CULTURAL HERITAGE IN CRISIS

CULTURAL HERITAGE RESEARCH AT EUROPEAN LEVEL – CHALLENGES IN TIMES OF CLIMATE CHANGE AND DIGITALIZATION

VillaVigoni
Centro Italo-Tedesco per l'Eccellenza Europea
Deutsch-Italienisches Zentrum für Europäische Exzellenz

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The organizers of the symposium would also like to thank the participants joining us in Italy for their lively contributions, which made the symposium such a successful scientific and cooperative event.

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INTRODUCTION

WORDS OF WELCOME

Christiane Liermann Traniello

It was a great pleasure and honor for the German-Italian Centre for European Dialogue Villa Vigoni to host the German-Italian Scientific Symposium "Cultural Heritage in Crisis" in November 2019. There is hardly any other place that is so perfectly suited to discuss cultural heritage, its exploration and the challenges it faces from a German-Italian-European perspective. We would like to thank the funding organization of the Villa Vigoni, the Federal Ministry of Research and Education BMBF (in particular Gisela Cramer von Clausbruch, Deputy head of department: Cooperation with European Countries, Israel), and the experts around Dr. Johanna Leissner from the Fraunhofer Institute Brussels, for organizing this important meeting.

The Villa Vigoni itself is a piece of "cultural heritage": Ignazio Vigoni (1905-1983) gifted his family's splendid property on Lake Como to the Federal Republic of Germany, on the condition that it should be used to develop a center for German-Italian discussions in a European perspective. Since then, Villa Vigoni, with its special German-Italian "mission", has also become part of the immaterial cultural heritage of Europe. This is always a matter of dealing with the history and present of Europe and with what is - not without controversy - understood as "European identity". The same goes for "cultural heritage" another dynamic entity in need of permanent revision; nothing fixed or predetermined, but, just like "identity", depending on attributions and decisions as to what and why one wants to regard "cultural heritage" at all.

For this reason, the theme of cultural assets has long been present at Villa Vigoni. This includes work on the research and preservation of the museum's own architectural holdings, works of art and objects, as well as the imparting of knowledge and sensitivity in dealing with cultural heritage, particularly with regard to the younger generations. Villa Vigoni also participates in German-Italian exchange, which brings together the topics of cultural heritage and international cultural relations. The foreign ministries of the two countries are in close contact with each other on this issue.

Villa Vigoni was a relevant and suited place to hold the symposium on the "crisis" of the cultural heritage, because theoretical research into cultural assets and technical progress for their protection and preservation, which the BMBF and Fraunhofer make possible, was already a central concern for Heinrich Mylius (1769-1855), the founding father of Villa Vigoni. Historical awareness, cultural awareness and openness to the opportunities offered by future-oriented technologies belonged together then as they belong together today.

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EDITORIAL

Johanna Leissner, Dario Camuffo, Cristina Sabbioni, Ralf Kilian, Uta Pollmer

All objects constituting our cultural heritage were born as the creation of an artist, but they were also adopted thereafter, as children of the entire human community. Recognized within these objects were the roots of universal values such as beauty, humanity and culture. Our cultural heritage represents the memory of human civilization and the highest expression of our identity; it allows us to understand our past and to create our future. The year 2018 was declared the European Year of Cultural Heritage to strengthen and highlight the multifaceted significance of this legacy for Europe and its citizens.

Unfortunately, our cultural heritage is now exposed to an unprecedented risk of unimaginable proportions. This threat is human-induced climate change, which entails an increased likelihood of extreme climate events and already poses considerable risks for humanity today. During the last few years, we have experienced some impressive events demonstrating the extent to which we may expect damages in the future. In 2017, a heat wave forced a shutdown of the famous Uffizi Galleries in Florence. Paramount examples from 2019 are the flooding of Venice and significant damages incurred at the Cologne Cathedral because of a hurricane. More and more evidence is emerging that cultural heritage is in severe danger (ICOMOS 2019). Still the cultural heritage sector is not sufficiently prepared to counteract these threatening changes and to develop protection measures.

Spanning the past 37 years, the European Union's research programme for the protection of cultural heritage is the world's longest running and most comprehensive. Thus, the sector can convincingly demonstrate its relevance for society: the EU was the first to address research to study the impacts of climate change on cultural heritage (Noah´s Ark 2004 - 2007). Since then, it has continued with more thorough examinations of climate impacts on historic buildings and future energy demands. These examinations have been coupled with adaptation measures and early warning tools for extreme climate events which are specifically designed to address cultural heritage challenges (Climate for Culture 2009 - 2014; Heracles and Storm 2016 - 2019).

However, in-depth interdisciplinary and transdisciplinary research on how to adapt to climate change on local, regional, national and European levels continues to be lacking. The intention of the symposium at Villa Vigoni was to bring together the leading German and Italian scientists researching cultural heritage issues. By doing so, the symposium sought to initiate a sustainable exchange of experiences in the fields of climate change, cultural heritage and digitization and jointly develop an integrative approach as a catalyst for new, innovative solutions. Scientists at the symposium focused on the analysis of damage potentials as well as on the discussion of possible solutions. These included the potential of digital technologies for heritage preservation, the value of cultural heritage for society and framework conditions for successful heritage protection and adaptation in Europe.

By facing some of the threats caused by climate change, digitalization can help to preserve cultural heritage in different ways: digital technologies allow non-destructive analysis of artifacts, 3D models connect these data, visualize damages and support conservators in prioritizing preservation work. While these models still cannot capture the material composition or the heritage values, they are able to store the appearance and related historical information about the objects, thus, to some extent, preserving the soul of these works of art. Unfortunately, the challenge and threats created by climate change are so significant that some of our heritage is at risk of being lost forever. Climatic impacts are already causing certain heritage to disappear. Here, digitalization and the use of Virtual and Augmented Reality applications can help to preserve at least a part of this endangered heritage for future generations. The opportunities created by digitalization include the development of a library with seemingly unlimited storage capability which comprises the full documentation and all details of the original objects. The challenge lies in defining digitization standards, providing the necessary infrastructures and the required financial resources.

The Villa Vigoni at Lago di Como, a site where a rich and interesting part of European history can be physically experienced, was the ideal place to exchange and discuss innovative ideas and concrete measures to save our heritage. The participants of the symposium „Cultural Heritage in Crisis" at Villa Vigoni would like to thank the German Ministry of Education and Research (BMBF) for the generous funding. To conclude, there is much to learn from the past: understanding how our ancestors responded to past environmental changes and crises can guide us to be better prepared for the future. The participants of the Villa Vigoni Symposium will meet this challenge by intensifying their cooperation in cultural heritage research and further developing their joint effort to reach innovative solutions.

Figure: Villa Mylius-Vigoni, Menaggio, Italy

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MOBILISING CULTURAL HERITAGE FOR CLIMATE ACTION

Andrew Potts

»*It would be foolish to imagine the practice of heritage remaining static while the world goes through the rapid and far-reaching transitions [required to address climate change]***«** [1]
Toshikyuki Kono, President of ICOMOS

The globe is currently on pace for over 3°C of warming [2], promising wide-ranging and destructive climate impacts that will almost certainly exceed the adaptive capacity of some local communities, overwhelming even well designed in situ adaptation plans and locking in losses and damages to heritage sites and values [3]. Humans have the ability to avoid or make significantly less severe some of these impacts, or so a landmark 2018 report of the Intergovernmental Panel on Climate Change (IPCC) concluded, but doing so would require rapid and far-reaching societal transitions [3]. Meanwhile, a 'business-as-usual' approach continues to characterize much of heritage practice, seemingly unfazed by either accelerating climate impacts or the urgent need to realise its potential to support transformative change. How to shift this paradigm presents one of the great research questions of our time. Unprecedented concentrations of greenhouse gases (GhGs), driven by human activities such as burning of fossil fuels and deforestation are warming the planet and changing the climate. The result has been an increase in hazards like sea level rise and coastal flooding, drought and extreme heat, the impacts of which are already damaging infrastructure, ecosystems, and social systems – including cultural heritage. In 2017 ICOMOS concluded that 'climate change has become one of the most significant and fastest growing threats to people and their heritage worldwide' [4]. ICOMOS also warned that such trends would worsen – as indeed in 2019 they did. For starters: July was the hottest month ever recorded on Earth [5].

According to the IPCC, humankind has already made the climate 1 degree Celsius (C) warmer since pre-industrial times. Warming is likely to reach 1.5°C around 2040 and 2°C by 2065 if GhG emissions continue unchecked. The IPCC Report highlights multiple climate change impacts that could be avoided or made significantly less severe by limiting global warming to 1.5°C. But limiting global warming to 1.5°C, the IPCC said, would require rapid and far-reaching transitions in the way we use land, energy, industry, buildings, transport, and cities. The world must change, and in many ways it already is.

But is heritage changing? A wealth of anecdotal evidence argues that the cultural heritage sector has not taken on board these lessons. Today, many heritage managers still lack the capacity to downscale climate scenarios to inform site management. Many national climate adaptation plans still miss the potential of heritage. Despite profound connections between climate change and cultural heritage, there are too many heritage officials, professionals, organisations and advocates not yet engaged in climate action – even in frontline communities and even in cities and regions that have made robust climate action pledges. Various explanations have been advanced for this, including that the methods for studying culture tend to be narrative-based and qualitative, often including ethnography and participant observation, and data from these methods do not sit comfortably with the quantitative approaches prevalent in other social and natural sciences on climate change [6]. The

IPCC has said that in just 11 years, that is by 2030, global net anthropogenic emissions of carbon dioxide (CO_2) would need to fall by about 45 percent from 2010 levels in order to give the world a fighting chance to stay below the 1.5°C mark. The window of opportunity is closing. So how does heritage conservation practice rapidly take on board the imperatives of a climate change emergency?

Addressing this question has been a top priority of the ICOMOS Climate Change and Heritage Working Group (CCHWG) since its launch in 2018. In July 2019, after 18 months of work, the CCHWG released its report, The Future of Our Pasts: Engaging Cultural Heritage in Climate Action [https://www.icomos.org/en/77-articles-en-francais/59522-icomos-releases-future-of-our-pasts-report-to-increase-engagement-of-cultural-heritage-in-climate-action]. Twenty-eight ICOMOS members spanning 19 countries served as lead or contributing authors, 32 National and International Scientific Committees provided feedback, and almost 50 invited experts provided peer reviews.

The Future of Our Pasts Report scoped hundreds of ways in which cultural heritage can drive the transitions that the IPCC has said are required to meet Paris Agreement targets. The analysis is divided into four categories, outlining the role of cultural heritage in heightening climate ambition and capacity, GhG mitigation, climate adaptation, and planning for losses and damages. It also catalogued the myriad climate change impacts that are already testing the adaptive capacity of every heritage typology. Addressing these impacts while simultaneously realising culture's potential to support equitable climate action, the Report concluded, requires both (1) adjusting the aims and methodologies of heritage practice and (2) better recognising the cultural dimensions of climate change. The finding that cultural heritage offers immense potential to support climate action is not surprising. Climate change is an anthropogenic, which is to say human, problem. It calls for planning with a multi-generational time horizon. It demands circular economy approaches that promote the reuse and conservation of resources. Solving it demands both social cohesion and creativity and cultural capital. These are the core considerations of cultural heritage. But realizing that potential at the needed scope and scale will require new multi-disciplinary research and approaches across heritage practice, including documentation, disaster risk reduction, vulnerability assessment, conservation, education and training as well as in the manner heritage sites are presented to visitors.

So what does this new practice look like? We get glimpses in places like Edinburgh, where Historic Environment Scotland has achieved a 40% decrease in Edinburgh Castle's GHG emissions, making this iconic World Heritage site a symbol of the national will to decarbonise and in the process demonstrating that if a castle can be retrofitted for energy efficiency without loss of heritage values, then so too can every other older building. Another example: Puerto Rico, where the DUNAS project [https://www.climatesciencealliance.org/dunas] interweaves archaeological, ecological and community heritage values in order to empower precarious communities to both restore sand dunes and salvage indigenous archaeology while buying time to develop locally relevant adaptation strategies. And we see it in Fiji where the Fiji Museum is mapping the heritage values of villages slated for planned relocation and collecting oral history before they're lost to sea level rise.

From this work, and others like it, we get a picture of what cultural heritage looks like when it is mobilised for climate action – and we see some common themes. This is work that

- aligns to the priorities of the Paris Agreement,
- integrates nature and culture,
- centers equity, and communities on the frontlines of climate impacts, and is
- expressly connected and correlated to climate science and broader climate policy making.

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The Future of Our Pasts report found that we must reorient heritage practice along these lines – but that alone is not enough. The cultural dimensions of climate change are often overlooked in the realms of climate science as policy as well. This too must change, and that means the cultural heritage field must claim a seat at the climate policy table. With this in mind, important international initiatives have formed: On 24 October 2019, the Climate Heritage Network [http://climateheritage.org/] was launched in Edinburgh with more than 160 delegates from all over the world to support the implementation of the Paris Climate Agreement. This was conceived at the Global Climate Action Summit hosted by the State of California in 2018 and will provide a platform for the sector to unite and tackle climate change.

Iconic historic places – from archaeological and prehistoric sites, such as Skara Brae in Orkney, to coastal cities like Venice, Italy and Saint-Louis, Senegal – are extremely vulnerable to these impacts, which also put cultural collections, such as archives, artworks and artefacts at risk. Intangible heritage, such as languages and oral traditions also face a fight for survival as climate change threatens to displace communities. Not only highlighting the severity of the threat climate change poses to historic sites worldwide, the Climate Heritage Network will also seek to inspire individuals, organisations and communities to implement climate action. It will emphasise how cultural heritage offers immense and virtually untapped potential to drive climate action and support equitable and just transitions by communities towards low carbon, climate resilient futures.

Better connecting cultural heritage and climate science is also key. The IPCC is the world's leading climate science body. The view of ICOMOS is that the cultural heritage research agenda should be driven to a greater degree by the global climate change research agenda in general and the IPCC's research agenda in particular. At the same time, but not unrelatedly, ICOMOS believes that the cultural dimensions of climate change are not adequately foregrounded in the IPCC's work. For this reason, ICOMOS, UNESCO and partners are seeking co-sponsorship from the IPCC for an Expert Meeting that would assess the state of scientific literature on cultural heritage and climate change.

In Europe, the European Green Deal contains deeply transformative policies which aim to reconcile the way Europe produces and consumes with our planet – and in a just and inclusive manner. There are significant cultural dimensions to every aspect of the 'EGD,' from circular economy to building renovation, 'farm to fork' to biodiversity. And, yet, 'art' 'culture' 'heritage' – none of these words currently appears in the European Green Deal. Therefore, it is evident from the aforementioned arguments that it is of crucial importance to include cultural heritage in the Green Deal and also the European Mission Board for Climate Adaptation to sustain Europe`s legacy for future generations.

Culture heritage is a climate change issue. Climate change is a cultural heritage issue. Now, is the time to urgently accelerate our understanding of this intertwined dynamic. The future of our pasts depends upon it.

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Figure: Villa Vigoni, Menaggio, Italy

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THE MOU BETWEEN CNR AND FRAUNHOFER

Anna Büchl

For the work and dedication of individual proponents of cultural heritage research and climate action to have an impact, there need to be supporting political and organizational framework conditions on an international level. One step to building an appropriate framework and joining forces in cultural heritage research is the Memorandum of Understanding (MoU) between the largest public research institution in Italy, the Consiglio Nazionale delle Ricerche (CNR) and the Fraunhofer-Gesellschaft, the leading organization for applied research in Germany and Europe. The MoU was signed by the president of CNR, Prof. Massimo Inguscio, and the president of the Fraunhofer-Gesellschaft, Prof. Reimund Neugebauer, in June 2019. It aims to enhance the existing collaboration in fields such as Smart Agriculture, Industry 4.0 and Cultural Heritage.

PRELIMINARIES

An agreement of such magnitude that involves two large research organizations does not occur overnight. The step of signing a MoU between CNR and Fraunhofer that overarches several fields of cooperation was preceded by successful joint activities and collaboration projects in the past. In the field of cultural heritage there has been a long lasting cooperation between the Fraunhofer Institute for Building Physics IBP and the CNR-Institute IBAM (Istituto per i Beni Archaeologici e Monumentali). For example, the Pompeii Sustainable Preservation Project. This was a collaboration which was already in March 2014 sealed in a MoU together with partners TU Munich and ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Property).

Figure: President of CNR Prof. M. Inguscio and President of the Fraunhofer-Gesellschaft Prof. R. Neugebauer sign the Memorandum of Understanding on June 11th 2019 in Rome

This was closely followed by a workshop in Brussels in October 2014. The workshop included 30 representatives of 7 Fraunhofer and 8 CNR Institutes, among them Prof. Neugebauer and the former CNR president Prof. Luigi Nicolais, consulted about new fields and possibilities to extend existing collaborations. It was here that the Preservation of Cultural Heritage was identified as one of the prominent fields of further bilateral cooperation, next to Mobility, Production-Technology, Industry 4.0 and Cross Energy Management. It should also be highlighted that in regards to intensifying the cooperation between Fraunhofer and CNR, the preservation of cultural heritage has always been on the agenda. Consequently, in the newly signed MoU it is one of the three fields of cooperation explicitly named in the introductory clauses.

OBJECTIVES

Prof. Neugebauer and Prof. Inguscio met in June 2019 in Rome, talking about possible fields of cooperation and in that context signing the MoU as a renewal of the relationship between Fraunhofer and CNR. Next to

AI, Quantum Technology, Industry 4.0 and Hydrogen Systems, Cultural Heritage was one of the discussed topics during this meeting and is even instanced in the preamble of the 2019 MoU:

[…] The Parties have already collaborated in several EU-projects and wish to extend their joint activities for example but not limited to the fields of: Smart Agriculture, Cultural Heritage, Industrie 4.0. […]

To further enhance their collaboration the parties agreed to promote research activities of mutual interest and develop a closer relationship by joining forces in innovation and technology transfer as well as in education and training. In pursuing these joint objectives and through active dissemination the parties also intend to increase the capacity to attract funds and resources from third parties.

GOVERNANCE

Separate project agreements will regulate each joint activity and detail all aspects necessary for the realization. However, the MoU – next to general regulations concerning IP, Confidentiality, Personal Data, Trademarks/Logos etc. – settles the governance of the collaboration on a rather concrete and operational level. It is stated that there shall be established a Joint Steering Committee with (at least) four representative members of each Party: one person from each central office and the others covering the research fields in which cooperation activity is carried out or planned. As an expert for cultural heritage on the CNR side Prof. Costanza Miliani was nominated, a senior research scientist and Head of the Heritage Materials Science Group at CNR-ISTM (CNR Institute of Molecular Science and Technologies) in Perugia. On behalf of Fraunhofer Dr. Ralf Kilian, head of the Cultural Heritage Unit at the Fraunhofer Institute for Building Physics IBP, was appointed to be part of the Steering Committee. The Committee is required to meet at least once per semester and has several tasks, such as to plan, coordinate and document the collaboration activities. The first meeting was held in January 2020 in Rome and focused on planning joint applications for both internal resources and external funding, and on developing topics for concrete projects where the skills and resources of both sides could be synergized.

CONCLUSION

A MoU is the expression of a convergence of will between two or more parties and as such marks the starting point of a process of actions – of workshops, joint projects, further agreements – that in the long term may even lead to a comprehensive contract for closer cooperation. In this sense a Memorandum of Understanding can be understood as a call to action, not only in the common and somehow static translation of the expression memorandum as "something to be remembered", but in the more future-oriented, propulsive sense of the Latin word memorare that also means "to urge" and "to warn". One can be positive regarding the field of Cultural Heritage Research because of the commitment and the readiness demonstrated by the participants of the German-Italian Scientific Symposium "Cultural Heritage in Crisis" at Villa Vigoni. It was here that it became evident that the MoU will soon be filled with life rather than simply being filed away as yet another document.

