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Concept for a Summer University on Cultural Landscapes in Climate Change[1]

(Intellectual Output 2 – CHePiCC online)

Natural and man-made hazards, anthropogenic effects and extreme events related to climate change increasingly threaten cultural and natural heritage in Europe and worldwide (Bonazza et al 2018).

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Appendix

Bertolin, C. / Califano, A. / Schwai, M. (eds.) CHePiCC Summer School "Cultural Heritage Protection in Climate Change". Trondheim, Norway. 30th May 2022 – 4th June 2022.

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Introduction

The concept of this summer university is firmly embedded within the Erasmus+ Strategic Partnership "Cultural Heritage Protection in Climate Change online (CHePiCC online)", which translates state-of-the-art research on climate change and cultural heritage protection into distance and blended learning programmes for higher-education learners, following EU guidelines and directives as well as firmly basing the preparedness approach for cultural heritage protection on the Sendai Framework for Disaster Risk Reduction. The main and long-term objective of this project is to bring heritage back into higher education teaching and learning, to enable future generations to protect cultural heritage and thereby identity for the future and to facilitate a behavioural change concerning cultural heritage protection and climate change, especially in the future professional lives of higher education learners and teachers. The necessary holistic approach to the wide topic of cultural heritage protection is ensured by the transdisciplinary composition of the partnership which holds expertise in cultural property protection, cultural landscapes, climatology and climate change, structural engineering, material handling, preparedness measures, heritage sciences, conservation-restoration and the collaboration with emergency responders. All project partners bring state-of-the-art research from current high-profile research projects to the partnership and thus guarantee a research-based approach to higher education and with their individual expertise on distance and blended learning in HE a student-centred approach in the developed outputs of the project.

CHePiCC online is firmly anchored within current European incentives to mitigate climate change and to protect cultural heritage which is an integral part of our identities, and which is severely threatened by climate change and climate change induced natural disasters. Following the success of the European Year of Cultural Heritage in 2018, the European Framework for Action on Cultural Heritage names the holistic approach to the topic as one of the four principles for success and highlights the importance of cultural heritage as a resource for the future. The project's main output, an open-access Massive Open Online Course on cultural heritage protection in climate change promotes cultural heritage as exactly that resource and enables higher education teachers and learners to build their future on our pasts. Cultural heritage is exposed to a number of risks in the 21st century, a fact that is highlighted by the joint EU-UNESCO Initiative#7 "Heritage at risk" as well as ICOMOS, which in 2019 put a focus on engaging cultural heritage in climate action and a number of high-profile research project programmes funded by the EU.

The immediately tangible objectives of the project are a) a Massive Open Online Course on Cultural Heritage Protection in Climate Change (covering cultural landscapes, built heritage, material preservation and climate change and thus create an interconnection between the topics), and b) a tested and evaluated concept for a transdisciplinary summer university on cultural landscapes in climate change. This paper provides the background concept for the transdisciplinary summer university, which was evaluated in May 2022 in Trondheim, Norway. It is designed as blended-learning add-on to the Massive Open Online Course on Cultural Heritage Protection in Climate Change, which means that the participants in the summer university are to finish the MOOC to be able to participate in the summer university. Whilst purely online summer schools have been evaluated by the project consortium during the pandemic, showing that practical approaches to heritage education for climate action can be transferred into a highly productive online setting, much appreciated by participants from different heritage backgrounds. The additional opportunity of providing the participants with an on-site exercise should be grasped wherever possible. Bringing together participants from heritage and emergency responders' sides has proved highly beneficial for both sides when it comes to training for cultural heritage protection.

The summer university was set up to be adaptable to any cultural landscape and built heritage in Europe, in any climate zone, exposed to its very own risks from climate change and resulting effects and natural catastrophes. The main issues treated within the summer university are

- Built cultural heritage as integral part of cultural landscapes
- Climate change and related natural catastrophes
- Climate change as connecting threat between cultural landscapes and cultural heritage.

The set-up is a blended one, where an on-site event follows an extensive online self-learning phase (the Massive Open Online Course developed in the project), student-centred, research based and with a clear hands-on approach in which the students must dive into the challenges on site and develop (together with guiding experts) innovative and tailored solutions.

