decision-makers who seemed concerned about the absence of probability estimates or uncertainty intervals. Actually, the label "risk maps" used by CfC is misleading as they are deterministic accounts of future damage, albeit with a presumably large amount of uncertainty. However, this did not seem to bother decision-makers. There were only a few of them who discussed or questioned the uncertainty of the information. The opposite was true of the experts, for whom uncertainty and the accuracy of predictions seemed to be the dominating issue.

5. Discussion

The methodology used in this paper provided a manageable way of understanding if risk information at all makes sense to decision-makers and if it is perceived as usable in their decision-context. In contrast to a survey, it was possible to get in-depth understanding on how the interviewees interpreted complex information and how they argued for giving their answers. The results can be used for customizing risk communication in a subsequent step. Furthermore, the methodology provided a cost-effective way of eliciting knowledge on the organizational constraints and possibilities for adaptation (this aspect is however out of the scope of this paper).

The interviews showed that the decision-makers and experts in general were interested in the risk information. For most of them, the information made sense in such a way that they could relate it to their own decision context. There was also in general a high level of trust vis-à-vis the provider of the risk information. These two factors – that the information related to topical issues and the trust given to the information provider - could explain why a majority of interviewees expressed that the information would have an impact on their own future behavior.

The magnitude of the predicted change and the accuracy of predictions were subordinate to the overall impression of the information as being credible and salient, factors which previous research has shown to be crucial for increasing usability (Cash et al., 2003; Kirchhoff et al., 2013).

Previous research in risk communication points out the need to evaluate how risk information is perceived in order to customize the presentation of risks and to guide future research (Renn, 2008). The risk maps were in this case ambiguous to the studied group, resulting in a broad range of interpretations. For example, in the case of the mould growth maps, the assessed risk levels were ranging from negligible to serious. Both decision-makers and experts were, however, generally hesitant about making risk assessments, claiming the information to be abstract, complex and ambiguous. In the end, a majority chose to give an assessment rather than selecting the "unable to assess" option. This indicates that the risk maps gave rather weak cues in comparison to already established individual beliefs about the issue at stake, for example their opinions concerning the impact of climate change in general (Morgan et al., 2001).

A complicating factor when interpreting the interviews was the elusive nature of risk itself. There are many different types of risks as well as conceptions of how they are constituted (Renn, 2008; Blennow et al., 2014). Experts and lay-people tend to use the concept in different ways, with experts preferring a technical definition where risk is characterized as a product of probability and negative consequences (Slovic, 2000). From the verbal reports of the interviews it was apparent that the understandings of risk varied considerably between individuals, and in general they did not adhere at all to the technical definition. In addition, when interviewees were asked to rationalize their risk assessments, they referred to existing or possible risk management actions, such as the extent of indoor climate control. These results points at the lack of realism in a position which states that the ideal of risk communication is the unbiased transfer of a "risk message", as discussed in the introduction. They also support previous research that shows how actors involved in practical risk governance tend to merge risk analysis, risk management and risk communication (Boholm et al., 2011).

An intricate problem with the risk information used in this study is that it shows possible future harm without giving any information about the likelihood. Apparently, this was not perceived as a major constraint for performing risk assessments. This indicates that the focus within the scientific community on reducing and communicating uncertainties, which was briefly described in the introduction, might have little impact on the usefulness of research in the direct way by informing decisions through more accurate and precise predictions. However, using state-of-the-art methods and communicating uncertainties have an important indirect impact on usefulness by making the scientific enterprise perceived as legitimate by end users.

In the introduction it was described as an open question when, how and by whom risk assessments should be made: when the quantitative information produced by modelling of physical processes should be transformed to usable knowledge via subjective, value-based, risk assessments. The results of the interviews indicate that this question indeed is a crucial one, but also that it defies simple answers. The range of interpretations and assessments made by decision-makers and experts were quite wide, a result that questions the idea that the risk information is "objective" and can be communicated to a broad group of end-users whom effectively will select and make use of the information. Leaving the task to assess the risks to end-users will lead to misinterpretation and misuse, or perhaps more likely, that the information will not be used at all. An important finding is therefore that risk assessment and dissemination should be a joint effort by end-users and researchers in order to produce actionable knowledge.

6. Conclusions

Risk maps produced by the Climate for Culture (CfC) project show future indoor climate related risks to historic buildings in Europe, based on building simulations of generic buildings. In this paper, a methodology for how to select adaptation-relevant parts of this risk information and pre-test its dissemination was developed in a collaborative effort by researchers and a specific stakeholder group, the Church of Sweden. The major objective of the paper was to understand how heritage decision-makers in the Church of Sweden made sense of the generic, ambiguous and complex risk information produced by CfC, and a secondary objective was the development of the methodology itself. Risk maps produced by the CfC-project were jointly selected by stakeholders and researchers. Twenty decision-makers and five indoor climate experts were interviewed with the aim to understand how they interpreted and made sense of the maps.

The interviews give a new and better understanding of why the risks were interpreted and assessed differently by the respondents. This is shown to be largely dependent on their pre-understanding and familiarity with the individual risks rather than on the information provided. Most interviewees were hesitant about making risk assessments, possibly because of that the information provided weak cues. In turn, risk assessments were dominated by already established notions of climate change and its impacts on Swedish churches. The magnitude of the change and the accuracy of predictions were subordinate to the overall impression of the information as being credible and salient. Multiple understandings and uses of the risk concept made comparisons of the risk assessments problematic. However, the lack of information about the range of uncertainty in the information was not perceived as problematic by most decision-makers.

The major conclusion of the paper is that the results from CfC are likely to be interpreted in misleading ways if the interpretation and assessment are left to the end-users. The dissemination of risk information, also from projects which at the outset have aimed at producing knowledge relevant for end-users, must be both customized and tested for specific target groups in collaborative efforts by stakeholders and scientists. This result is important for guiding further dissemination of results from CfC as well as for future projects aiming at producing usable knowledge for cultural heritage management. By extension, this is also a call for further qualitative research concerning how climate risk information is shared to and acted upon by different stakeholder groups.

Acknowledgements

The present study has been supported by the Swedish Energy Agency as part of the National Research Programme on energy efficiency in historic buildings and the European Commission through the EU Climate for Culture project 226973 within FP7-ENV-2008-1.

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