Despite the MoU not being a binding contract, it is still a written declaration of the will of both parties to collaborate and as such it can and must be utilized for further actions – it may provide the basis and justification for funding requests, enable numerous project realizations in the future and altogether form international collaboration possibilities on a structural and more comprehensive level.

CNR and Fraunhofer are two important players in the European scientific landscape and for them to join forces to advance Cultural Heritage Research and Preservation, constitutes a great chance for this field. In this context, the German-Italian Scientific Symposium at Villa Vigoni, which was made possible through funding by the German Federal Ministry of Education and Research, has been the first important step on this path towards a European collaboration in Cultural Heritage Research.

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IMPACTS OF CLIMATE CHANGE – NEW CHALLENGES AND SOLUTIONS

HOW CAN CLIMATE MODEL INFORMATION BE USED TO BETTER PRESERVE CULTURAL HERITAGE IN TIMES OF ANTHROPOGENIC CLIMATE CHANGE

Lola Kotova

The IPCC special report "Global Warming of 1.5°C" provides clear scientific evidence that global warming is likely to reach 1.5°C between 2030 and 2052 if warming continues to increase at the current rate [1]. Major impacts of rising temperature on natural and human systems are already observed [2]. Archeological sites, museum collections, historic buildings and structures might be affected among others by rising sea level or storm surges, freeze/thaw cycles or more rapid wetting and drying cycles. In this regard, continued preservation of cultural heritage requires the best available scientific information on climate change.

The increase in global average temperature since the mid-20th century can most likely be attributed to the observed increase in anthropogenic greenhouse gas concentrations (GHG). The time-dependent (over centuries) climate response to changing concentrations of GHG can be studied by using Earth System Models (ESM) with a representation of different forcing, e.g. concentrations or emissions of GHG [4]. ESM are the most advanced and complex models of the Earth system. They provide not only a large-scale picture of climate signals but also the interactions between different components of the system.

To investigate the impact of climate change on cultural heritage, the data with high spatial resolution are required to identify climatic and climate-driven differences across the selected sites. In this regard, two different principles of transferring the information from a global ESM to a regional scale have been developed. These are statistical and dynamical downscaling. While statistical downscaling techniques connect the climate change signal provided by ESM with observations from measurement stations, dynamical downscaling uses high resolution three-dimensional regional climate models (RCM). Addressing uncertainties in climate projections resulting from structural differences or parametrization of the models and variations in GHG emissions, a multi-emission-multi-model ensemble is essential to achieve scientifically robust information on possible ranges of future climate change.

The most recent ensemble of regional climate change projections for all land regions world-wide has been produced by the CORDEX initiative, launched by the World Climate Research Program (WRCP). Among others, EURO-CORDEX [www.euro-cordex.net] is part of the international network of climate modelers that consistently contribute to projections of climate change over Europe across different spatial scales. Furthermore, for a number of European countries the Dutch (KNMI'14), Swiss (CH2011), French (DRIAS) and UK (UKCP09) are four of the most well-resourced of the recent climate projections. Using dynamical and statistical downscaling, the ReKlies-De project generated the current largest database of high-resolution regional climate model data for Germany [5].

All these data can be served as an input for different studies of climate change impacts and adaptation options.

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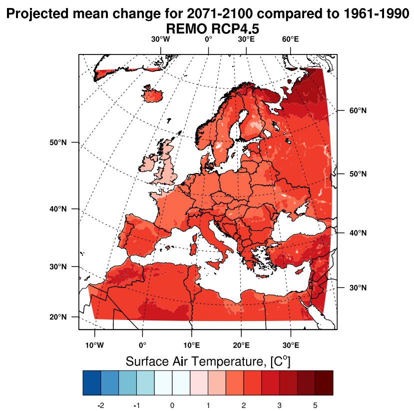
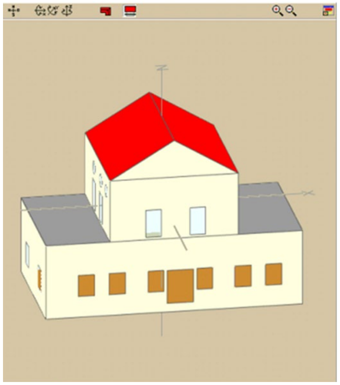
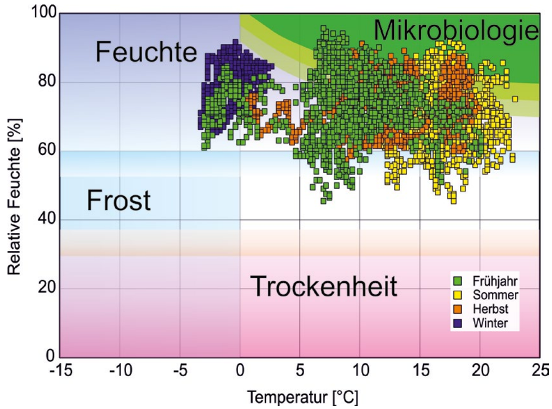
Climate information

Building Simulations







Assessment of damage potential

Figure: From climate models to works of art in buildings

The first attempts to apply climate model information to preserve cultural heritage in times of anthropogenic climate change were conducted in two large scale integrated projects. These are Noah's Ark (www.noahsark.isac.cnr.it) and Climate for Culture (www.climateforculture.eu). Noah's Ark studied the impact of the climate change of outdoor environments on typical materials, structures and infrastructures of built cultural heritage. The results presented in the project's atlas clearly indicate that serious impacts of anthropogenic climate change on cultural heritage are likely to take place, especially towards the end of this century [6].

In the Climate for Culture project, the regional atmosphere model REMO in its hydrostatic version (REMO 2009) has been applied [7]. In addition, REMO was run on the horizontal grid of 12.5 km (EUR-11) with a 27 vertical level at the EURO-CORDEX domain.

A control simulation for the recent past (1961 to 1990) was forced with observed GHG concentration. Two scenarios were considered to project the concentrations of anthropogenic GHG for near (2021 to 2050) and far future (2071 to 2100). These are the A1B emission scenario [11] and the representative concentration pathway RCP4.5 [4]. The results of these simulations show that the annual mean of near-surface air temperature statistically significantly increases for the entire model domain in all simulations for near and far future [8, 12]. The projected spatial patterns of the mean near-surface air temperature are very similar in both scenarios with stronger annual mean warming in Southern and Northeastern Europe. Despite near-surface air temperature rising everywhere, the REMO model does not simulate a clear tendency in precipitation for the entire Europe. The results show that the general tendency is enhanced precipitation for most regions in Central and Northern Europe and decreased precipitation in the Mediterranean region (up to 40 % over the Iberian Peninsula for A1B).

For coastal regions relative sea level change is an important feature. Here, a dynamical downscaling of the RCP4.5 scenario was performed with a regionally coupled climate model REMO/MPIOM [9]. The results indicate, that changes in ocean circulation and the inverse barometer effect lead to an enhanced (compared to the global mean) sea level rise of more than 10 cm in the North Sea and approximately 20 cm in the Baltic Sea at the end of the century [12].

Nevertheless, climate model information cannot be treated as an isolated topic and should be effectively embedded into the real world of cultural heritage (see Figure). For example, in Climate for Culture a novel approach of offline coupling of climate modelling with a building simulation was developed. By doing so, future indoor climates and energy demands were calculated not only for selected buildings but also on a Pan-European level and thus suitable mitigation strategies were identified.

Furthermore, the research community of Climate for Culture was very diverse. Climate modelers to conservation scientists, architects and heritage managers and the required meteorological variables were all used for different impact studies and therefore risk assessments varied strongly. In this context, it was required to have easily understandable and accessible climate model information.

For this, relevant climate variables have been selected to estimate how different types of buildings respond to the outdoor climate change and how heritage artifacts inside the building will be affected [10]. The analysis was performed not only for the case studies representing the historical buildings, but also for 474 locations, that are equally distributed over Europe. As for the results, 55,650 high-resolution thematic maps have been produced to highlight the potential changes and related risks for a number of key materials, building types and deterioration mechanisms for the near and far future. The maps of Europe can be further used for climate change impact assessments and for planning adaption and mitigation measures in view of preventive conservation or other applications, e.g. human health, energy consumption, cultural tourism.

Although the project Climate for Culture has made a significant contribution to understanding the effects of anthropogenic climate change on cultural heritage across Europe, there is still a demand for translating climate information into practical applications. In this regard, the development of climate services for cultural heritage is of high importance. The European Road Map of Climate Services [13] facilitates 'the transformation of climate-related data – together with other relevant information – into customized products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions and any other service in relation to climate that may be of use for society at large'. The experiences gained in Climate for Culture demonstrate the need for an open dialogue between the research communities involved and users of climate information in the cultural heritage sector. Bringing together climate scientists, conservation scientists and heritage managers as well as SMEs working in the field of conservation helps to exchange existing knowledge and to translate all available information into adaptation and precautionary measures to protect in a sustainable way cultural heritage in times of anthropogenic climate change.

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HERITAGE RESILIENCE AGAINST CLIMATE EVENTS ON SITE – HERACLES PROJECT: MISSION AND VISION

Giuseppina Padeletti and HERACLES Consortium

CULTURAL HERITAGE AND CLIMATE CHANGE: HERACLES OVERALL APPROACH

Europe's significant cultural diversity together with exceptional ancient architectures and artefact collections attracts millions of tourists every year. These global assets are of incalculable value and have to be preserved for future generations. The effects of floods, extreme wind storms or rains on these assets are clearly identifiable but it should be worth to note that all these effects are seriously amplified on ancient and fragile assets where advanced techniques, commonly used for modern buildings and structures, cannot be applied to preserve their originality.

In the previous years we have seen the world face the effects of climate change. This has required interventions in a variety of fields ranging from the environment, agriculture and also to land protection.
The cultural heritage (CH), particularly in Europe and the Mediterranean basin (where many of these important and prestigious monuments and sites are located), must also face this emergency: in many situations, the presence of meteorological extreme events can severely damage historical buildings and works of art. Effects on CH assets deriving from natural and environmental hazards related to climate change (CC) are varying and complex. Environmental and natural hazards can cause damage or destruction of CH assets through various natural catastrophic processes; this entails the necessity to consider preservation and protection issues. Different types of natural hazards may have different impacts on CH assets. Sites of cultural significance can be affected by catastrophic events of both endogenous (earthquakes, volcanic eruptions, tsunamis) and exogenous origin (landslides, floods, ground collapses, wildfires, cyclones), for which little or no warning has been received. However, these sites may also suffer from processes, which are not catastrophic in the conventional sense but their cumulative effects and aging in the long term may have a highly adverse impact. These include ground subsidence, especially in coastal settings, accelerated weathering of building stone, sandstorms, and the recession of coastal cliffs.

CC impact is functioning as a risk multiplier to already existing problems and not only increases but accelerates them. Climate stressors can directly affect CH buildings, monuments, and settlements. Sea level rise threatens coastal assets with increased erosion and salt water intrusion. More frequent and intense storms and flooding events can damage structures, which were not designed to withstand prolonged structural pressure, erosion, and immersion. Changing precipitation patterns can quickly erode assets built for a different climate. Also, stability issues can arise since during extreme rainfall events, the increased ground soil moisture can reduce the physical stability and thus trigger landslides. Warmer temperatures and increased humidity can damage building materials and structures by encouraging rot, pest infestations (e.g. wood materials), and erosion.

Several key indicators are used in the scientific literature to describe CC which include: greenhouse gas composition (in particular CO_2), outdoor

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surface temperature, precipitation (rain, snow, hail), snow cover, sea and river ice, glaciers, sea level, climate variability and extreme weather events over time. The most significant global CC risks and impacts on CH are well known and an example is reported in the table Principal Climate Change Risks and Impact on CH of Working Document 30 [1]. In the previous years, many European projects have addressed these problems [2].

In order to address all of the above challenges, the concept underpinning the HERACLES project is to propose a holistic, multidisciplinary and multi-sectorial approach with the aim to provide an operative system and eco-solutions to innovate and to promote a strategy and vision of the future of CH resilience. In this framework, HERACLES proposes a novel systematic approach to ensure the sustainable management and protection of the different CH typologies in not only European but worldwide territory with respect to the CC impacts. The approach benefits from a multidisciplinary methodology that bridges the gap between the two different worlds: the CH stakeholders and the scientific/technological experts, which are both involved in the project. The Project was funded by the EU within the Horizon 2020 research and innovation programme under grant agreement no. 700395, and coordinated by CNR (National Council of Research of Italy) [see HERACLES website].

One of the key elements of the HERACLES systematic and interdisciplinary approach is the identification of the needs of the end-users/stakeholders. The proposed solutions are based on:

- an integrated dashboard populated by heterogeneous tool boxes based on sensing/environmental technologies (at wide and local scale) coupled with diagnosis/structural analysis methodologies for a multi-temporal/multi-spatial monitoring of the CH asset;
- an ICT platform able to provide a situational awareness about the CH status and support the short and long term decisions of the stakeholders involved in CH site management for risk reduction;
- innovative solutions and materials, for the economically sustainable maintenance and remediation, preserving the integrity and improving the social value of the CH;
- guidelines and protocols not only for the preservation of the CH site but also able to manage the overall risk cycle management;
- methodologies and strategies aiming at improving the awareness of the social and cultural value of CH from the different communities.

Specifically, the integrated observation and monitoring of the CH assets was planned and organized from both macro and micro scales:

i. a macro-level to gain a wide vision of the site and to detect and predict the long term CC impacts and
ii. a micro (local) level through monitoring and diagnosis of buildings and artefacts present on the sites.

HERACLES will allow to constantly monitor these CH assets and their surroundings combining data collected by the different observational platforms (satellite, aerial, traditional as well as innovative in-situ sensing technologies).

An innovative flexible and scalable ICT (Information Communication Technology) platform is being designed and developed in order to integrate, correlate and manage the data collected over a long period of time from external sources. This is then intrinsically related to CH object behaviour and to its physico-chemical status in terms of:

- integration with historical information of the site (including past critical events);
- integration of different monitoring data to obtain an on-line updated situation of the site and its surroundings;
- vulnerability and risk evaluation by means of advanced modelling (geomorphological site modelling, climate change and extreme weather condition modelling, anthropogenic pressure modelling);

- integration of information about the structural and physico-chemical status of materials and site;
- visualization (3D) of information through maps and 3D models;
- situational assessment, information for awareness building and decision support system (including warning and alert messages).

Such structured information is crucial for the development of effective solutions for the mitigation and remediation of CC effects.
In particular, by taking into account the complete set of information derived from the platform, HERACLES includes also activities related to:

- new environmentally sustainable materials and solutions for innovative, fast and effective maintenance and restoration of damaged sites;
- new procedures to respond to operational requirements for heritage sites suffering CC risks and damaging effects.

HERACLES METHODOLOGY

A flow chart of the HERACLES methodological approach is depicted in the Figure, with the analysis to be carried on. As previously mentioned, it consists of the integration of innovative and complementary elements aimed at monitoring, preserving and valorizing CH sites affected by CC events and progressively increasing risk. The multidisciplinary method and composition of the partnership allows focus on each component of the project and, at the same time, to carry out a strong and effective integration and systematic effort. This combines the progressive steps starting from the site analysis and monitoring, up to the development of new operative solutions for restoring and minimizing CH damage risk.

Italy and Greece are amongst the countries most susceptible to cultural emergencies and in this context the HERACLES decision was not to focus on the most well known locations, which are already the object of attention but on minor historical centers/areas as they represent the essence of these European countries. These places of interest characterize

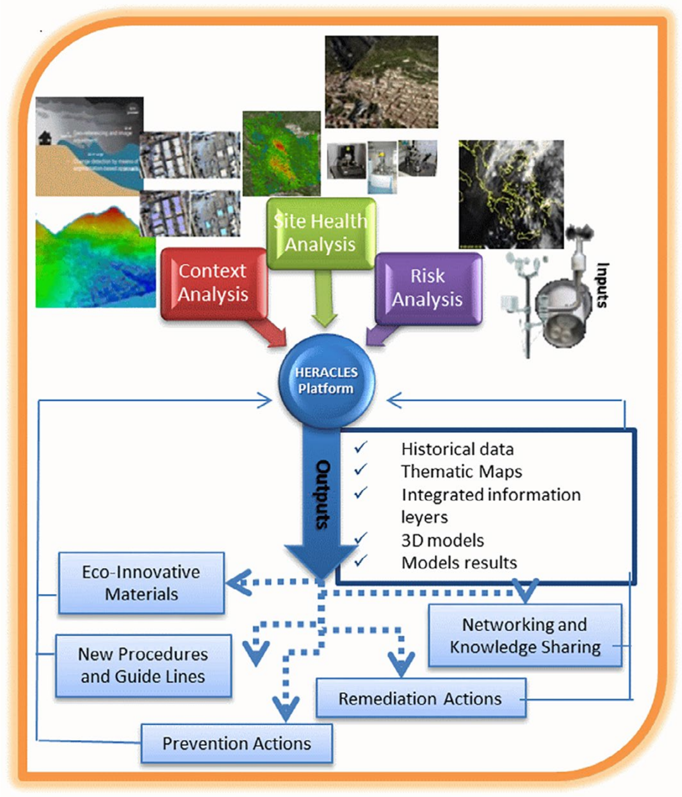

Figure: Procedural scheme of the HERACLES solution approach

European countries' cultures, identities, economies and people's livelihoods, however, despite this they are often ignored and not taken into account. The Sea Fortress of "Koules" is located in the port of Heraklion and is symbolic of all monuments and sites facing the risk of hazards from CC, such as significant impact from the sea (rising sea levels, increasing intensity of extreme weather phenomena that combines with

air and land associated hazards and also increased salinity are accelerating corrosion and deterioration of materials and structures). The Minoan Palace of Knossos is a spectacular Bronze-Age archaeological citadel representing the ceremonial, economic, social and political centre of the first European civilization of the Mediterranean basin, namely the Minoan civilization, and this suffers from the sea-linked effects.
Gubbio, on the other hand, wants to represent all the historical monumental towns in Italy and Europe, which were conceived and built in the past, following criteria when the climate conditions were very different from nowadays and that now suffer the present CC effects, which would endanger their safeguard, particularly the hydrogeological instability (heavy rains, floods, landslides), moreover this is worsened by the seismic risk. In this regard, the Consoli Palace and the Town Walls are object of investigation.

PROTOCOL DEFINITIONS

Activities carried out in the HERACLES framework were directed towards the definition of protocols for each monument of interest in HERACLES test-bed on the basis of its structural and material preservation state. To this end, the available (satellite, airborne and in situ) sensors together with a number of laboratory-based material characterization instruments and techniques are considered to be able to give relevant information to assess the weathering state and the degradation processes of the investigated materials.

To assess their efficiency and validity, the defined protocols were verified during the demonstration activities of the project. The final scope was their generalization for a wider applicability.

ECO-INNOVATIVE MATERIALS

The partner background and the experience in the field of CH in studying ancient materials are addressed to the assessment of degradation phenomena affecting the CH asset and to study and design innovative protection solutions aiming at site proper preservation; also new materials to safeguard the site from atmospheric agents are developed and implemented in HERACLES. These innovative materials and accompanying solutions embrace the concepts of smart design, eco-friendliness, and multi-functionality, always with respect to the guidelines and ethics of CH restoration as indicated by the articles 9 and 10 of the Venice Charter [3]. These experimentations generated sufficient information related to the definition of sustainable best practices and to guide restorers, conservators and people that actively operate on site.