The workload was designed with 50 hours for the participation of the intense week, with an academic reflection paper to earn ECTS the workload lies with 150 hours.

The target groups of the summer university are higher education students of architecture, structural and material engineering studies, climatology, landscape and urban planning, restoration, conservation, heritage and landscape professionals as well as stakeholders of the local, regional and national levels.

The detailed set-up of the test run in Trondheim, Norway, can be seen in the extensive documentation booklet provided by the project partners from the Technical University in Trondheim, Norway, which is attached to this concept paper. The concept paper provides the technical background information for reproducing a tailored summer university at any place in Europe or around the world. We recommend that both the booklet and this paper are used in tandem. The chapters below focus on the main topics of the CHePiCC online project, which are mirrored in the summer university set-up:

- Cultural landscapes
- Climate change
- Built heritage
- On-site hands-on training

References:

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Chapter 1 – Cultural Landscapes

1.1 Cultural Dimension, Architecture, Heritage and Landscapes[2]

The cultural dimension is a part integral to the concept of landscape. Landscapes are therefore, including cultural and natural ones, the result of the interaction between nature and human beings and reflect the intimate and longstanding relationship between people and their natural environment.

Cultural landscapes are combined works of nature and humankind that express a long and intimate relationship between peoples and their natural environment. They are representative of the different regions of the world and can reflect specific techniques of land use that guarantee and sustain biological diversity. Some cultural landscapes are associated with powerful beliefs and artistic and traditional customs, embodying an exceptional spiritual relationship of people with nature.

Landscape and heritage are closely related. Architecture can play an important role in landscape intervention, both natural and cultural, by establishing precise actions to protect and preserve cultural and natural heritage. For example, in the case of cultural landscapes that reflect specific land use techniques that ensure and sustain biodiversity, architecture can intervene to protect and preserve these techniques and the resulting landscape. In other cases, where cultural landscapes are associated with powerful beliefs and artistic and traditional customs, architecture can intervene to protect and preserve these sites and their unique spiritual relationship with nature.

Heritage and Landscape in climate change is a topic that explores how the natural and cultural heritage of the world is affected by the impacts of climate change, and how it can also contribute to mitigating and adapting to those impacts. Heritage and landscape in climate change also examines how tourism, which is often dependent on the attractiveness and integrity of heritage sites, can be a source of both threats and opportunities for heritage conservation and sustainable development in a changing climate.

Some examples of heritage and landscape affected by climate change are:

- **Venice and its Lagoon:** A World Heritage site, which is threatened by rising sea levels, flooding, erosion, saltwater intrusion, and subsidence.
- The **Bandiagara Escarpment** in Mali, which is a cultural landscape that reflects the traditions and beliefs of the Dogon people, but is facing droughts, desertification, land degradation and loss of biodiversity.
- The **urban landscapes** of European cities, which are shaped by historical and cultural influences, but are also vulnerable to heat waves, storms, floods and air pollution.
- The **Canary Island Word Heritage**, where natural and cultural landscape are integrated

[2] Juan Manuel Palerm, University of Las Palmas, Gran Canaria (ULPGC).

The conflicts between landscape, architecture and heritage are those that arise from the interaction between the natural and cultural environment, the artistic and technical expression of construction and the historical and social memory of places. Some of these problems are:

- The contradiction between architecture that allows immersive access to the landscape and tourism that consumes and degrades natural monuments.
- The threat of climate change on the outstanding universal value, integrity and authenticity of heritage sites, as well as on the economies and communities that depend on tourism.
- The difficulty of defining the spatial and temporal limits of cultural landscapes, as well as of recognizing their diversity and complexity.

Based on the recognition of these conflicts, the proposed solutions focus on:

- Heritage conservation by restoring, reinforcing or replacing deteriorated or damaged structural elements, using appropriate techniques and materials.
- The integration of architecture with the landscape, respecting its character, its scale and its materiality, and creating forms that dialogue with the natural and cultural environment.
- The participation of the local community and stakeholders in landscape and heritage management, promoting education, awareness and commitment to protection and sustainable development.