CONCLUSIONS

The HERACLES project has the ambition to design, implement, validate and promote a full innovative systematic strategy to the CH management and protection in order to increase CH resilience with respect to CC impacts. The HERACLES key point is the multidisciplinary and collaborative approach based on a large set of expertise present in the Consortium and Advisory Board, such as CH Domain Experts and Technological and Problem Solving Expertise.
HERACLES presents an innovative perspective, with many strengths and advancements beyond the-state-of-the-art:

1. An innovative context analysis based on an approach integrating climate and weather conditions, anthropogenic pressure and the modelling of socially impactful activities.
2. Multi-dimensional observation capability based on the integration of sensors (mostly non-invasive) acting from different platforms (satellite, airborne, RPAS; ground based) in order to enable a multi-scale (spatial and temporal), multi-sensing, multi-depth monitoring and diagnosis.
3. Multi-scale modelling capabilities to support the different requirements of HERACLES based on data processing and fusion from multiple and heterogeneous sources.

4. Integration of the results from multi-source information in the structural models for an improved vulnerability assessment of the single element of a CH site.
5. Imaging and mapping techniques for material characterization at a micro and macro scale, with the final aim to assess the preservation state and the material functionality.
6. Novel solutions and materials for CH preservation and protection.
7. An advanced scalable ICT platform for efficient use and integration of multiple information sources as well as a provision of the HERACLES services to the stakeholders.
8. Guidelines and protocols for sustainable long-term maintenance as a key element for adaptation strategy.
9. Operational procedures for risk management and crisis mitigation.

Further details on the HERACLES activities and achievements can be found in the technical reports and at: www.heracles-project.eu.

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   - RESIN: https://resin-cities.eu/home/
   - RESCCUE: http://www.resccue.eu/resccue-project
   - URBANFLUXES: http://urbanfluxes.eu/
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LONG-TERM MONITORING OF CLIMATE CHANGE ON HISTORICAL BUILDINGS

Chiara Bertolin

INTRODUCTION

Immovable built cultural heritage (BCH) constituting a diversified variety of historical buildings and remains is globally threatened by climate changes. In fact, there is a general consensus [1][2][3][4][5][6] on a range of local climate parameters and hazards which can damage the BCH significance as a primary impact result of global climate change patterns. These climate patterns are: Increase in air temperature (T), increase/decrease in precipitation with flooding effects or higher risk of fire and damaging wind, sporadic heavy precipitation, flooding and sea level rise (SLR), storm and hurricane events, erosion, melting of permafrost and increased intensity of freezing-thawing cycles, and people's perception of climate change impacts with repercussions on cultural landscapes, as well as economic and social pattern changes. Today, the impacts of climate change are predicted effectively. Information like forecasts, climate reconstruction, and the data collected in the ongoing recent climate normal period (i.e. 1991-2020), with respect to past data sets (i.e. 1961-1990), are indicating a riskier future in the frame of climate change hazards. Conservators and cultural heritage managers, having assessed climate hazards that may endanger their region, site, and historic buildings, should retain a clear, updated and detailed understanding of the expected climate change impacts in the future.

As described above, from both the occurrence of extreme temperature events (i.e. heat and cold waves) and intense rainfalls, cultural heritage managers could expect impacts such as progressive abandonment of historic buildings because of poor comfort parameters or at the very least an increase in energy use demand. All these impacts can lead to a partial destruction, progressive or immediate loss of cultural heritage coupled with a related decrease in touristic attractiveness and activities. Despite the progress in scientific research and understanding of climate change hazards disseminated through the well-known IPCC reports (IPCC, 2018 [7]), one main limitation still remains: our ability to predict and manage hazards as well as the effects (or impacts) of climate change well in advance. This happens because they are both factors constituting risk. The risk is far more complex than hazard itself because it is determined by the accuracy of: hazard prediction, exposure prediction, sensitivity, and adaptive capacity prediction.

The predictions of a riskier future however do not prevent us from planning long term strategies to achieve a modification of that forecasted future, and thereby transforming it from a riskier future to an equally or less risky future. To do this, we might follow the established long-term roadmap of implementing good practices day by day. Some examples of good practices are as follows:

(1) to reduce hazard: create, implement and follow policy of climate change mitigation, to make long term plan for urban design, to plan a more rational use of resources;
(2) to reduce exposure: to plan in advance better land use, to more effectively plan and manage urban expansion, guaranteeing constant monitoring;

(3) to reduce vulnerability: to establish/facilitate social safety nets as well as rescue plans; to constantly and on a long-term basis, monitor and assess material sensitivity; to create tools and policies for increasing resilience and adaptive capacities.

The theoretical understandings of risk assessment can help in planning a long-term change in the management of cultural heritage preservation, which may be able to account for the probability and consequences of climate change beginning at an early stage. However, to be effective in planning for change we have to understand and accept the following:

- Rapid environmental changes are now the new climate norm because many variables have exceeded what has been understood to be the historical range of variability.
- New conservative goals have to be set, because it could happen that the current procedure of preventive conservation may no longer be adequate due to the new material sensitivity to changed environmental conditions.
- Although there are emerging areas of consensus thanks to continuous improvements in projections, the uncertainties associated with climate change are still significant.
- Climate adaptation should be viewed as an ongoing process rather than as a process that is simply adjusted to another new static regime.

EMERGING CONCERNS ABOUT THE VULNERABILITY OF CULTURAL HERITAGE SITES

Although previously the determining factor to predict and control vulnerability at cultural heritage sites was exposure; nowadays, becoming effective in risk management and translating theoretical risk information into action, we must focus our attention towards emerging concerns about vulnerability control as sensitivity (i.e. the "new or modified" sensitivity of historical materials/site) and adaptive capacity (of nation/region/community/heritage managers). In fact, a better understanding of these two parameters can improve the model capability for (1) assessing acceptable, tolerable and intolerable risks of cultural heritage loss and (2) estimating the social implications when specific planned adaptation options are not implemented within the expected temporal deadline because of political, administrative, management or decision-making issues, in specific areas. In this worst-case scenario, any adaptation option (even the most costly and originally effective one) will be no longer successful because of the intolerable situation of risk after implementation. It becomes fundamental that climate change adaptation efforts keep risks to thresholds of tolerable risk.

An example from scientific literature

An interesting example of the importance of producing scenarios that consider spatial and temporal adaptation option deadlines for effective reduction of climate change vulnerability is provided by the work of Reimann et al. published in 2018 in Nature Communication [8]. They calculated two risk indexes (i.e. flood risk index>6.5 and Erosion risk index >7.5) under the high-end SLR scenario for UNESCO Cultural World Heritage Sites located in the Mediterranean Low Elevation Coastal Zone (LECZ) based on the flood area and depth from 2000 to 2100. The outcome is a flood-risk map that provides to the stakeholders practical information to move towards action. These risk maps provide information about temporal adaptation threshold limits, in essence a point of no-return after which there is the "intolerable" risk of cultural heritage loss. Reimann et al. reported that in the recent past, such intolerable risk limits have been already surpassed in Aquileia, Venice, Ferrara (Italy); this year's predictions (2020) have been surpassed in Split (Croatia); and very soon (2050) Dubrovnik (Croatia) is at risk; 2060 Valletta (Malta) and later on (in 2070) Ephesus (Turkey). The latest extreme events that have occurred in November 2019 in Venice, have sadly given reason to this research outcome. The research outcome highlighted Venice over 1 year ago as being at the point of no return for the implementation of

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any adaptation option (e.g. the Experimental Electromechanical Module MOSE Project).

Overview of the most common adaptation actions which can be implemented on cultural heritage sites

This paper provides an overview of the most common adaptation options which stakeholders and heritage managers who work with the protection of cultural heritage, can implement. These findings are presented visually in Figure 1 and described in the following:

- Monitoring, Document and Maintenance options are central in supporting any decision to establish hard or soft barriers and in assessing whether or not they are needed in the first place. Maintenance Actions reduce condition decay rates and keep the integrity for historic buildings. As a general best practice suggestion, carrying on long term monitoring and documentation reporting allows conservators not only to constantly know the conditions of cultural heritage site conservation or effectively plan the building maintenance and the management of the indoor environment, but also to have data for assessing the climate change impact (see Haugen et al. 2018) [9].
- Core and Shell Preservation options are implemented to improve conditions of historic buildings and maintain their integrity. However, they are insufficient to reduce vulnerability.
- Elevation, Relocation, or a Mix of the two options (which also may include core and shell preservation) can reduce vulnerability of historic buildings, and the conditions of the historic buildings could be improved to a higher rating classification. These adaptation options can include the introduction of a buffer zone reducing/controlling the flooding. They can include nature-based solutions (e.g. trees and other vegetation which slow and absorb flood waters); or they can be artificial (e.g. construction of sea defense structures like dikes).

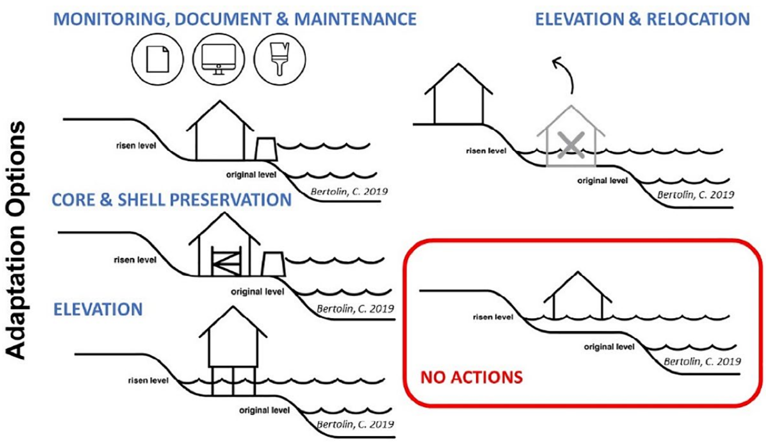

Figure 1: Climate change adaptation options identification to protect the built cultural heritage

It is evident that the ability to implement one or more of these options is mainly affected by budget scenarios of heritage institutions or boards that are in charge of preserving the cultural heritage site. However, what is also necessary for heritage managers is a clear vision of what will happen if they do not take measures to adopt any adaption options (see red square in Figure 1). In such a case, the risk of complete loss of the cultural heritage site/ buildings will soon become reality. Therefore, the final cost and impact of not taking action is to surpass the temporal threshold of intolerable risk with no possibility of returning back to a previous status. Clearly, this scenario presents an unacceptable cost to present and future generations.

THE NORWEGIAN CONTRIBUTION TO THE EMERGING CONCERNS ABOUT REDUCING CULTURAL HERITAGE SITE VULNERABILITY

The SyMBoL Project – Sustainable Management of Heritage Buildings in a long-term perspective

This project coordinated by the Norwegian University of Science and Technology (NTNU) aims to resolve the debate about the appropriate environmental conditions in which to preserve, in this time of climate change, the most precious heritage buildings in Norway, i.e. the stave churches and their distempered paintings. The research activities include monitoring the sensitivity of aged and decayed materials constituted by pine wood substrate and its decorative layer characterized by a porous, usually matte, surface. The novelty of this project is the use of the acoustic emission (AE), non-destructive technique (NDT) for both purposes of structural health monitoring and as a real-time monitoring tool to record climate-induced mechanical decay on wooden elements inside the stave churches. The results of this research [10] have proposed a characterization of residual and newly-formed salts, whose presence and amount have been related to differences observed in the acoustic emission amplitude which were monitored on four different structural elements in order to obtain information about their state of conservation. In addition to the monitoring campaigns in real case studies, the SyMBoL project deals with laboratory tests with the use of nano-indentation and the same AE technique used in the field. These NDT are implemented for studying the accumulation of climate-induced mechanical damage in original wooden samples or in samples mimicking original elements to obtain their mechanical properties (as poisson ratio, moduli of elasticity, fracture toughness).

The MOV Project – Environmental monitoring of the impact of climate change on protected buildings

The second Norwegian contribution to the emerging concerns about reducing the vulnerability of cultural heritage sites is provided by research conducted within the framework of the international MOV project coordinated by the Norwegian Institute of Cultural Heritage Research (NIKU). The project is strictly focused on long-term monitoring of climate conditions indoors and outdoors and on determining the climate change impact on building materials (both in terms of intensity and rate of decay) from the standard weathering within the expected material service life. The case studies are spread all over Norway, some of which can be found in extreme environments, such as subarctic climate conditions or north of the arctic circle with continental subarctic climates. The type of buildings monitored are: medieval stone churches, medieval stave churches, and medieval wooden buildings. This project is novel because of researcher's use of domain specific indicators for monitoring climate change effects and the work done to create and establish a user friendly management structure to allow the project to be implemented long term. The data collection structure reported in Figure 2, besides recording of environmental monitored data, includes the compilation of a range of general common information, such as: protection law categories, date of building construction, and future climate change scenarios.

In the MOV project monitoring campaigns a special tool called climate panel – constituted by data-loggers and control material mounted on a base – is used. It is located within a building in the most threatened place with the highest level of moisture. In such a case the climate panel can be considered a sort of indicator of climate-induced decay on a historical building and is useful to acquire information about the adaptation threshold limit at the case study. In each monitored building the parts that are likely to be the most (northeast corner, climate panel location) and least (southwest corner) threatened by moisture have been identified both on the ground level and at the highest levels in the buildings.

The climate panel continously monitors T, RH and moisture content (MC). While biological decay is monitored through the analysis of a certain number of standardized material specimens or small blocks used as test (control) material to provide an early warning about conditions that favor the proliferation of microorganisms. In addition, environmental parameters and the MC measured by an electrical resistivity probe (inserted into a specimen of the same material that the meter is calibrated for) can also provide a biological decay risk assessment in continuous. All climate panels must have a set of standard blocks of a single type of material but may also have additional materials adapted to issues specific to the location. The specimens are evaluated each time (i.e. once per season/month depending on the case study) any subsequent registration is made in the building through visual inspection by recording visible growth or other visual changes in the control material. The evaluations are performed through photography, sampling and analysis of the surface layer of the block closest to the logger at the first follow-up and then are repeated for block 2 from the logger for the second follow-up, and so on.

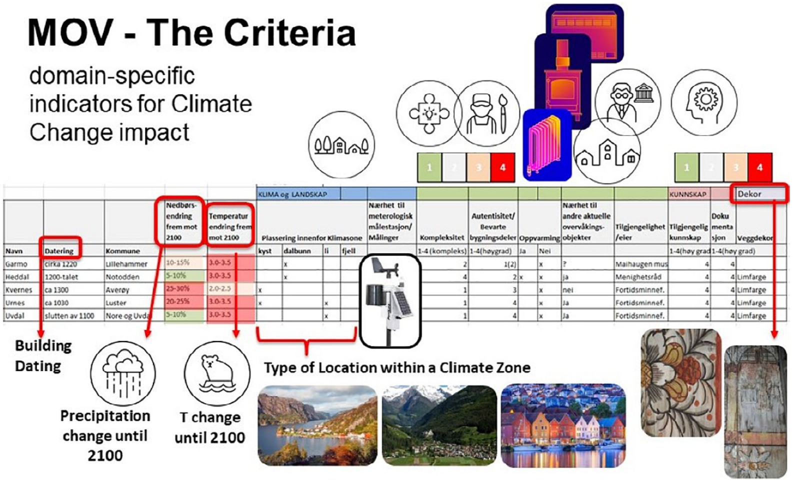

Figure 2: Domain-specific indicators in the environmental monitoring of the impact of climate change on protected buildings

Monitoring using climate panels makes it possible to define the damage from the zero status (i.e. a period used as reference which may be the conservation conditions evaluated over the recent past or at the beginning of the monitoring campaign) and symptoms of the moisture impact on building materials (e.g. progress of damage, new damage, and symptoms) in relation to the zero status. The MOV project's preliminary results have highlighted that the most important climate-related decay observed until now is the biological decay on wood. While at landscape level, the project has observed a faster increase in flooding and landslides than the scenarios forecasted just a few years ago.

CONCLUSIONS

This intervention clearly states the importance of knowing all the components of climate change risk scenarios (i.e. Hazard, Exposure, Sensitivity, Adaptive Capacity) for the cultural heritage site/ cultural heritage landscape under examination in advance. This type of assessment includes understanding the actual implemented protocols on: conservation policy, cultural heritage site management and planning strategies. Ongoing climate change may require the modification of conservative goals that worked effectively over the past decades, but that are now less effective because of the change in cultural heritage material sensitivity and exposure. On the other hand, the urgency of setting adaptation threshold limits as well as a range of feasible climate adaptation options require a complete revision and redefinition of conservative goals. These goals should be easily measurable, revisable, achievable, relevant and time-bound because of the situation of continuous transformation.

Therefore, a careful knowledge-based approach is the only method that cultural heritage owners, managers, heritage scientists and conservators can adopt in order to embrace "climate change related uncertainty" and not to succumb to "analysis paralysis," but instead to keep adaptation options open to potential future scenarios. The pillars of this knowledge-based approach are the collection and understanding of data and information on hazards throughout the region/area where the cultural heritage site is located both in terms of climate conditions over the recent past and the forecasted future. This understanding summed up in the continuous monitoring and analysis of cultural heritage sites will be of aid to assess any change from an initial temporal reference point (i.e. the zero status) and in general in the early detection of cultural heritage site/ material vulnerability.

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DIGITALIZATION OF CULTURAL HERITAGE – NEW TECHNOLOGIES TO PRESERVE CULTURAL HERITAGE

THE CURSE AND BLESSING OF THE DIGITISATION OF CULTURAL HERITAGE

Paul Bellendorf

INTRODUCTION

Cultural Heritage is an essential part of our society's identity. Therefore, it is imperative that the preservation of Cultural Heritage for society is highly prioritised, this is best achieved when divided into three basic tasks: documentation, preservation and research. In recent years, the possibilities offered by digitisation have led to the development of new methods and procedures that have significantly changed the way cultural assets are handled. Digitisation has paved the way for the three areas of activity in a way that has yet rarely been achieved. The following three tasks highlight some of the possibilities through digitisation but also address some issues that can arise.

DOCUMENTATION

By means of digital methods, existing and new data stocks can not only be made accessible, but also presented and visualised in previously unfeasible contexts. For example the now ubiquitous and omnipresent digital photography facilitates the high-resolution acquisition and documentation of data stocks such as archives or works of art. The digital methods enable not only a time-optimized but also a quality-assured workflow. The previously necessary developing of films is eliminated. A quality control on the screen is possible immediately after the recording. With 3D scanners a digitalisation of three-dimensional objects is possible. Depending on the size of the object and the desired degree of resolution, various methods are available today. Terrestrial laser scanners are particularly suitable for recording buildings, ensembles, cultural landscapes or archaeological excavations. These can quickly detect objects with millimetre precision. Smaller objects such as architectural details or sculptures can be digitised with hand-held structured light scanners. Depending on the type and design of the device, accuracies down to the sub-millimetre range are possible. Using the method of image-based modelling, object digitisation can also be carried out by using many photographs. From a sequence of images, software can calculate homologous points from the overlapping areas of the images and can thus extract three-dimensional information from an image package. However, it is not only data acquisition that has been revolutionised by digitalisation, new possibilities also arise for the storage and visualisation of data. For example, the University of Passau and the University of Bamberg are currently developing an information system under the title "Monarch" (https://wp.uni-passau.de/monarch/), which specialises in the spatial digital documentation of historical buildings and geographical areas. This allows semantic information to be assigned to the building structures. As a result, all information belonging to the building, such as plans, file notes, mapping, etc., can be stored in an uniform and structured system. The system is already in use at several large churches, e.g. at Bamberg Cathedral, Passau Cathedral and St. Lorenz in Nuremberg, where it facilitates the storage, search and cross-linking of construction-related information.

The digitisation of art and cultural assets has become a business field for various disciplines. However, these are often not adequately trained

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in the special requirements for handling cultural heritage. Surveyors, for example, are specialists in the recording of buildings etc., but they are not trained to record details specific to monuments, such as junctions in roof constructions. Due to the intricate and small-scale structure, these can be recorded poorly or not at all with digital methods. Therefore, it is required that a well-founded interpretation and evaluation of the findings by a monument expert occurs.

PRESERVATION

Digitisation has also provided unprecedented opportunities in the field of preservation. With the already mentioned methods of 3D-digitisation, contactless and dimensionally accurate virtual models can be created. However, these do not have to remain in the virtual world. For example, using 3D printers or 3D milling, these virtual models can be turned back into real objects. The starting point for this must be a model that is set to the desired scale. It is important for the models to be "waterproof", therefore they must not contain any holes. If the scan of the object cannot be completed, e.g. due to undercuts, these gaps must be closed automatically or with human assistance.

The models thus prepared can then be the starting point to produce a three-dimensional object. In 3D printing, the virtual model is divided into individual parallel slices. In analogy to a 2D printer, the first layer of the printing material is printed on a base. Then the table is moved in z-direction by the height of the printed substrate and the next layer is printed. Thus, layer by layer, a three-dimensional object is created. This additive process is contrasted with the subtractive process. Here, material is removed from a block, e.g. of stone, by means of a milling machine until the desired geometry has been exposed from the block.

With the 3D processes, copies of real existing sculptures or construction elements can be created. At the Adam's Gate of Bamberg Cathedral, the original sculptures, which had been severely damaged by environmental factors, could thus be brought into the interior and thus protected and preserved for future generations. Instead of the originals there are now copies made using digital methods.

The number of copies is not limited. The digital methods do not distinguish whether a copy is reproduced only once or a thousand times. For example, when the "Berliner Schloss" was built, eagles, capitals or façade elements were created in multiple copies using 3D milling. In the future, the question of the authenticity of holdings must be critically examined. What constitutes the original and what is a copy?

Especially in the acquisition of environmental parameters, immense progress could be made through digitalisation. Simple data loggers, e.g. for temperature and relative humidity, are now inexpensive, easy to use and can continuously monitor the environmental conditions of art and cultural assets. If the measured parameters exceed previously defined limits, a signal can be automatically sent to an authorized person who can promptly remedy the problems. The digital methods thus actively contribute to the preservation of cultural assets.

RESEARCH

In the field of research, digitisation opens up new and expanded possibilities. For example, large volumes of data can be evaluated (partially) automatically, and digital techniques can be used to link a larger number of individual parameters. This makes it possible to correlate data and facts to an unprecedented extent. Particularly in the case of interdisciplinary questions, correlations can be made in this way, which bring completely new insights, also through the support of artificial intelligence.

The 3D models described above are not only suitable for visualisation or the creation of real models but can also be used for research questions.

Figure: 3D scan of the tomb of Emperor Heinrich and Kunigunde in Bamberg Cathedral

The 3D scan represents the surface of the cultural asset at a defined point in time. If several scans are now made at different points in time, the 3D models can then be digitally compared with each other using the relevant software. By means of false-colour images, for example, it is possible to determine how surfaces react to changing climates. The methods of target/actual comparison can also be used to determine whether an artist's model has been cast several times or whether two figures can be traced back to the same model. Due to the ongoing digitalisation, it will be possible in the future to create real "digital twins" of real objects. However, these must not only reflect the optical appearance, but must also be structurally and materially identical. These twins can then be used in the virtual world to test, for example, conservation strategies and measures for cultural assets, without having to expose the object to incompatible or incorrect measures for it to be protected. The potential for the protection of cultural property is significant, especially in the development of materials and the simulation of ageing behaviour. However, it will be a long time before the digital twins can correctly reproduce a cultural asset in all its facets, with the handcrafted materials that have aged over years and centuries.

SUMMARY

Digitisation can represent a significant added value for the cultural heritage sector in the areas of documentation, preservation and research. The various digital tools not only make it possible to create better conditions for the preservation of cultural property, but above all to create new data and knowledge networks in interdisciplinary research.

However, the current prevailing mood of departure for digitisation in all areas of society can bring with it the danger that the original object itself will be pushed into the background and forgotten. Digital methods are threatening to become an end to the means themselves, with the result that real objects are being held in ever lower esteem. In Germany, several calls for proposals for funding have recently been published by government authorities that focus on the digitisation of cultural assets. However, the restoration of cultural property, which is often necessary for error-free digitisation, is often explicitly excluded. The consequence of this is that the focus of digitisation is only on those objects that are already in very good condition, often because they are already in the public eye and preservation is actively pursued. The large number of objects of equal cultural-historical importance that are stored away from mass tourism or in depots are threatened to be excluded from digitisation unless restoration and conservation is also an active part of digitisation strategies.

How far the idea of a digital world has already spread today is indicated by a statement from the "Digital Agenda 2014-2017" of the German Federal Government, which can be translated as follows: "By making digital content and images available online, the basis for culture, science and research as well as social participation will be strengthened. With that in mind, we will continue to develop Germany into a digital cultural country." [1] This statement testifies to how little the concern for the protection of cultural property has been received by decision-makers. We do not want to live in a digital cultural country. We want to live in a country that is rich in real cultural heritage, which is evidence of our past and which shows us where we come from. Digital methods are welcome, but they are only tools for the protection of cultural assets, like a paintbrush for the painter or a scalpel for the doctor.

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INNOVATIVE DAMAGE AND MATERIAL ANALYSIS IN 3D BY INTEGRATING DIFFERENT TECHNOLOGIES

Peter Weber

INTRODUCTION

The German Research Alliance Cultural Heritage (FALKE – Forschungsallianz Kulturerbe) consists of 22 Fraunhofer Institutes, 8 Research Museums of the Leibniz Association, the Prussian Cultural Heritage Foundation, the Dresden State Art Collections and the Saxon State and University Library Dresden. Its aim is "to combine the humanities, social, natural and cultural scientific expertise of the partners in order to jointly develop and test new procedures and methods for the restoration, conservation and preservation of cultural assets in practice" [1].

From 2015 to 2018 several partners of the alliance completed a project funded internally by the Fraunhofer Gesellschaft called FALKE I. The aim of this project was to implement innovations for cultural heritage addressing different topics [2]. One of the topics was digitization and the implementation of novel damage and material analysis in three dimensions (3D), which will be in the focus in this article. Other topics dealt with pollution in exhibition rooms, microclimate in showcases, biocides in textile objects, the unblocking of documents, risk management and the socio economic value of museums.

Concerning digitization in the area of cultural heritage, a lot of work has been done in the last forty years. The digitization of written cultural heritage is standard and millions of documents and books have been brought to digital electronic format since the 1980s. The digitization of auditive (acoustic) cultural heritage is also a standard procedure although a lot of sound storage media are still not yet recorded digitally, such as the early cylinder recordings of the world's musical traditions in the Berlin Phonogram-Archive. In the case of digitization of intangible cultural heritage, a classical digitization is not possible. It has to be taught and cultivated to preserve it.

THE DIGITAL TWIN

One of the main tasks of the FALKE I project was to use different technologies for the digitization of sculptures in order to obtain a digital twin. The challenge was to use these technologies on site in the exhibition rooms of museums, i.e. to mobilize them. Additionally, a damage and status detection has been performed using nondestructive testing methods on site. Together with the digital twins of the sculptures, a consolidated interactive display of the findings has been developed.

METHODS AND RESULTS

The 3D digitization of the surface of the sculptures was done using optical methods like Photogrammetry and Structured Light. Photogrammetry entails taking pictures with a camera from different directions of an object in order to generate a digital 3D surface model of this object. The method was developed at the end of the 19th century to measure objects that cannot be measured directly because of their size such as terrain formations or water surfaces. For the 3D digitization of the surface of antique sculptures, it is necessary to make hundreds of photos and to use the calculation capabilities of a state of the art workstation to

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obtain a three-dimensional digital twin (3D model) with a spatial resolution in the sub-millimeter region. Additionally, the texture of the surface of the sculpture can be projected onto the surface of the 3D model so that information about the material and the color can be included.

When using structured light, a light pattern is projected onto the surface of the sculpture. The deformation of the reflected pattern caused by the irregular shape of the surface is captured three dimensionally using a digital stereo camera. Repeating this procedure for all parts of the surface delivers a dataset of digital photos that allows the reconstruction of the 3D surface of the sculpture. Compared to photogrammetry, information about the texture and color is not made available by using this method. Researchers must use additional photos without the projected pattern.

Interestingly, most of the original antique sculptures were colored, which does not correspond to the ideal picture we have from these sculptures. The ideal picture of non-colored antique sculptures is a product of the art-understanding developed during the Renaissance.
During a measurement campaign in the collection of sculptures in the "Staatliche Kunstsammlungen Dresden", which was performed in March 2017 with all partners of the Falke I project, it was shown unexpectedly that a 4,000 year old relief from Egypt [3] and a 2,000 year old Roman sculpture [4] have traces of color. The method for the relevant measurement was the confocal microscopy with a mobile device used for the first time inside a museum.

Because the methods mentioned above cannot look under the surface, ultrasound and terahertz technology were used to obtain information about the inner condition of the sculptures.

The method of ultrasound tomography for the analysis of sculptures made of stone has been used since the late 1980s. As the same method used for the medical diagnosis of patients, ultrasound is applied through the surface to obtain digital images of the inner status of a sculpture. Cracks can be visualized and the weathering of the material is identified. The innovation obtained in the project was that instead of working with one transducer as transmitter and a second as receiver, a belt of up to 54 transducer is used. This reduces the time needed to capture one tomogram from hours down to a few minutes. Additionally, the tomogram can be visualized directly on a laptop. Before this development, the visualization of the tomogram took several days. The progress in the project was that ultrasonic tomography became a real time measurement and evaluation method for on-site use in the field. The disadvantage is that it is necessary to press the transducer directly on the surface of the sculpture which is not allowed in all cases or need special coupling technologies.

The terahertz technology helps to alleviate this situation by coupling electromagnetic energy inside an object without touching the surface. In the FALKE I project, a mobile device was developed and used to image the interior of sculptures for the first time. The information which can be obtained pertains to the damages or state of the structural reinforcement. The method for this application is quite innovative and the algorithms for the analysis of the recorded data are still in the developmental stages.

CONSOLIDATION AND VISUALIZATION, THE VIRTUAL FRAUNHOFER MUSEUM

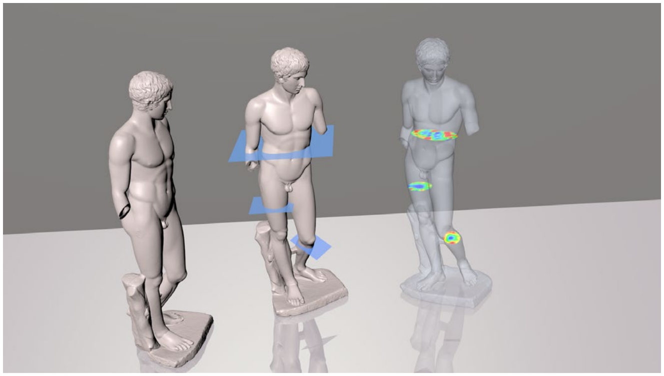
As described above, we used different methods for the generation of a digital twin and several modalities to obtain information about the interior of the relevant sculpture. Of course, there are many other methods to increase the content of information. One aspect in this project was just to adopt special methods for its mobile use on site in the museum as described above. Another aspect was the consolidation and interactive use of the collected data. Therefore, a virtual reality system was set up that displays the digital twin and that allows for a gesture-based interaction. Information about the sculpture's interior, provided by the ultrasonic tomography and the terahertz measurements can be faded in and displayed by virtually opening the surface of the digital twin. Information about the colored version obtained by confocal microscopy are shown on the surface where they have been found. The data model which contains this information is open for additional information like origin, history, preservation, restoration situation, etc.

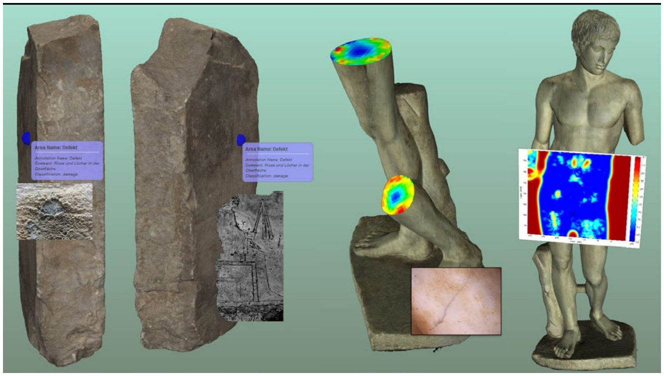
The "Cultural Heritage Expo" project was initiated as a follow up of this result and a first step to the Virtual Fraunhofer Museum concerning preservation technologies [5]. It combines the described digitization technologies and full 3D camera technologies to build a fully-immersive space that can be experienced by VR headset.

OUTLOOK

Through the FALKE I project, Fraunhofer has shown that it is possible to use different mobile technologies to generate a digital twin of a cultural object consisting of a 3D model augmented through the use of additional status information and how to make it interactively accessible.

Officially starting in March 2020 within the FALKE II project, the methods will be adopted for use in urban and rural environment. Researchers will evaluate how they can contribute to the preservation of cultural heritage with regard to climate change and catastrophes.





Figures: Digital Twin and consolidated Information: Left: the digital twin of the "Dresdner Knabe" [4] and three ultrasonic tomograms projected in those cross section they were recorded. The color map shows the weathering information. Right: "Dresdner Knabe" [4] and "Egyptian Relief" [3] with consolidated information like terahertz tomogram (right), ultrasonic tomogram, crack information (microscopy), surface texture (terahertz) and color fragments (microscope). The digital twins were generated using photogrammetry and structures light. All data were recorded during a measurement campaign in March 2017 in Dresden.

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EPILOGUE, WHERE IS THE PERGAMON ALTAR?

Inside the "Pergamon Museum" in Berlin, Germany, the famous "Pergamon Altar" has been shown for the last 120 years. Since 2014, the part of the museum which contains the altar has been closed until 2025 and cannot be visited until the renovation of the museum is finished. Fraunhofer IGD, together with the Staatliche Museen Berlin (SMB) has completely digitized the altar at high resolution so that the three dimensional digital twin of it can be visited virtually in the internet [6].
At this point, the question arises: what is and will be the use of the digital twin of cultural heritage? As already described, it can be used for interactive displays including augmented information or simply as a digital representative for an object that is not available at the moment or, perhaps, never will be again.

During a workshop concerning "Digitization and Cultural Heritage" which was part of the event "Cultural Heritage in Crisis," held in November 2019 in the "Villa Vigoni" in Como, Italy, this issue was discussed. One of the results of the discussion was the use of the digital twin also for scientific research. This leads to a number of questions which are still open and must be addressed in the future:

- How authentic is a digital twin compared to the original?
- Are there any common standards concerning the digitization process?
- Are there any common standards for the digitized data format which can be used by all researchers now and in the future?
- What about the copyright of the digitized data?
- Etc. …

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THE DIGIPLACE H2020 PROJECT FOR THE EUROPEAN DIGITAL PLATFORM FOR CONSTRUCTIONS

Luigi Perissich

European construction companies employ 18 million people and represent 9% of EU GDP. Additionally, half a billion EU inhabitants live, work and travel in the built environment shaped by construction industry and create 100% of the GDP in it. Well built, used and maintained built environment (including buildings, infrastructures and the linked services) is therefore crucial to address the societal challenges of the European Union. This sector is therefore moving into the centre of policymaking, innovation and research. Nevertheless, the construction sector is lagging behind many other sectors, even agriculture, when it comes to digitalization.

The Digitizing European Industry (DEI) WG2 on Digital Industrial Platforms was set up during the DEI Roundtable on September 20th, 2016 in Brussels and was tasked to support the creation of next-generation digital platforms. This roundtable was focused on how building platforms should be approached on the European level, and considered how existing and future EU-wide, national, and/or regional platform development activities could contribute to our goals. This endeavor required a collective effort, involving public and private stakeholders across Europe at regional, national and EU levels. WG2 defined next-generation digital platforms for the vertical sectors of Connected Smart Factories, Smart Agriculture, and the Digital Transformation of Health and Care. These sectors were chosen as examples of industrial domains. Two horizontal topics were also addressed: Industrial Data Platforms and the Internet of Things (IoT). Subgroups were set up for each of the five vertical sectors and horizontal topics. The WG2's Final Report describes the current landscape of platform development and related activities in Europe, reflects on the type of supporting initiatives needed, and outlines recommendations addressed to the High-Level Representatives who attend the aforementioned roundtables and oversee the implementation of the DEI initiative.

That is why Federcostruzioni, with the support of FIEC, the European Federation of the Construction Industry, has taken the lead in asking the DEI WG2 to add the construction sector to the other selected pilot industrial sectors. The rationale being centered on the importance and size of the sector globally and at European level as well as its lateness in reaping the benefits of digitization. Based on the data of the recent report of the McKinsey Global Institute, Reinventing Construction, "the sector is one of the largest in the world economy with about 10 trillion spent on construction related goods and services every year. The sector employs 7 percent of the world's working population and has fundamental role for society as it builds the constructions where we work, live and the infrastructures necessary for global trade and travel. If everybody agrees that the health sector has a global impact on society and quality of life, the construction sector matters too. However the industry productivity has trailed behind that of other sectors for decades, and there is a 1.6 trillion dollars opportunity to close the gap" [1].

The MGI Report shows that the labour-productivity growth has been 3.6 times higher in manufacturing and 2.8 times higher in the total world

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economy. If construction productivity were to catch up with the rest of the economy, the industry value could rise by 1.6 trillion dollars/year and an increase of global GDP of 2%. Reasons for this poor performance are: extensive regulations, a dependency on public sector demand, and a highly fragmented market with big differences between large players operating internationally in heavy large scale construction either civil or industrial, and much smaller players engaged in fragmented and specialized works. Even if large companies are from 20% to 40% more productive than the small ones, they are still far from the productivity levels obtained by manufacturing and the gap risks to become much wider when manufacturing will benefit from industry digitization.
The WG2 Final Report confirms the WG2 assembly's important decision to accept Federcostruzioni's request and include construction as one of the main EU pilot sectors for digital industrial platforms [2].

Construction is also very important for cultural heritage preservation and management. As stated by the European Construction Technology Platform's (ECTP) strategic research agenda for 2021-2027 (SRIA) [3]: with more than 12% of its building stock protected due to its cultural and architectural value, the European built environment also contributes significantly to cultural tourism income and European identity in a multicultural environment. With the Davos declaration of 2018, world leaders highlighted the importance of *Baukultur* in the European Built Environment. The ECTP SRIA [3] has identified one of the focus areas as: "living cultural and historical built environment" and the need to develop a holistic technical and methodological framework for cultural heritage maintenance, building bridges of understanding and compatibility between the existing stock of buildings with cultural value, and current requirements for safety, habitability, environmental sustainability, support for the elderly, preservation of identity and tolerance. For ECTP, cultural heritage is no longer about the restoration of symbolic (iconic) heritage or the importance of a single asset, but rather the expansion of older notions of preservation to include historic buildings and cities, cultural landscapes, modern architecture and other elements representative of European identity. These sites should become an essential part of the living environment and the fulfillment of societal needs in a changing world, in which cultural heritage should be adapted to reach citizen's needs: a continuous evolution, which still preserves authenticity and integrity. An objective for 2030 is zero loss of cultural heritage. In accordance, these are the main R&I topics: solutions for a more open, accessible and inclusive cultural heritage, solutions for a low carbon, resource efficient and resilient cultural heritage, from prevention and monitoring to maintenance and retrofit and sustainable tourism strategies compatible with conservation of cultural assets.