Some of the benefits of integrating architecture with the landscape are:

- Improves air quality by incorporating vegetation that absorbs carbon dioxide and produces oxygen.
- Reduces the environmental impact by using local, recycled or renewable materials, and by optimizing the use of natural resources such as light, water and climate.
- Promotes cultural identity by respecting and valuing the historical, artistic and social heritage of places.
- It enriches the human experience by creating spaces that stimulate the senses, promote well-being and generate emotions.

Some of the challenges that architecture integrated with the landscape has, are:

- The contradiction between immersive access to the landscape and tourist consumption that degrades natural monuments.
- Adaptation to the climatic, geographical and cultural conditions of each place, using appropriate techniques and materials.
- Innovation in the form and function of architecture, without losing respect for the historical heritage and local identity.
- Sustainability in the use of natural resources and mitigation of the environmental impact of construction and occupation.

Architecture and landscape are two disciplines that can work together to create more sustainable, liveable, and beautiful spaces. Integrating architecture and landscape means considering the natural and cultural context of a site, as well as the needs and desires of the users and the community. Some of the benefits of integrating architecture and landscape are:

- It can enhance the environmental quality and resilience of urban areas by promoting biodiversity, water management, climate adaptation, and energy efficiency.
- It can improve the social and psychological well-being of people by providing access to nature, recreation, and public spaces.
- It can create a sense of identity and belonging by reflecting the history, culture, and values of a place.
- It can foster innovation and creativity by combining different fields of knowledge, tools, and perspectives.

Some examples of projects that integrate architecture and landscape are:

- The Role of Integration of Architecture and Landscape in Shaping Contemporary Urban Spaces: A research paper that analyses how different urban design strategies can create more integrated and harmonious spaces.
- Architecture and Nature: A Framework for Building in Landscapes: Research that explores the experiences and design philosophies of several architects and practices that have built in natural settings.
- Special Issue \"Integrating Urban Design and Landscape Architecture\": A collection of papers that address various topics related to the integration of architecture and landscape, such as urban regeneration, green infrastructure, participatory design, and cultural heritage.

Landscape and architecture are influenced by the ongoing climate change as well as the actions of the protection of heritage in several ways, such as:

- Climate change poses a threat to the integrity, authenticity and value of many World Heritage properties, especially those that are vulnerable to natural disasters, sea level rise, erosion, biodiversity loss and extreme weather events.
- Climate change also creates an opportunity for architecture to adopt more sustainable and resilient practices, such as reducing greenhouse gas emissions, improving energy efficiency, using renewable sources and materials, and integrating with the natural environment.
- The protection of heritage requires a balance between preserving the cultural and historical significance of the sites and adapting them to the changing conditions and needs of the present and future generations.
- The protection of heritage also involves **a** responsibility for architecture to respect and enhance the local identity, diversity and culture of the places, as well as to engage with the community and stakeholders in the management and conservation processes.

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The quality of the architectural project integrated with heritage and landscape, depending on climate change, can be evaluated from different perspectives, such as sustainability, adaptability, integration and participation.
Sustainability refers to the project's ability to reduce its environmental impact, both in the construction and use phase, using local, recycled or renewable materials, the optimization of natural resources such as light, water and climate, and the generation of ecosystem benefits such as climate regulation, carbon sequestration and biodiversity conservation.
Adaptability refers to the ability of the project to respond to changing conditions of the natural and cultural environment, both present and future, using flexible, resilient and reversible techniques and solutions, which allow preserving the outstanding universal value, integrity and the authenticity of heritage sites.
Integration refers to the ability of the project to harmonize with the landscape, respecting its character, its scale and its materiality, and creating forms that dialogue with the natural and cultural environment, enhancing the identity, diversity and beauty of the places.
Participation refers to the ability of the project to involve the local community and stakeholders in the process of design, management and conservation of heritage and landscape, promoting education, awareness and commitment to protection and sustainable development.
An architectural project integrated with heritage and landscape that meets these criteria may contribute to mitigating and adapting to climate change, as well as generating cultural and natural value for present and future generations.

Some of the challenges that exist in achieving these criteria are:

- The lack of information on the current and future state of heritage and landscape, as well as on the best practices and solutions for their conservation and adaptation to climate change.
- The lack of economic, technical and human resources to implement quality projects, which require a higher initial investment, but which generate long-term benefits.
- The lack of coordination between the different agents involved in the project, such as the owners, managers, designers, builders, regulators and users, who may have different or conflicting interests or visions.
- The lack of awareness about the importance and urgency of protecting heritage and landscapes against climate change, as well as about the role that architecture can play in this regard.