The EC approach to industrial data platforms is evolving and the goal for the programming period of 2021-2027 is to build a Common European Industrial IoT, Data and AI Ecosystem, federating all the vertical industrial digital platforms, while also adding other sectors to the selected pilots. For the construction sector the selected H2020 project for the topic: DT-ICT-13-2019, Digital Platform/Pilots Horizontal Activities, was DigiPLACE.

The DigiPLACE project, has the goals of defining a reference architecture for the European Digital Platform for Constructions and the creation of a Strategic Innovation Roadmap defining the future development of demonstrators, pilot projects, and appropriate business models. From a technological point of view, we want to move from a linear construction digital information flow to a circular one which centers on a Common Data Environment (CDE).

The CDE could be extremely large (Big Data) if populated by private, national and European data made interoperable and accessible by

European and national platforms allowing for BIM software packages to greatly expand their access to the data necessary, for example, to complete sophisticated simulations and data analytics with Artificial Intelligence. This can be of great interest for public procurement sources that play a very important role in the construction market, thereby allowing tendering authorities to fully digitize their tendering, construction and management process with important potential gains and increased simplification.

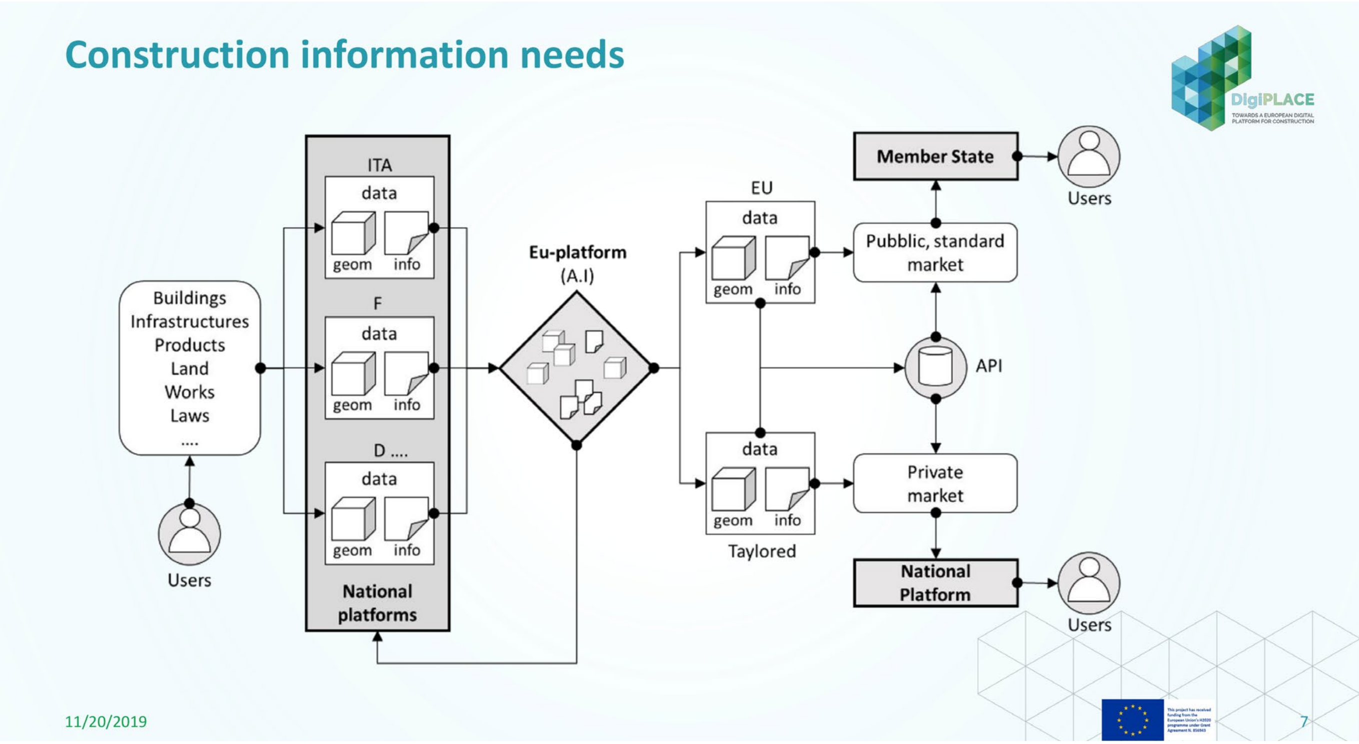

Figure: EU digital Platform and construction information needs

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The expected impacts of DigiPLACE are as follows:

01: the increased productivity and sustainability of European Construction Industry;
02: the facilitation of diffusion processes concerning a common language in the construction sector;
03: to pave the way for the growth of smart cities and smart infrastructures;
04: the strengthening of the EU’s role in the Global Construction Ecosystem;
05: fostering accelerated and efficient collaboration between public authorities and industry;
06: validation in usage context of usability, risk and security assessment and sustainability;
07: maintaining and extending an active eco-system of relevant stakeholders, including start-ups and SMEs;
08: promoting the diffusion of knowledge and facilitating the introduction of digital practices;
09: tangible contributions from European key players to actively engage with the platform building process;
10: efficient information sharing across the program stakeholders for horizontal issues of common interests;
11: facilitating the introduction of Digital Transformation of the construction sector.

The management structure of a project which is simultaneously complex and limited in its duration of only 18 months, is comprised of the following 7 work packages:
WP1 Project management – Politecnico di Milano;
WP2 Long term community building – Federcostruzioni;
WP3 Digital level and comparison analysis – ECTP;
WP4 Challenge barriers and gaps – BBRI;
WP5 Reference Framework Architecture – CSTB;
WP6 Strategy roadmap (private and public markets) – MEEM;
WP7 Communication and dissemination – CECE.

All Work Packages are important, but I want to focus on the one that is coordinated by Federcostruzioni, because a project with such a strategic endeavor cannot be successful without an open and inclusive approach that assures the active and widespread involvement of all interested parties in the project activities. In order for the future European Digital Platform for Construction to be successful, it needs to respond to the needs of all users. That is why DigiPLACE has started to create an open and inclusive Community of Stakeholders (CoS) that will be composed of at least 1,000 members from all over Europe, will accompany the project during its duration of 18 months, and will continue to exist after project completion in March 2021. Additionally, an Advisory Board has been set up, made of 30 high level experts, that will accompany the consortium for the whole duration of the project.

As digitization will dramatically change the way the construction chain will operate, impacting all areas of businesses, professions, clients on both private and public markets, DigiPLACE needs to build these 2 communities and actively engage with them several times during the project. This will ensure that the project results will be in line with the needs and challenges of the whole construction chain. These expert communities will be involved in the project in 3 main ways:

1) they will be informed about the project objectives and its preliminary outcomes, mobilized through questionnaires and invitation to take part in project events, and asked to provide their feedback;
2) they will be made active participators in the communication and dissemination of the Pan-European approach and methodology to digitization developed within the project;
3) they will be asked to influence institutions and organizations at local, national or European level to "create support" for the concrete deployment of the results of the project. If anybody is interested in joining the CoS, they can easily do it by filling in an online form that can be accessed through the follwoing link: https://docs.google.com/forms/d/e/1FAIpQLSdvtdZ_C9N-4QrJfF0ah-cL0IJ0-TKP-6sLe1ucW5qLF8dR6mA/viewform?vc=0&c=0&w=1

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CULTURAL HERITAGE AND SOCIETY – PRESERVATION AND IMPORTANCE OF CULTURAL HERITAGE

THE CHALLENGE OF PARTICIPATORY APPROACHES FOR THE DIGITALIZATION OF EUROPEAN CULTURAL HERITAGE

Fernando Ferri, Patrizia Grifoni, Noemi Biancone, Chiara Bicchielli

INTRODUCTION

This paper discusses a new challenge in the sector of the heritage platforms: the emerging technology of Heritage Social Platforms. Following the success of Social Platforms in many sectors, these new heritage-based platforms implement a more participatory approach for stakeholders and citizens. After the presentation of some examples of relevant Heritage Social Platforms, the paper introduces the Innovators in Cultural Heritage platform recently implemented by CNR-IRPPS along with its functionalities and sustainability strategy.

FROM HERITAGE DIGITAL PLATFORMS TOWARDS HERITAGE SOCIAL PLATFORMS

Heritage Digital Platforms use top-down approaches and require the support (and funds) of large organizations. Several Heritage Digital Platforms already exist (Europeana, Google Cultural Institute are two relevant and large examples). These platforms digitize and virtualize collections from museums, libraries and other institutions. Citizens are not involved in their creation and they do not have the objective to establish heritage communities around them.

Heritage Social Platforms, on the other hand, use bottom-up approaches and are based on the support of large communities. In several fields, social platforms have proven remarkably successful at building networks based on the contributions of their users. However, their possibilities have not been fully exploited in the sector of cultural heritage. Heritage Social Platforms could become the place where citizens, heritage communities, and professionals will be able to contribute their voices, images, ideas, emotions, and experiences in digitizing, documenting, preserving and promoting heritage assets.

In particular, the added values of Heritage Social Platforms are:

- Establishing heritage communities to raise awareness on the importance of cultural heritage
- Increasing and facilitating the content production by involving civil society, local communities and private organizations that are interested in cultural heritage
- Bringing cultural heritage into the people's everyday life: digitization of tangible and intangible cultural information when it happens
- Making cultural heritage contents more accessible and dynamic
- Involving citizens and civil society in mechanisms integrated with public action for cultural heritage preservation

HERITAGE SOCIAL PLATFORMS: APPROACHES AND EXAMPLES

Several Heritage Social Platforms have been launched in the last few years. The following three examples are good representatives of the opportunities created by Heritage Social Platforms in the cultural heritage sector. These platforms are: PLUGGY, NETCHER and REACH.
PLUGGY provides innovative 3D models and audio, augmented reality, geolocation and collaborative games tools and apps to enable users to share their local knowledge and experiences. PLUGGY allows individuals to create virtual museums by grouping virtual exhibitions, which are

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curated by users, thereby allowing citizens to participate in the preservation of heritage elements. Additionally, visiting virtual museums, and browsing digital collections is organized by other users. PLUGGY also allows users to create new stories and highlight the connections between any materials they deem fit for their virtual exhibition. Finally, it provides users experience stories in new and fascinating ways.

NETCHER's main foci are traceability, preservation and reconstruction of cultural goods as well as the cross-sectorial fight against trafficking and looting of cultural goods. NETCHER aims to set up a lively international and multidisciplinary network of practitioners with shared convictions, values and protocols, and enhance their active cooperation and experience. NETCHER has the ambition to raise the awareness of stakeholders and the general public about the consequences of illegal trafficking of cultural goods. As a running H2020 project, this platform also has the goal of becoming a landmark piece of technology for any actor who needs tools, data, and documents on the issues tackled by the project.

REACH is an online space, which is open to contributions from the community of heritage researchers, practitioners, professionals and citizens interested in promoting the value of cultural heritage and supporting its public recognition. The platform allows the exchange of expertise and experience between people and institutions, aiming to foster debate and reflection on the importance of cultural heritage and its impact. The main sections of the REACH platform are:

- HERITAGE SERVICES: providing access to a collection of databases created by heritage research projects.
- POLICIES and RESEARCH: offering a mapped list of links to research publications and policy documents about heritage research, including joint statements, position papers, calls for action, research deliverables, etc.
- PROJECTS: providing the links to the projects in the domain of heritage research, which are collaborating with open-heritage.eu.
- BLOGS: offering a collection of blogs on the theme of cultural heritage and participatory activity in culture.

THE INNOVATORS IN CULTURAL HERITAGE COMMUNITY

The Innovators in Cultural Heritage platform was born as exploitation of the MARINA community (https://www.marina-platform.eu) and a joint effort of the European Commission together with two Horizon 2020 projects: MARINA and ROCK. The community platform is in continuous evolution and has two other twin platforms in the marine and bioeconomy sectors. These three platforms co-evolve together. The target that the platform wants to address is a complex combination of public administrators, associations, research, groups of interests, and enterprises, for federating them.

The Innovators in Cultural Heritage platform offers a set of functionalities that can be used by the cultural heritage stakeholders for a wide range of purposes. When exploited to its highest capabilities, the platform allows the stakeholders to: 1) Meet others with whom they share interests and build communities to strengthen their voice, 2) Disseminate or access knowledge that helps them solidify and enlarge their visions about their interests, 3) Be aware of or organize events dedicated to their matters of concern (see Figure 1), and 4) Inspire debates in order to learn from others.

The platform was developed so that each piece of content and the entire platform can be easily embedded in any external portal or website. This option may be particularly appealing for any group of stakeholders, organizations or communities looking for new ways to attract new audience or provide functionalities from their portal or website to the users. Among other examples, this could be the case for those interested in developing strategic collaborations to promote a given cause, those seeking to set up a virtual working group or those concerned about improving the circulation of information and the networking within their networks. The platform can also be particularly useful during public consultations and early stages of the decision-making process. Governance-related stakeholders involved in such law-oriented procedures can therefore use the platform to build bridges connecting themselves to the scientific community, industry and society.

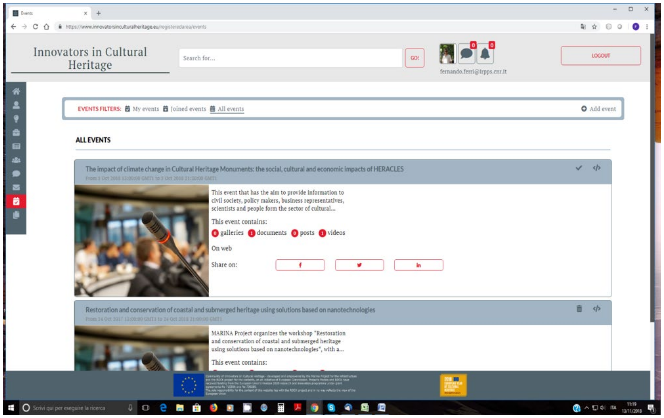

Figure 1: Page for accessing events reported in the platform, or organized on the platform as virtual https://www.innovatorsinculturalheritage.eu/registeredarea/events

Anyone producing data, information, knowledge, and technology (see Figure 2) can use the platform to promote the outcomes of their activity. The platform can facilitate new working procedures in which the dissemination of data sets, scientific papers, technical reports, etc., among a wide audience concerning the cultural heritage sector or a given geographical area is a perceived by all as a day-to-day activity.

There are various online solutions for anyone interested in disseminating or having access to knowledge. Facebook and ResearchGate, for instance, are two very popular examples, both of which are quite efficient. However, within Facebook, a platform that is very popular to citizens, scientific information represents a very small part of the content of this generalist social network. Another shortcoming of Facebook is its tendency to be subject to a variety of fake news. On the contrary, ResearchGate is mostly used by researchers and the impact of posting a scientific paper, for example, is limited mostly to the science community. Citizens and other stakeholders groups are not able to use ResearchGate unless they release scientific publications. Innovators in Cultural Heritage are committed to encouraging both stakeholders and citizens to use the platform.

INNOVATORS IN CULTURAL HERITAGE SUSTAINABILITY

The term sustainability has gained significant popularity in policy-oriented research, business development and social sector over the last few decades. Sustainability, a word frequently used across several disciplines, has become part of our everyday lexicon. Sustainability of a platform is about the continuation of its activities and sustainability of its outcomes and is particularly important for the users who spend their time producing content and activities on the platform.

Sustainability of Innovators in Cultural Heritage requires long term planning to facilitate diverse stakeholder engagement and improve the institutional capacity of one’s target population. Two main components of sustainability have been considered:

Technical Sustainability - The Platform is a web application developed as a personalization of the PLAKSS framework (CNR patent IT2015000917) for managing the needs of the Cultural Heritage communities. PLAKSS is a very large software library developed in Java, Java script and JSP by

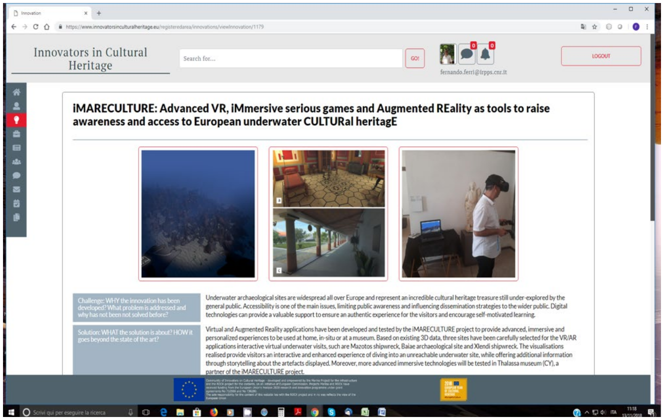

Figure 2: Page dedicated to the IMARECULTURE project innovative technology https://www.innovatorsinculturalheritage.eu/registeredarea/labs

CNR-IRPPS with own resources. The PLAKSS library includes interface modules (API) towards many software products and web services that allow for a composition of web services using the functionalities of the software interface. Software, web services and web applications are prone to security and technological issues that require continuous updating to avoid a rapid obsolescence. Taking into account security and technological risks the approach focuses on the migration to the new versions of the PLAKSS framework. The majority of other approaches could determine a rapid obsolescence of the platform and security issues. However, in general, the migration toward to new versions of PLAKSS requires minor effort.

Financial Sustainability – maintenance of the platform requires few financial resources for this reason any extra financial resource could be dedicated to further advance the work initiated with Innovators in Cultural Heritage including both new functionalities and content of the platform.

CONCLUSION

This paper presented the Innovators in Cultural Heritage platform. In implementing the platform, CNR-IRPPS has considered the potentiality of this new approach in the sector of cultural heritage and sustainability issues for assuring a long continuation of its activities. The objective is now to attract financial resources for developing new functionalities having a particular relevance in the sector of cultural heritage.

THE SOCIO-ECONOMIC VALUE OF CULTURAL HERITAGE

Uta Pollmer

The protection of cultural heritage is often difficult, because of insufficient funding for taking necessary measures. A key question for cultural heritage protection is therefore, how to convince public financiers to invest more in our cultural heritage. One way to do this is to invite potential sponsors to get in direct contact with and to experience cultural heritage first hand in order to create awareness and a personal connection to this topic. Another way is to prove the importance of cultural heritage for our society through scientifically-based evidence as a means of arguing in favor of protection. Referencing the societal well-being, specifically social cohesion and sustainable development with regard to cultural heritage can be a successful line of argument.

Experience shows that it is often more effective to argue based on the economic benefits of a project. Economic arguments are often needed to justify the use of taxpayer money and therefore play an important role in the allocation of subsidies. That is the reason for us to investigate different economic methods to determine the value of cultural heritage, and to discuss the advantages and disadvantages of these methods. The aim of our research in this field is, in the words of the OECD (2018), to help "…decision makers to have a clear picture of how society would fare under a range of policy options for achieving particular goals" [1], and to show which methods are most suited to demonstrate the value of cultural heritage.