Some of the solutions proposed to overcome these challenges are:

- The generation and dissemination of knowledge about heritage and landscape, through research, documentation, monitoring and communication of the impacts of climate change and mitigation and adaptation measures.
- The mobilization and allocation of resources for the development of quality projects, through the search for alternative or complementary sources of financing, the application of efficiency and profitability criteria, and the assessment of social and environmental benefits.

- The cooperation and participation of the different agents involved in the project, through the creation of spaces for dialogue, consultation and consensus, the establishment of objectives and shared responsibilities, and the promotion of trust and mutual respect.
- Education and awareness about the importance and urgency of protecting heritage and landscapes against climate change, through the dissemination of good practices and successful examples, the promotion of responsible attitudes and behaviours, and the generation of emotions and positive links with the environment.

1.2 Terraced Landscapes as Case Study[3]

Cultural Landscape in the Elements for a National Strategy for Adaptation to Climate Change

The strategic document "Elements for a National Strategy for Adaptation to Climate Change" of the Italian National Strategy proposes, as main action to be undertaken for facing the impact of climate change on cultural heritage and landscape, the integration of the management plans (existing ones or under definition) with measures of preparedness, recovery and response to emergency specifically addressed to the safeguarding of the built and natural environment. This can be achieved either by adding specific sections concerning adaptation to climate change or inserting appropriate measures in existing sections through a review of directives and management plans already adopted.

General short (by 2020) and long (over 2020) term "soft" recommendations are also given aiming at increasing the awareness on impacts, vulnerability and adaptation measures.

Concerning landscaping assets, the safeguarding of terraced landscapes by the recovery of dry-stone walling technique is recommended as adaptation strategy to strengthen the resilience to climate change by preventing hydrogeological instability and desertification.

Within this framework, the present contribution aims at illustrating the first "Introductory course, theoretical and practical, for the construction of dry-stone walls typical of the Aeolian terraced landscape" organized in the Island of Lipari with the major objective of training local people on traditional techniques for the construction of dry-stone walls typical of the Aeolian landscape.

Experience in the field. Sharing best practices for safeguarding the heritage of hand-built terraces in Aeolian islands in a changing environment

In the last decades, land abandonment and tourism pressure has caused serious threat to functions and the integrity of the Aeolian Islands rural heritage landscape. Entirely abandoned after the second World

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[3] Alessandro Sardella, Alessandra Bonazza, Institute of Atmospheric Sciences and Climate of the National Research Council of Italy (CNR-ISAC).

War and extremely deteriorated because of lack of use and maintenance, terraces in the Aeolian Archipelago and their traditional techniques of cultivation, represent a significant resource for strengthening the resilience of the communities of small islands to climate change impact.

The Aeolian Islands are in the Southern Tyrrhenian Sea at the North of Sicily and consist of the seven main islands and several uninhabited islets. Lipari, Vulcano, Filicudi, Alicudi, Panarea and Stromboli belong to the Municipality of Lipari, the largest island of the Archipelago, whereas Salina belongs to the Municipalities of Santa Marina, Leni and Malfa.

The current shape of the islands landscape is due to the succession of eruptive activity over 250,000 years. Providing an outstanding record of volcanic island-building and destruction, and ongoing volcanic phenomena, the Aeolian Archipelago is listed in the World Heritage List of UNESCO since 2002.

The islands are well known since the prehistoric time (4,000 B.C.) thanks to the strategic geographical position in the Mediterranean and to the presence of the obsidian, a volcanic glass from lava flow enriched in silica erupted in Lipari. The human presence on the islands determined the start of the use of land for subsistence with the practice of agriculture and pastoralism. The first builders of dry-stone walls to the Aeolian Islands constructed artificial terraces to create arable areas supported by high stone walls.

Terraces are distributed in all the islands, with exception of Vulcano [1]. Terraced areas in Lipari are distributed patchier and the islands of Alicudi, Filicudi, Salina and Panarea are entirely terraced except for land composed of loose substrates (skiing) and cliffs. In Vulcano, the almost total absence of terraces is due to last eruption in 1888-1890, which determined the abandonment of large parts of cultivated terraces.