The crucial point is to find a common language with politicians and sponsors. The specific ways in which facts are presented in economic contexts can help to support one's arguments, as demonstrated by developments in the areas of climate change (Stern Review on the Economics of Climate Change, 2006) [2], and biodiversity (Millennium Ecosystem Assessment, 2005) [3]. In both cases, scientific studies have shown the economic consequences of human action, demonstrated the need for change and developed options to reduce or even avoid negative impacts. As a result, the issues of climate change and biodiversity have been actively integrated into policy and legislation and are now part of the decision-making process for sustainable development.
Since investment decisions are traditionally made in the framework of a cost-benefit analysis, it is helpful if the preservation of benefits and the expected loss of benefits can be presented in the same unit of measurement as the costs. In the search for suitable concepts to determine the value of cultural heritage in a holistic manor, the approach of ecosystem services is promising.

The first major study on the global mapping of ecosystems and their services commissioned by the United Nation, the Millennium Ecosystem Assessment (MEA), used this concept to represent the contribution of ecosystems to human well-being [2]. Currently, an overall economic concept for integration into political, economic and private decisions is being developed for every EU member state.

Against this background, there are studies in the field of cultural heritage, which aim to evaluate cultural heritage economically and to make investment recommendations on the basis of cost-benefit considerations. The authors of the Millennium Ecosystems Assessment study used the concept of Total Economic Value (TEV), integrating marketable and non-marketable values. The value of an object is defined through the benefit it provides. In a similar way as for ecosystem services, we can define individual benefits or values in the field of cultural heritage, thereby illustrating its influence on human well-being.

Referring to the concept of the TEV, we obtain the following classification of values adapted to cultural heritage:

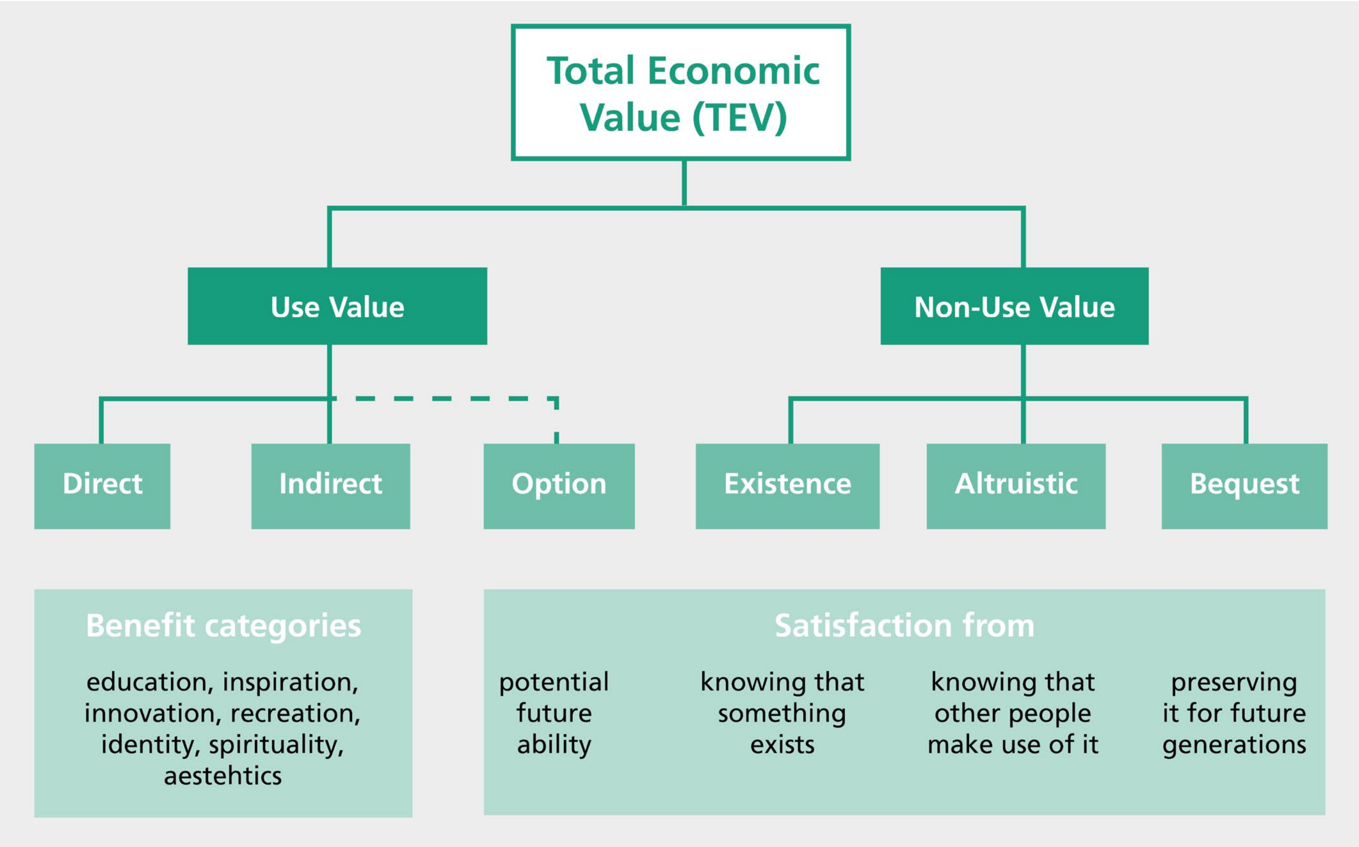

Figure: The Total Economic Value of cultural heritage. Own figure based on TEEB (2010) [4]

The TEV approach differentiates between the Use Value and the Non-Use Value. The Use Value is split into Direct and Indirect Use Values, and the Option Value – the value of the potential future ability to use a resource. When applied to cultural heritage, we identified the following benefit categories as the most relevant for use values: education, inspiration, innovation, recreation, identity, spirituality, and aesthetics. The Non-Use Value includes the value of the existence of the natural resource (Existence Value), the Altruistic Value – the value of knowing that other people can benefit from using the resource, and the Bequest Value – the value of satisfaction from preserving a resource for future generations.

Conventional studies use a number of methods to measure the economic value. We found the following main methods:

- market price-based or cost-based methods,
- methods based on revealed or stated preferences, and
- the benefit transfer.

Market prices can be determined for a range of cultural goods as can be seen at auctions, but what about whole museums with their exhibitions or historic gardens? The value of such assets is far higher than the market price for the real estate or the income generated from admission. Cost-based methods, for example, take the virtual reinstatement costs, or the costs for protection of an asset as its value. These values may be part of the calculation, but the real value of our cultural heritage lies in its benefit for individuals and for society.

But how can such benefits be quantified? For this purpose, we mainly use preference-based methods, which reflect individual preferences and – depending on method – the willingness to pay for certain benefits as a measurable expression for appreciation. For Use Values, we can use Revealed Preference Methods, which means observing the behavior of users and drawing the appropriate conclusions. For Non-Use Values, we are forced to fall back on Stated Preference Methods, which means acting on a hypothetical market and asking people for statements.

Taking the case of cultural heritage sites, it may be useful to apply the Travel Cost Analysis, which means to survey the travel and admission costs of visitors as an indicator for their individual benefit from visiting a site. The idea behind this is that the expenses directly related to the visit express the appreciation of visitors. A similar approach but harder to apply is the Hedonic Pricing Method. This assumes that certain attributes like the proximity of a property to a cultural site influence its market price. The difference to the price of a comparable property without this attribute corresponds to the appreciation of potential buyers.

For non-use cases or to complement the methods described above, it is common to apply the Contingent Valuation Method. According to this method, we describe the current state of an object, then create an alternative scenario and let the interviewees choose their preferred scenario. Moreover, interviewees are asked for their willingness to pay to maintain or achieve that desired state. The alternative scenario mostly concerns the degradation of heritage assets as a result of natural weathering or insufficient conservation work. Under certain preconditions, it is possible to apply Benefit Transfer, which means to transfer the results of one case study to another.

All these methods produce statistics, but the challenge is to choose the right methods and to interpret the results in a reasonable way to provide for convincing arguments. It is essential, especially for the Contingent Valuation Method, to define a relevant alternative scenario and realistic modes of payment. However, the basic challenge is that people are not used to estimating the benefit of public goods. Furthermore, they have little incentive to disclose their true willingness to pay, therefore, a high degree of experience and sensitivity are required to interpret the results and to convert them into solid arguments.

Since the 1980s, various studies have sought to apply these methods to cultural heritage. But until today there is no comprehensive investigation with a strong influence on global cultural heritage politics, equivalent to the Stern Review or the MEA. Existing methods have to be adapted to the specifics of cultural heritage and tested in case studies. The first project on this topic in which Fraunhofer was involved, was the FP7 project Climate for Culture, where Work Package 6, led by the London School of Economics, published a study on "The Economic Benefits of Cultural Built Heritage Interiors Conservation from Climate Change Damages in Europe" [5].

Since then we have been working on a methodology to evaluate cultural heritage adequately. Last year, we finalized a project "Using Fraunhofer innovations to protect our cultural heritage", where we tested one Revealed Preference Method and one Stated Preference Method to determine the value of a museum. We designed two surveys: the first survey - an onsite survey - aimed at the visitors of a little-known museum in Saxony, where we used the Travel Cost Method to obtain insights about the Use Values of Cultural Heritage. During a 20 day interview phase, we collected data about the costs (travel, accommodation, admittance, etc.) and expenditure of time spent visiting the museum, about the motivation of users and their benefits. According to the accompanying survey, the main reason for visiting the museum was education followed by recreation and spirituality. The level of admission prices was regarded as appropriate or even too low. Almost all interviewees can at least imagine a repeated visit, and all respondents would even consider a recommendation to friends, acquaintances or relatives.

The second survey, conducted online, addressed the total population over 18 years old in Germany. Here, we used the Contingent Valuation Method to measure the Non-Use Values and the Option Value. As mentioned above, the Contingent Valuation Method confronts the respondents with the choice between two scenarios: in our case the choice between the financial support to keep the museum at the current state, or to reduce its services due to a lack of funding. The interviewees were asked how much they would be willing to pay annually to preserve the museum. In addition, we asked a few questions about the importance of certain services, such as museum tours, and workshops for pupils, as well as questions directly about the importance of preserving the museum in relation to the option, existence, altruistic and bequest values.

The results show that a majority, 55 percent, of the respondents would be prepared to make an annual financial contribution to the preservation of the museum. The net household income and familiarization with the museum turned out to have a positive influence on the willingness to pay. Other variables used to differentiate between demographic groups, such as educational level, age or place of residence, had no influence.

This is just a short overview at the results. Overall, the case study shows the respondents expressed very positive attitudes towards the preservation and protection of cultural heritage. The interviewees regard the educational and knowledge sharing functions of the museum as particularly important as well as access for other people today and in the future.

Finally, what can we gain from such investigations? Studies like the one described above may provide statistical justifications for the use of taxpayer money and can help convince decision makers of the importance of investing in the preservation of cultural heritage. They make it possible to better visualize the benefits of cultural heritage, make it easier to compare the cost with a corresponding value or benefit and as such also help guide the budgetary decision making processes regarding heritage preservation and protection.

However, using economic methods to evaluate cultural heritage should not just mean monetizing these values. There is a real danger of misinterpreting the results of such statistics, if they are not put into context and interpreted with the requisite care. We are still on the way to identify more methods from other disciplines to develop an integrative methodology to measure and adequately present the value that cultural heritage holds for society.

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FRAMEWORK CONDITIONS FOR CULTURAL HERITAGE RESEARCH

THE GERMAN FUNDING SCHEME FOR CULTURAL HERITAGE RESEARCH

Constanze Fuhrmann

The preservation of cultural heritage is an important societal goal and a duty for future generations. In order to meet this objective, methods and approaches for assessing, archiving, protecting and storing historic artefacts are to be continuously updated and improved as new risks and challenges emerge. This requires ongoing research efforts within the field of conservation science on new threats such as global warming as well as on new technological possibilities such as those afforded by digital technologies. It also requires a funding structure that provides adequate budgets for this research to be carried out.

An important starting point for specific funding of conservation science in Germany was rooted in a perceived ecological crisis of the 1980s and 90s. Widespread damage to forests due to air pollutants and so-called “acid rain” led the German Federal Ministry of Education and Research (BMFT, later BMBF) to establish a large-scale national research programme focused on forestry. Modelled on this initiative, a similar joint programme, the so-called Naturwissenschaftliche Forschung für den Denkmalschutz, focussed on the negative effects of acidic rain on historic monuments. Their corresponding mitigation strategies were initiated in 1985 [1][2][3]. With total funding of the equivalent of 186 million Euro for the period of 1985-1997, it was the largest conservation research and development programme of its time. It covered a broad range of cultural heritage assets and applications and included various universities, research institutions and laboratories, as well as restoration professionals and historic preservation offices.

The impact of this programme was profound and it later served as a blueprint for the European Commission’s research programmes for the preservation of cultural heritage. It turned Germany into one of the leading actors in the field of applied research in conservation. To this day, Germany benefits from the pioneering research conducted and the interdisciplinary professional community the programme helped create. Today, Germany no longer has a national research programme for conservation science and the initiation of another comprehensive effort is currently not foreseeable [4]. Instead of a consolidated and well-funded programme, initiatives are now spread out and draw upon a scattered set of funding schemes. These include the current BMBF programme Research for Civil Security 2018-2023 on crisis management, in which cultural heritage for example, is addressed among others of so-called critical infrastructure, and the Framework Programme for Humanities and Social Sciences. This programme exists since 2012 and covers primarily three subject areas: e-heritage for indexing and digitising historic collections [5], Language of objects, Material Culture in the Context of Societal Development for revealing knowledge embodied in cultural heritage objects [6] and Alliance for University Collections [7] for connecting and exploring university collections. However, the focus lies rather on scientific research in the humanities such as art history and archaeology as well as on current societal challenges such as digitisation. Research on conservation materials, analytical methods and technologies hardly receives any attention. Furthermore, this dearth in funding is compounded by the fact that cultural heritage research as

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an interdisciplinary science eludes classical disciplinary classifications and therefore often does not succeed in competitive third-party funding rounds, for example from the German Research Foundation (DFG). This deficit in public funding has led private foundations to become the most important funding sources for research on cultural heritage. Along with selected tenders initiated by the Volkswagen Foundation, the German Federal Environmental Foundation (Deutsche Bundesstiftung Umwelt, DBU) emerged as the only funding body for conservation science in Germany. This is – in view of the need to research and incorporate current challenges such as digitisation or climate change into conservation science – an unsatisfactory situation. With its funding priority „Environment and Cultural Heritage", the DBU has funded 828 cultural heritage projects since 1990.

CULTURAL HERITAGE FUNDING BY THE GERMAN FEDERAL ENVIRONMENTAL FOUNDATION

The DBU is one of Europe's largest foundations and among the world's largest environmental foundations [8]. It promotes innovative and solution-oriented projects in the following areas:

1. Research, development and innovation in the field of environmental protection
2. Cooperation projects addressing the application of environmental technology
3. Projects aiming at transferring knowledge and experience about the environment – be it among science, business and other public or private entities
4. The protection and recuperation of natural heritage
5. Preservation and protection of cultural assets with regard to harmful environmental factors

These funding topics are linked both to current scientific findings on the Planetary Boundaries and to the United Nations' Sustainable Development Goals. Activities address challenges in the areas of climate change, biodiversity loss, unsustainable use of natural resources, and harmful emissions. Since the foundation began its work in 1990, the DBU has provided funding for nearly 9,700 projects of over € 1.74 billion.

The priority the DBU places on the principles of sustainable development is also guiding the organisation's commitment to cultural heritage protection. With the unit Environment and Cultural Heritage, the DBU contributes significantly to research related to the protection of buildings, museum collections, historic parks and gardens or cultural landscapes from harmful environmental effects [9]. This includes damages by anthropogenic emissions as well as through the effects of climate change. The DBU has always funded projects focusing on the protection of cultural heritage from anthropogenic environmental influences. Recent adjustments to the funding guidelines, however, have put a growing emphasis on global warming and included "climate change" as a separate research topic. With this sharpened focus, the DBU is one of the few institutions that promote awareness of the negative consequences of global warming specifically on cultural heritage.

With a growing number of historic parks and gardens affected by climate-induced damage, the DBU initiated projects to allow for more research on threats posed by changing climate conditions. One example is the project Water Regime and Plants - Challenges and Solutions at the Beginning of the 21st Century (2013-2015; 125.000 € of funding). The project was carried out in cooperation with the Prussian Palaces and Gardens Foundation Berlin-Brandenburg who is overseeing a large number of gardens with World Heritage Status suffering damage because of extreme weather events. The project brought together experts for an international conference and two expert colloquia to discuss the current state of research and to present climate change predictions and corresponding actions for damage mitigation. Upshot of these discussions was a consensus on the need for improved water management solutions, historical horticultural planting and cultivation techniques as well as measures to increase the resilience of historical plants.

Following this session, the Sanssouci Declaration on the Preservation of Historic Gardens and Cultural Landscapes was adopted [10]. This document stresses the need for further research on mitigation strategies for parks and gardens and increased interdisciplinary exchange (forestry, nature conservation, botanical gardens and plant nursery) to tackle the problem successfully for the long term.

The ensuing project Innovative Management of Woodland Vegetation in Historic Gardens in Times of Climate Change (2014-2018; 348,459 € of funding) was the first scientific research project on woody plants in historic gardens affected by climate change. Using the two case studies "New Garden in Potsdam" and "Schlossgarten Charlottenburg in Berlin", the Prussian Palaces and Gardens Foundation together with the Technical University Berlin elaborated answers to ecological processes, the local cultivation of woody plants, solutions for replanting and revitalisation as well as questions regarding water and pest management or the diseases of plants.

Figure: Potsdam, Sanssouci Park, Charlottenhof Palace, View from the basin with bust of Queen Elisabeth to the New Palace

In the early years of funding, the DBU's focus was on anthropogenic environmental factors resulting from the burning of fossil fuels and the ensuing release of immense amounts of damaging sulfur dioxide. Today, projects which analyse the potential of damage of other sources of emissions on cultural heritage are also eligible, for example nitrogen, oxide, ozone, dust or traffic-related emissions such as carbon black or tire wear. One example is the project on the "Development of a low-cost sensor for monitoring VOC pollutions" (2018–2020; 396,000 € funding) carried out by the partners Care for Art, BioChip Systems GmbH, Technical University Munich, University of Stuttgart (Doerner Institute). Museum collections are often endangered by a variety of different man-made substances such as organic acids or aldehydes which are summarised as "volatile organic compounds". These so-called VOCs can be emitted by different materials, such as wood composites, paint coatings or textiles, or derived from former conservation measures and are especially damaging in close spaces such as showcases or boxes with little airflow. Even low emission rates of VOCs can accumulate and lead to irreversible damage. There are various sensors for detection available on the market. However, they are often expensive and have their detection spectrum calibrated to meet the legal requirements for workplace safety rather than being designed for conservation purposes. Against this background, the project aims to develop a smart-sensor application tailored to the needs of museums both in accuracy and cost.

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When revising the DBU funding guidelines, particular attention was given to digitisation. The DBU considers digital technologies as key enablers for environmental protection and sustainable development and therefore places a funding priority on projects focused on digital solutions. Digital technologies offer great benefits to heritage protection, e.g. in the context of specific sensor development, 3D-scanning, data-processing, building modelling or AI-driven analyses, e.g. automatic mould and damage detection. Also, cultural heritage artefacts and changes to their conditions can be presented and communicated using digital technologies such as 3D or 4D to increase awareness among different stakeholder groups such as children.

SUMMARY

The DBU has funded the development of innovative methods and products for the conservation of cultural heritage since its inception in 1991. A key trait of this funding activity has been the constant adaptation of funding guidelines to relevant topics presented by current societal and ecological challenges. This would ensure further progress for conservation science in Germany. Limitations are the capped amount that can be devoted to individual projects as well as the focus on applied research. The funding scheme thus limits the influence of progress achieved on funded projects in comparison to basic research funding that can exert a broader enabling function across various projects. Given the dire situation of many cultural heritage assets, it is necessary for a broader spectrum of funding for research in conservation science to include basic science as well as natural sciences. Policy makers, science organisations and heritage professionals should address this. An example for such an alignment is the call for action for a long-term, interdisciplinary and adequately funded research programme for conservation science that was drafted as part of the conference "Quo Vadis Conservation Research?". The event took place during the European Cultural Heritage Summit on June 20, 2018 and was funded by the DBU.

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CULTURAL HERITAGE AT RISK: FROM RESEARCH TO POLICY IN ITALY

Cristina Sabbioni

Cultural heritage, in all its facets, is subject to a variety of natural and anthropogenic processes of change and transformation. Environmental change, tourism, war, terrorism, and the digital turn are only a few examples of a wide variety of processes impacting the world's cultural heritage and, thus, people's living space and cultures, including aspects of self-conception, identity, origin and inheritance. During the last decades, researchers, focusing on at-risk cultural heritage, were able to develop knowledge, tools and strategies for the protection, conservation, management and valorization of cultural heritage. Italy has historically been a leading actor in the development and support of the research applied to cultural heritage in general, with particular attention to assets at risk.
Now is the moment to be proactive and ensure that the results already provided by the research may form the basis of our society's policies.

CULTURAL HERITAGE RESEARCH IN ITALY: MAIN ACTORS

Italy has been very active in promoting research applied to cultural heritage during the last forty years. The main actors who were able to promote and develop this innovative and pioneering research sector at national level are Universities and Public Research Organizations, mainly the National Research Council (CNR), with the support of the Ministry of Education, University and Research (MIUR).

A very important role was also played by the Italian Ministry of Cultural Heritage, Activities and Tourism (MIBACT). The core of MIBACT in the field of research applied to the protection of Cultural Heritage is represented by the activities carried out in its research institutes, including the Central Institute for Restoration (ISCR).

At present, regions have also included cultural heritage within their research and innovation agenda mainly in the Regional Development Program. An example is provided by ART-ER Territorial Research Attractiveness, a consortium implemented in 2019 by the Emilia-Romagna Region to favor the sustainable regional growth through the development of innovation, knowledge, attractiveness and internationalization.
More recently, private foundations have funded research and innovation including cultural heritage. In 2019 the Compagnia di San Paolo Foundation has in fact launched two calls, namely on 'Sustainable Environmental Restoration' and on 'Integrating Different Perspectives on Heritage and Change'. Finally enterprises, particularly in the AI sector, space, construction, security and big data, are extending their activities within the cultural heritage domain. Within this complex scenario one major challenge remains: to bridge research and application, particularly in the contemporary world, where the financial paradigm is facing the transition from development to sustainable development.

Economic development, where growth is the main driver, is characterized by research and innovation having profit as main target and the instruments of finance looking at short term return of investment (ROI). Sustainable development foresees economic growth in association with this sustainability concept at a broad range. In this case, research and innovation need to consider the so-called triple bottom lines (i.e. profit, planet, people) and be funded by patient capitals, which is a challenging aim in an era dominated by impatience.

In promoting development, research and innovation companies are expected to produce products or processes though technology transfer. Similarly, researchers routinely claim that a funding gap or a 'Valley of Death' exists between research and innovation processes (see Figure). The Valley of Death occurs in the presence of "non-economic" investments (such as government expenditure on basic research) that are made in the early stages of research without sufficient attention to the investment at later steps of the innovation processes. The challenge of bridging this gap requires the coordination of all the actors funding research in this very specific area.

CULTURAL HERITAGE RESEARCH IN ITALY: ACTIONS

Three examples of the effective role provided by cultural heritage research in Italy are provided in the following section: the coordination of the research programming initiative; the coordination of research infrastructures at the European level; the development of the challenging sector of remote sensing applied to cultural heritage within a transnational research project.

Joint Programming Initiative on Cultural Heritage and Global Change (JPI CH)

The Joint Programming Initiative on Cultural Heritage and Global Change (JPI CH) is the collaborative research initiative aimed at ensuring coordination between Member States, Associated and Third Countries in the field of tangible, intangible and digital cultural heritage. The initiative was launched in 2010 following the recommendation to establish medium to long-term research needs and objectives concerning cultural heritage in the context of global change. During the period 2010-2018 the JPI CH was coordinated by MIBACT (Italian Ministry of Cultural Heritage and Activities and Tourism) with the MIUR (Italian Ministry of Education, University and Research).

To this aim, JPI CH developed a common Strategic Research Agenda structured in four priority areas: i) Developing a reflective society (identity, perception, values, ethics); ii) Connecting people with heritage (ICT, use, sustainability, security); iii) Creating knowledge (methods, measures, damage, integrating risks); iv) Safeguarding our cultural heritage resources (conservation, adaptation and mitigation). JPI CH implemented joint actions and funded 26 transnational R&I projects on tangible, intangible and digital heritage under joint calls between participating countries. JPI CH also promoted funding opportunities for transnational projects on the priority thematic areas of 'Digital Heritage' and 'Heritage in Changing Environments'.

European Research Infrastructure on Heritage Science (E-RIHS)

The European landscape of research infrastructure is wide and rich, encompassing a vast number of disciplines and domains. In this complex landscape the European Strategic Forum for Research Infrastructures (ESFRI) is planning and organizing the infrastructural offer, according to the needs expressed by the research communities, emerging research trends and the EC priorities. The European Research Infrastructure for Heritage Science (E-RIHS), coordinated by the Italian National Research Council (CNR), pursues the integration of world-class European facilities to create a cohesive entity that connects the global community to heritage science by: i) supporting research on heritage interpretation, preservation, documentation and management; ii) fostering cross-disciplinary research towards advancement of knowledge about heritage; iii) devising innovative strategies for its preservation, by connecting researchers in the humanities and natural sciences; iv) favouring a trans-disciplinary culture of exchange and cooperation. E-RIHS gathers 20 participants representing 14 EU countries and Israel.

Cultural heritage at risk: JPI CH project results – A case study
PROTHEGO (PROTection of European Cultural HEritage from GeO-hazards), a three year JPI CH collaborative research project coordinated by the Institute for Environmental Protection and Research – ISPRA (Italy), developed and validated an innovative multi-scale methodology for the detection and monitoring of European Cultural Heritage exposed to natural hazards, namely monuments and sites potentially unstable due to landslides, subsidence, ground settlement, active tectonics and monument deformation, all of which could be effected by climate change and human interaction.

By applying integrated remote monitoring, including satellite remote sensing and Geographical Information Systems (GIS), to the UNESCO world heritage sites in Europe, and by integrating these data with existing databases of geo-hazards, PROTHEGO identified and ranked the most critical cultural heritage sites throughout Europe. The Project produced the UNESCO WH geo-hazards PROTHEGO ATLAS® presented in 2018.

FROM RESEARCH TO POLICY

The impact of research on policy is of primary importance for a balanced development of our society, in particular when cultural heritage is involved. Three examples may be provided in Italy in different sectors, which are promoted by different governmental bodies, namely management, climate change and security.

Cultural Heritage Management: earthquake areas
Remote sensing using satellite data has been used by the Italian Ministry of Cultural Heritage and Activities (MIBACT) to manage the earthquake areas in central Italy. The Satellite Interferometry analyses have been validated, calibrated and tested through site scale field survey, advanced geotechnical models and detailed monitoring data. The technology provides millimetric measurement of ground displacements from a series of satellite SAR images. The measurements are obtained in relation to objects: man-made or natural structures such as buildings, metallic objects, rocks or bare soil.

A wide area, the Macerata province with an area of 2,774 km^2, was surveyed by monitoring 1,331 cultural heritage sites, 69 of which were situated in alluvial plains and 1,262 in hilly-mountainous areas. During the period 2003-2010 RADARSAT images show slow movements constituted 86% of a total of 9,118 landslides. 36 cultural heritage sites with a moving position in the buffer area have been identified on which field surveys and more detailed analyses were performed. This application proves the potential of satellite data enabling the protection and management of cultural heritage in wide areas.

Cultural heritage and climate change
The Italian National Strategy for Adaptation to Climate Change set up by the Italian Ministry of Environment (MATTM) includes the cultural heritage sector.

For public and private institutions responsible for the management of cultural heritage, the most effective way to respond to the impact of climate change is, as mentioned in the strategy report, the integration of the necessary measures management plans which already exist or are under development.

The following general actions are strongly recommended:
- Dissemination of existing knowledge
- Continuous monitoring

THE CHALLENGE: BRIDGING THE VALLEY OF DEATH

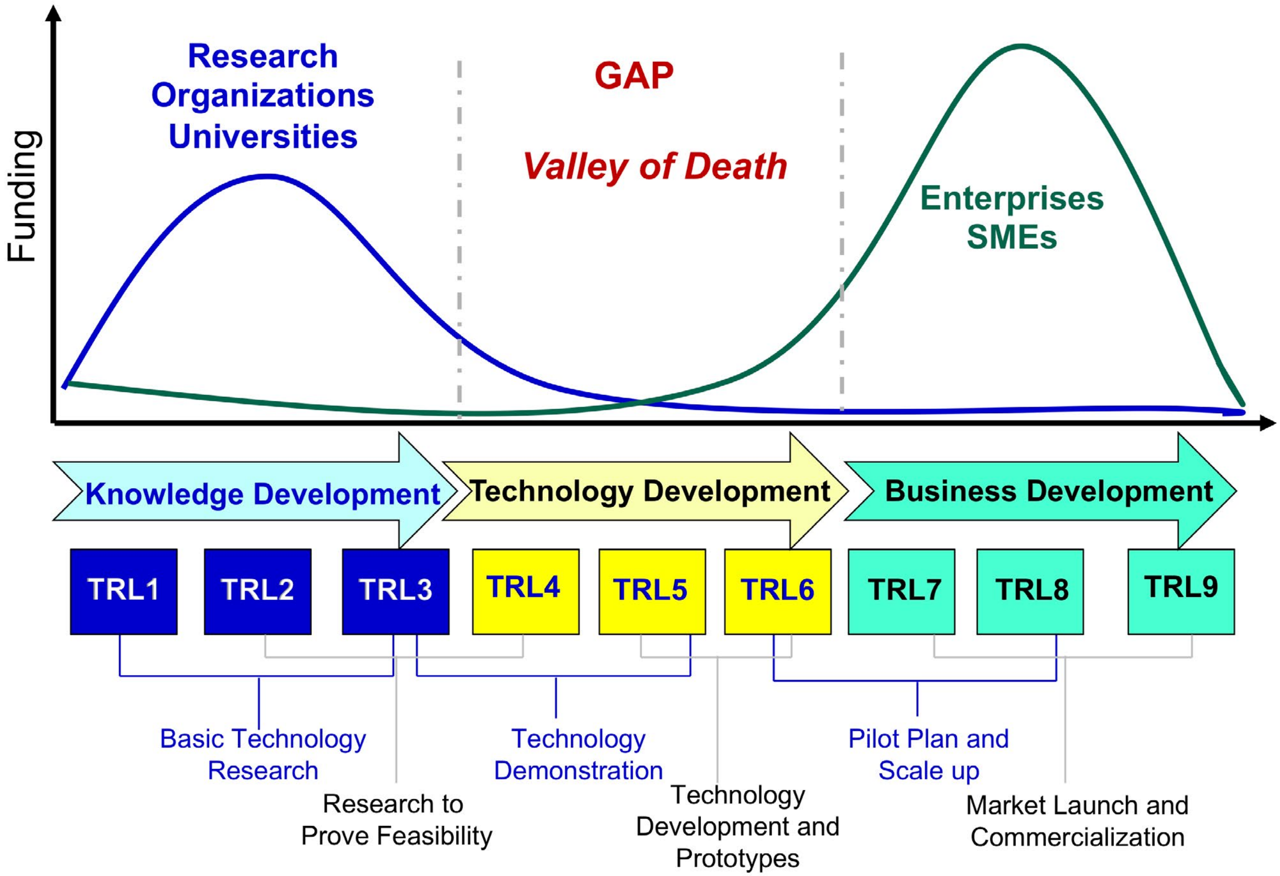

Figure: The Valley of Death in the research and innovation process

- Ordinary maintenance
- Evaluation of priorities in relation to the state of conservation of the artifacts
- Evaluation of the state of conservation of the artifacts in relation to the environmental conditions of conservation detected
- Assessment of priorities in response to climate change
- Data collection to support decisions both nationally and regionally
- Understanding the environmental, economic and social context of cultural heritage

The priority importance of the maintenance interventions of the cultural heritage is emphasized in the restoration interventions, made particularly necessary if we consider the impact of climate change as a further factor leading to heritage damage. It is therefore necessary to also promote different, long-term financing strategies for maintenance, such as:

- Correlating different funding resources and financial approaches
- Recognizing a valid ally in the insurance sector
- Introducing tax breaks for maintenance
- Directing resources in training towards traditional and artisanal building techniques to complement advanced technologies in order to improve our understanding of cultural heritage in a period of change

These issues are also included in the Italian National Plan for Adaptation to Climate Change.

Cultural Heritage and Security

Within the priority field of security, the 'Report on the promotion of security from natural risks of cultural buildings' has been developed under the Presidency of the Council of Italian Ministers. Within the Executive Summary the following recommendations are included:

- A systematic framework on the theme of improving the safety of cultural housing stock against natural risks
- A survey of the main activities already under way in public and private bodies to ensure their valorization and to avoid unnecessary duplication
- A list of priority action plans built on legislation and ordinary administration to ensure applicability throughout the Italian territory

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THE EUROPEAN CONSTRUCTION TECHNOLOGY PLATFORM ECTP – HERITAGE AND REGENERATION (H&R)

Adriana Bernardi

The European Construction, built environment and energy efficient building Technology Platform (ECTP) is a leading organisation promoting and influencing the future of the built environment (http://www.ectp.org). Heritage built is one of the targets of this platform. ECTP is today one of the 38 European Technology Platforms (ETPs) which are industry-leading stakeholders, recognised by the European Commission as key actors in driving innovation, knowledge transfer and European competitiveness.

ECTP activity started in 2004, gathering around 150 member organisations from across construction and other sectors which are part of the built environment's supply chain. The main mission of ECTP and its committees is to develop new RD&I strategies to improve competitiveness, meet social needs and take up environmental challenges through an innovative built environment.

- 2004 Launch of ECTP to better connect the European Built Environment
- 2005 National Technology Platforms founded
- 2006 First vision document published
- 2007 First Strategic Research Agenda to shape the path of research and demonstrate the value of innovation to the built environment
- 2009 E2BA and the PPP EeB launched
- 2013 ECTP reFINE Roadmap published
- 2015 ECTP becomes an Association
- Today ECTP is a leading voice, driving innovation in Europe

ECTP includes members from across 26 countries. It is composed by large enterprises, SMEs, universities, research organisations and professional associations and is known for pushing these entities to work collectively to improve activities including energy, climate change, efficiency and infrastructure. Today ECTP is one of the leading voices driving innovation for industry in Europe, providing advice to national governments and the European Union with the goal of transforming the sector, and shaping research strategy and future change.

ECTP activity includes:

- Nurturing and promoting industry growth through innovation
- Supporting research challenges today and preparing for the challenges of tomorrow
- Enabling collaboration
- Partnering with the National Technology Platforms

The main areas of focus for ECTP today include:

- Active Aging & Design
- Energy Efficient Buildings (E2B)
- Heritage & Regeneration
- Infrastructure & Mobility
- Materials & Sustainability

Each of these areas is addressed by a specific committee with its own webpage. The Heritage & Regeneration Area was created to act as "A

LIVING CULTURAL HERITAGE FOR AN ATTRACTIVE EUROPE." As a testament to our common past and the basis of our identity, the European cultural heritage must be preserved.

The aim of the ECTP Heritage and Regeneration Committee is to represent the interest of all the stakeholders active in research, development and innovation in Cultural Heritage and Urban Regeneration, at a European level. In particular, the Committee helps to identify the RDI needs of the construction sector with regards to the conservation, management, to promote European built heritage as a valuable asset. Additionally the ECTP has the goal of responding to European socio-economic needs and environmental challenges while preserving the rich European cultural values.

The preservation of our built heritage's cultural values is performed with a wide-ranging perspective, which focuses on the complete process of cultural heritage preservation, from the materials to the end product.

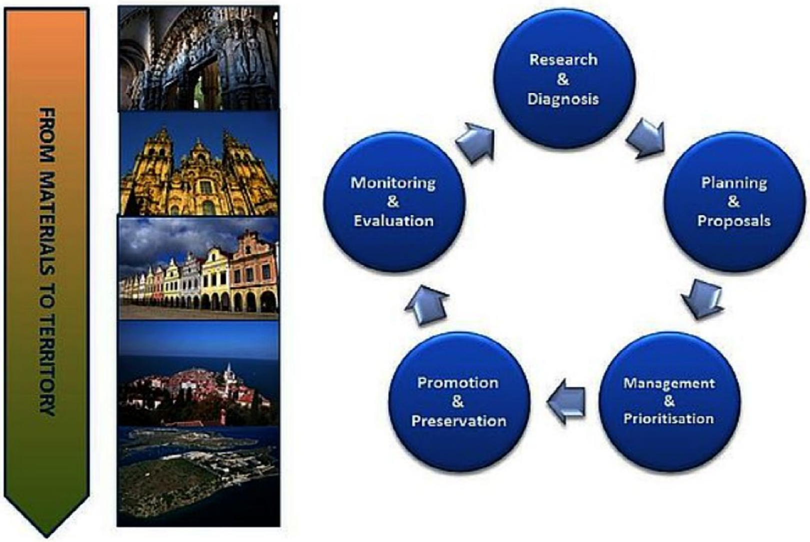

Figure: ECTP Heritage & Regeneration Committee. A Living Cultural Heritage for an Attractive Europe. Available at: www.heritage.ectp.org Last accessed: 16.04.2020

The structure of the Heritage & Regeneration Area is composed as follows:

- Chair: TECNALIA (Isabel Rodríguez-Maribona)
- Coordinator: ISAC-CNR (Adriana Bernardi)
- Executive Board:
  - Univ. Stuttgart (Jürgen Frick)
  - TNO (Timo Nijland)
  - Fraunhofer (Johanna Leissner)
  - CARTIF (Pedro Martín Lerones)
  - NCPP (Rita Moura)
  - ACE (Sara Van Rompaey)
- Plenary Assembly: All ECTP members

The main activities that Heritage & Regeneration performs inside ECTP activity are:

Coordination activities

- H&R meetings
- Attendance at ECTP Presidium & SC meetings
- Participation in the ECTP Conferences

Links with stakeholders and networks

- Interaction with policy makers: EP and EC
- Participation in the Community of Innovators in Cultural Heritage, promoted by the European Commission
- Member of stakeholders group for the future PPP

Contribution to Horizon 2020 proposals

- Letter of Support and participation to different proposals

Elaboration of ECTP documents

- Participation and contribution to elaborate the ECTP SRIA for Horizon Europe
- Contribution to draft document of the future PPP activity

Dissemination

- Different disseminations activities

The last Activities performed by the Heritage & Regeneration Committee were to contribute to ECTP activities for the creation of the Horizon Europe 2021-2027 Strategic Research and Innovation Agenda (SRIA). The committee followed and contributed to every step of the process throughout 2019, from creation of the document, to its validation and completion of the final version. Finally, inside the four objectives of the ECTP SRIA, namely: 1) clean built environment and cities, 2) built for and with the people, 3) prosperous construction ecosystem, 4) digitalisation, the emphasis on the cultural heritage is present in a direct or indirect way. In particular, in the second objective: "built for and with the people," the focus on cultural heritage is specifically cited in the 4. sub object: "Living cultural and historical built environment". The Heritage & Regeneration Committee wrote a position paper where the main topics, successively categorized in 9 priorities, blocked in 4+1 priority areas:

- Low Carbon Buildings: resource efficiency in cultural heritage maintenance and use
- Resiliency and Climatic Change: preventive conservation and innovative maintenance
- Smart Cities: recovering the importance of the historic city
- Digitalisation: Cultural Heritage in the digital era
- Socioeconomic Challenges
  - Integrated management and promotion of natural and cultural assets
  - Enhancement of local and European identity and cultural heritage as a vehicle for multicultural tolerance
  - The economic value of cultural heritage
  - From research to practice

In conclusion, the activities in the field of Heritage and Regeneration are an important contribution encouraging the Commission to consider the important issue of future commitment for research and development inside the Horizon Europe agenda.

MANAGING HERITAGE SITES AT RISK

Alessandra Bonazza

INTRODUCTION

In spite of the resources already committed at research and policy level in Europe in order to strengthen cultural heritage protection against environmental impact, further steps are undoubtedly needed. These changes are necessary in order to ensure the sustainable management and conservation of cultural heritage sites, structures and artifacts in facing climate change, particularly extreme events. Disasters and weather catastrophes pose risks not only to the conservation of the historical, cultural and artistic assets of cultural heritage, but also to the safety of visitors, staff and local communities living on the site or in neighboring areas. Additionally, extreme weather events cause undoubtedly negative consequences for the local economies and for the livelihoods of locals dependent on them, due to the loss of tourism revenues. Moreover, climate change is contributing to an increased intensity and frequency of hydro-meteorological events, such as heavy rainfall, wind-storms, heat waves and droughts. cultural heritage is put at risk not only by impending disasters, but very often also by emergency and post disaster recovery actions. Severe damage is often inflicted to cultural property during disaster response and also during the restoration and remedy phases, due to lack of preparedness in emergency situations and to misdirected actions taken during post disaster emergency and rehabilitation phases. Some reasons might be the lack of proper attention and funds, the bureaucracy barriers and the hazardous situations, which make cultural heritage assets not accessible to rescue teams. Unfortunately, it has also to be emphasized that existing measures on climate change adaptation, aiming at Cultural Heritage safeguarding, are still not exhaustively integrated in national strategies and plans.

THE ITALIAN NATIONAL STRATEGY FOR ADAPTATION TO CLIMATE CHANGE

The Italian National Strategy for Adaptation to Climate Change consists of three technical-scientific documents published in 2014, that constitute an updated basis on the technical knowledge of the impact of climate change and its vulnerability and provide a strategic perspective on adaptation:

- Strategic document "Elements for a National Strategy for Adaptation to Climate Change" [1]
- Technical-scientific Report "State of scientific knowledge on impacts, vulnerability and adaptation to climate change in Italy" [2]
- Technical-legal Report "Analysis of the EU National legislation relevant to impacts, vulnerability and adaptation to climate change" [3]

The strategy has been developed through a highly multidisciplinary approach and the coordinated action of different actors, such as scientific national experts, operational bodies (Civil Protection, rescue services), and policy and decision makers at national, regional and local levels. The strategy development processes, coordinated by the Italian Ministry of the Environment and Protection of Land and Sea with the technical and scientific support of the Euro-Mediterranean Centre on Climate Change (CMCC), foresaw a stakeholder involvement since the very

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beginning with ad hoc consultations with ministries and an online public consultation with citizens from October 30th, 2013 to January 20th, 2014. The preparation of this document's structure and contents began in July 2012 with the support of 232 experts.

The main objectives of the national strategy are the following:

- Assessment of the impact of climate change on diverse social-economic sectors and natural systems
- Reduction of risks induced by climate change
- Identification of a set of actions for adapting to and facing the impacts
- Improvement of adaptation capacities of natural, social and economic sectors
- Integration of the opportunities derived by new climatic conditions

Cultural Heritage is included among the different sectors under risk taken into consideration.

The Technical-scientific Report "State of scientific knowledge on impacts, vulnerability and adaptation to climate change in Italy" highlights the climate change impact assessment on cultural heritage. This assessment is based on the identification and prioritization of climate parameters concerning the cause of damage on cultural heritage located outdoors (built heritage, monumental complexes, archaeological sites, etc.) and indoors (museums, churches, hypogea, etc.). This identification derives mainly from the results achieved within EU FP6 Project "Global climate change impact on built heritage and cultural landscapes - Noah's Ark" (2004-2007) [4]. This project coordinated by CNR-ISAC produced a Vulnerability Atlas and Guidelines for cultural heritage protection towards climate change for the first time. The Noah's Ark coupled climatology with conservation science expertise, acquired a unique know-how in delivering future forecast of cultural heritage vulnerabilities induced by outdoor-indoor climate changes, including extreme weather related events [4]. In addition, the report contains an identification of the main damage processes, occurring on heritage materials mainly located outdoors, that are expected to undergo modifications in the future due to climate change:

i) corrosion on metals;
ii) mechanical damage and fungal growth on wood;
iii) surface recession, blackening, thermal stress, frost weathering, salt crystallization, biodegradation on stone, brick and mortars.

The expected changes for each deterioration process are clearly described on the basis of the available scientific literature on the topic [4-10]. It should be underlined that vulnerability and risk assessment is provided in accordance with the approach adopted within the Noah's Ark project, that considered a synergic action of different climate and pollution parameters occurring over time on architectural surfaces and provided a quantitative evaluation of the effects of "slow" climate changes through the use of damage functions.

A major concern on the effects of disasters and natural hazards (such as floods, landslides and heavy rain) is evidenced for the built heritage and cultural landscape in general, while the conscious adoption of environmental monitoring is proposed as a fundamental tool for preventive conservation of collections in museums. Concerning the existing gaps within the current state of knowledge in relation to the impact of climate change on cultural heritage, a major concern is the lack of an exhaustive set of observation data from environmental monitoring, necessary for a proper correlation of the damage with changes in climate. Additionally, there is evidence of the need for damage implementation modeling which aims to produce future scenarios on local scale, based on quantitative evaluation and vulnerability indicators. Finally, the development of multi-risk scenarios for complex systems (i.e. urban historic centers, archaeological sites, cultural landscape) is recognized as a priority.

DG-EAC STUDY: "SAFEGUARDING CULTURAL HERITAGE FROM NATURAL AND MAN-MADE DISASTERS. A COMPARATIVE ANALYSIS OF RISK MANAGEMENT IN THE EU"

The overall objective of this study was to contribute to the development of good practices in order to integrate cultural heritage into national disaster and risk reduction strategies developed by EU Member States [11]. In order to support and achieve this aim, the following specific objectives were accomplished by:

1) Providing an overview of the information available at the EU and international level on risk assessment and prevention to safeguard cultural heritage from the effects of natural disasters and threats caused by human action;
2) Mapping the existing strategies in all 28 Member States for disaster risk management of cultural heritage, with a focus on existing competence centers and tools, by surveys and interviews to key experts;
3) Providing recommendations on possible measures to improve the risk management of cultural heritage at European level.

To achieve these objectives, the 12-month study was structured in 3 main tasks:

- Task 1 drew an overview of the information available at EU and international level on risk assessment and prevention for safeguarding cultural heritage from the effects of natural disasters and threats caused by human action, using a State-of-the-Art approach.
- Task 2 mapped the existing strategies and practices in all 28 MS on disaster risk management of cultural heritage, with a focus on existing competence centers and tools. This task was conducted through surveys and interviews with key actors in public and private research entities, policy-oriented international and national organizations (including UNESCO, ICCROM, ICOMOS, Council of Europe, Europa Nostra, National Ministry of Culture, etc.) and stakeholders operating on cultural heritage protection (e.g. Blue Helmets, Blue Shield, National, Regional and Local Authorities, Civil Protection, Private Associations).
- Task 3 identified strengths and weaknesses through information exchanges and consultations amongst team members with the final aim of formulating conclusions and recommendations for Europe.

Diverse risk factors were taken into consideration. Acting individually and in combination, these factors are linked to threats caused by natural and man-made disasters (e.g. climate change, air pollution, flood, landslide, earthquake, volcanic eruptions, fire, armed conflicts, and illicit trafficking). Special attention was also given to the impact of climate change as a consequence of human activity's impact on the intensity and frequency of the occurrence of slow and extreme events damaging cultural heritage (e.g. surface recession and erosion by precipitation, bio-deterioration, de-cohesion and fracturing due to salt crystallization, sea level rise and thermal stress amongst other factors). The activities carried out within the Study highlighted that the integration of cultural heritage into national disaster and risk reduction strategies developed by EU Member States still suffers from:

- The lack of coordination between and across the different (European, National and Regional) strategies of risk management policies in most countries
- The lack of alignment in the responsibility chain from policy making to practical application
- The low current priority of cultural heritage in risk management planning
- The lack of integration of cultural heritage protection measures into risk management strategies

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The Study's conclusion indicated that in order to maximize synergies between the political, governmental and operational levels in the field of disaster awareness, an integrated approach is required, as illustrated in the diagram below.

INTERREG CENTRAL EUROPE PROJECT PROTECHT2SAVE. "RISK ASSESSMENT AND SUSTAINABLE PROTECTION OF CULTURAL HERITAGE IN A CHANGING ENVIRONMENT"

The ongoing Interreg Central Europe ProteCHt2save Project aims to improve the capacities of the public and private sectors to mitigate the impacts of climate change and natural hazards on cultural heritage sites, including: monumental complexes, historic buildings and archaeological sites in urban and coastal areas in Central European Countries. The project focuses primarily on the development of feasible and tailored solutions for building resilience of cultural heritage to extreme events linked to climate change by supporting regional and local authorities with preparedness measures and evacuation plans in case of emergencies.

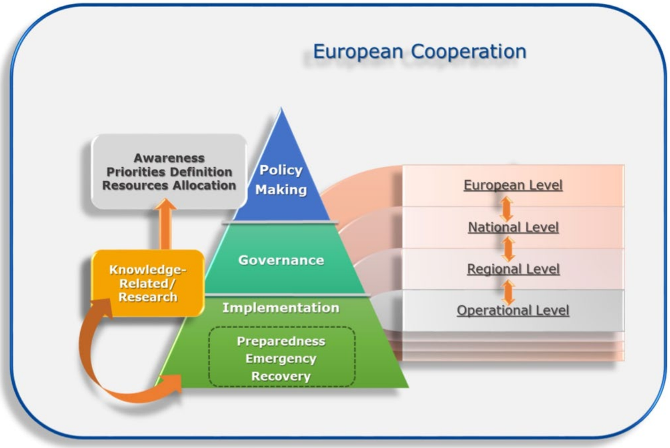

Figure: Flow of relevant data and information across political, governmental and operational interests to aid decision making in disaster awareness and risk aversion functions across all levels of involvement [11]

A Web GIS Tool has been designed to support policy decision makers in the identification of risk areas and vulnerabilities for cultural heritage in Central Europe which are exposed to extreme events linked to climate change. Risk maps with spatial resolution of 12x12 km referring to heavy rain, flooding, drought and extreme heat are provided. Specifically changes of temperature and precipitation and of climate risk indices are available for 2 historical periods (1987-2016 and 1951-1980) and under Representative Concentration Pathway scenarios RCP4.5 (stabilization) and RCP8.5 (pathway) for 2 future 30-year periods (2021-2050 & 2071-2100) with respect to the reference historical one (1976-2005).

Reliable, high-resolution climate change projections associated with a quantification of their uncertainty are crucial for estimating future climate change impacts and for planning adaptation/mitigation strategies. The WCRP Coordinated Regional Downscaling Experiment (CORDEX, http://wcrp-cordex. ipsl.jussieu.fr) is an internationally-coordinated effort aiming to harmonize the evaluation of state-of-the-art regional climate models (RCMs) and to generate multi-model ensembles of regional climate projections worldwide. A sub-ensemble of the CORDEX framework is the EURO-CORDEX initiative (http://www.euro-cordex.net), which provides regional climate projections for Europe at two different spatial resolutions, namely the "standard" resolution of 0.44 degrees (EUR-44, ~50 km) and a finer resolution of 0.11 degrees (EUR-11, ~12 km). Within the EURO-CORDEX experiment, seven regional climate models were employed to dynamically downscale the Climate Model Intercomparison Project phase 5 (CMIP5) global climate model (GCM) projections using the latest Representative Concentration Pathways (RCPs) emission scenarios. When RCMs are driven by a large-scale global model, in addition to the uncertainties inherent in the specific RCM at hand, additional uncertainty is inherited from the driving GCM. This reality is affected by model inadequacies as well. In order to estimate this type of uncertainty, a common approach consists of considering an ensemble of simulations performed with a given RCM, driven by different GCMs. The spread among the RCM outputs provides an estimate of the effects of GCM diversity on the RCM simulations.

Within ProteCHt2save, we selected the EURO-CORDEX simulations at 0.11 degrees resolution among those available (http://euro-cordex.net/imperia/md/content/csc/cordex/20161219-eurocordex-simulations.pdf). RCM historical and projection simulations have been analyzed in order to calculate anomalies and changes of future climatologies with respect to past conditions. The historical period we accounted for is 1986-2015, while for the future, we referred to long-term climatologies around mid-21st century (e.g. 2021-2050) and end of the century (e.g. 2071-2100). We have considered two future emission scenarios among those employed in the latest IPCC assessment report (AR5), namely RCP4.5 and RCP8.5. We also considered historical and scenario simulation with the state-of-the-art high resolution global climate model, EC-Earth, run by ISAC-CNR in the framework of a PRACE project (Climate SPHINX, http://sansone.to.isac.cnr.it/sphinx). These simulations include existing experiments performed at resolutions ranging between 125 and 16 km and the analysis focused on the European region. The biases the models may eventually exhibit have been corrected using state-of-the-art station-based reference datasets, such as E-OBS, available for the European domain, which is a robust and widely used dataset, regularly updated. E-OBS provides long-term daily precipitation and near surface air temperature climatology (from 1950 to present, http://www.ecad.eu/download/ensembles/ensembles.php). Its spatial coverage includes all land areas in Europe and in the Mediterranean region; it is supported by a clear documentation on the methods used to derive it (interpolation techniques, underlying stations, etc.) and the underlying orography (elevation data) and individual station data are available as well.

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LETTER TO MEMBERS OF THE EU MISSION BOARD "CLIMATE ADAPTATION"

Prof. Daniela Jacob, German Climate Service Center, Hamburg, Prof. Johan Rockström, Potsdam Institute for Climate Impact Research, Potsdam, Dr. Jaroslav Mysiak, Euro-Mediterranean Centre on Climate Change (CMCC), Venice

BACKGROUND TEXT FROM EU COMMISSION ON MISSIONS:

A mission in this area will help maximise the impact of the EU's support to research and innovation and demonstrate its relevance for society and citizens.

Its focus will be on solutions and preparedness for the impact of climate change to protect lives and assets. It will include behavioural changes and social aspects by addressing new communities beyond usual stakeholders, which help lead to a societal transformation.

Why cultural heritage must be included in the "Mission Climate Adaptation"? Europe has a rich and divers cultural heritage which has multifaceted significance for Europe and its citizens as it was highlighted in 2018 by the European Year of Cultural Heritage. It offers immense and virtually untapped potential to drive climate action and adaptation and support ethical and equitable transitions by communities towards low carbon, climate resilient development pathways.
With this background in mind important international initiatives have formed: On 24 October 2019 the Climate Heritage Network (http://climateheritage.org/) was launched in Edinburgh with more than 160 delegates from all over the world to support the implementation of the Paris Climate Agreement. On 25 October 2019 the Working Group Cultural Heritage for IPCC started in Sterling (Scotland). These initiatives will be presented at #COP25 with the team from #ClimateHeritage telling heritage stories of climate action.

Realizing that potential, however, requires both better recognition of the cultural dimensions of climate change and adjusting the aims and methodologies of heritage practice. Cultural heritage is the memory of our civilization and is a non-renewable resource that needs to be included in the EU mission Climate Adaptation to better communicate and visualize climate issues and adaption to the European citizens and decision makers. Furthermore, the European Union has the longest (35 years) and most diverse research programme for the protection of cultural heritage in the world and thus the sector can demonstrate convincingly its relevance for society: The EU was the first in addressing research to study the climate change impacts on cultural heritage (2004, Noah´s Ark) and has since then continued with more in depth research on climate impacts on historic buildings and future energy demand as well as adaptation measures and early warning tools for extreme climate events (Climate for Culture 2009 – 2014; Heracles and Storm 2016 – 2019).

Limiting global warming to 1.5°C would require "rapid and far-reaching" transitions in land, energy, industry, buildings, transport, and cities, the Intergovernmental Panel on Climate Change (IPCC) has said. Better addressing the ways in which cultural heritage is both impacted by climate change and a source of resilience for communities would increase the ambition for --- and effectiveness of -- transformative change.

There are significant cultural heritage dimensions to every aspect of climate action covered by the Paris Agreement, including heightening ambition to address climate change, mitigating greenhouse gases, enhancing adaptive capacity, and planning for loss and damage. For instance, historic and existing buildings represent an important source of embodied carbon and their reuse is a key strategy in many regions for avoiding future emissions associated with new building construction. Cultural heritage supports climate adaptation in a variety of ways, including learning from past social adaptability to environmental change and leveraging pride of place and social values to guide contemporary resilience planning. Climate change is already impacting communities and heritage globally, and these trends are rapidly worsening. It is paramount to systematically cataloguing the impacts of climate change drivers, in order to aid in evaluating and managing both climate risks to cultural heritage and the positive role it can play as a source of resilience.

"No community, culture, region or type of heritage is immune from climate risks. Climate change impacts from sea level rise and coastal flooding to drought and extreme heat, will sorely test the adaptive capacity of diverse cultural systems," said Adam Markham of the Union of Concerned Scientists.

Given the nature and scale of climate impacts it will require fast updating how we conceive of heritage and how we manage it. Multi-disciplinary research and approaches will be required in areas such as heritage documentation, disaster risk reduction, vulnerability assessment, conservation, education and training as well as in the ways heritage sites are presented to visitors. While the heritage community must intensify its climate action, so too must climate scientists and policy-makers responsible for implementing the Paris Agreement finally fully engage with culture and heritage. The European mission Climate adaptation will help to build bridges between cultural heritage practice and climate science, including strengthening involvement by cultural heritage experts in the work of the IPCC. "What climate science tells us is that adaptation and mitigation are necessary. What climate science cannot tell us is what adaptation options are most workable within any given human system. Cultural heritage is a source of creativity and inspiration that can answer this," said Dr. Marcy Rockman, a Lead Author of the ICOMOS report 2019 and ICOMOS's IPCC Working Group Lead.

AGREED ON NOVEMBER 29, 2019 AT VILLA VIGONI

on the occasion of the German-Italian Scientific Symposium at Villa Vigoni funded by the German Ministry of Education and Research (BMBF) Cultural Heritage in Crisis – Cultural Heritage Research at European Level – Challenges in Times of Climate Change and Digitalization

By following participants:

- Prof. Dr. Cristina Sabbioni, coordinator of Noah`s Ark project (CNR-ISAC, Bologna)
- Dr. Johanna Leissner, coordinator of Climate for Culture project (Fraunhofer-Gesellschaft, Brussels)
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Supporting documents:

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Figure: Participants of the Symposium „Cultural Heritage in Crisis“ at Villa Vigoni

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