Highly inhabited and extensively cultivated (olive tree, wheat, barley, caper plant, legumes, citrus tree, vegetables, etc.) since the middle of the 20th century, terraced cultivated areas were almost abandoned in 1950-1960 reaching currently the 90% [1]. The progressive abandonment of agricultural activity and the lacking maintenance of dry-stone walls implied consequently a severe damage of the landscape [2].

Deterioration of dry-stone walls, because of abandonment, in the islands is determined by:

- increasing of the spontaneous growth of vegetation that causes the destabilization of the wall (dislodging and collapsing of single stones);
- dislodging of top stones by action of large animals;
- erosion by rain and wind, particularly during extreme events of rain;
- fire, particularly during prolonged drought periods.

Following the recommendation included in the strategic document “Elements for a National Strategy for Adaptation to Climate Change”, from 2018 CNR-ISAC collaborated with Aeolian associations and with the Italian branch of the International Terraced Landscape Alliance (ITLA Italia APS) in the organization and realization of training activities at territorial scale in order to increase awareness and disseminate best

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practices of landscape maintenance for strengthening local resilience to extreme event linked to climate change.

The Introductory Course, theoretical and practical, for the Construction of Dry-Stone Walls typical of the Aeolian Terraced Landscape

The first "Introductory course, theoretical and practical, for the construction of dry-stone walls typical of the Aeolian terraced landscape" held in the island of Lipari in 2018 was funded by the Aeolian Island Preservation Fund (AIPF). The major objective of the course was training local people on the traditional techniques for the construction of dry-stone walls typical of their landscape.

The course consisted of theoretical and practical sessions, including the construction of a dry-stone wall in situ, conducted under the coordination of professionals on environmental science, building technologies, biodiversity, geology, archaeology, and craftsmen expert on traditional building techniques. It was structured to allow the participants to take advantage of an action learning process on significant and peculiar aspects of territorial identity.

The exchange of knowledge and experience were addressed to recover intangible aspects of rural heritage and contribute to the sustainable maintenance and environmental protection of landscape from the environmental, social and economic point of view.

The course aimed to train artisans capable of conducting an important work of ordinary and extraordinary maintenance of existing ruined masonry or to build ex novo dry-stone walls following the traditional construction techniques, researching and choosing the equipment, the materials and the products needed.

The activities and the results of the project interested residents, farmers, craftsmen, unemployed persons, voluntary associations, experts of the academic and scientific community. The course lasted for five days with classroom lectures and practical sessions.

Classroom lectures focused on environmental, rural and cultural value of the dry-stone walls of the terraces in the Aeolian Archipelago; landscape protection and conservation; climate change and related risks on natural environment; building construction techniques of dry-stone walls (basics of static and stability of walls, analysis of materials and their application, sizing site, types of building materials and equipment); management of safety in situ.

Guided excursions on historic terraces in the Islands where the construction technique of the traditional dry-stone walls is particularly representative were a fundamental part of the course. Practical activity was based on the restoration and construction of a dry-stone wall in an area in Lipari through the following activities under the guide of experienced craftsmen: setting the work, preparation of the site area, selection of suitable stone, stone working with traditional tools, method of laying the stones.

The main phases of work conducted during the practical session of dry-stone wall building are listed below:

- cleaning and preparation of the reconstruction area with movement of the crumbled stones to the recovery area and separation of the big stones from the small ones to facilitate the reconstruction of the new wall;
- preparation of guides to regulate the slope of the wall
- excavation of the foundation trench, basement compaction and realization of the first layer positioning the larger stones;
- placement and embedding of stones following their natural shape;
- internal filling with small-sized stones, locally named minutame;
- layering and levelling.

Future perspectives

Geomorphological features of the Aeolian Islands determined over the time the human settlements distribution empowering the better use of landscape for the survival of the community. One of these landscape modelling has been since ancient times the construction of terraces on these inhospitable volcanic lands by realizing dry-stone walls to contain soil and obtain arable lands. Terraces are recognized of primary importance for the strengthening of landscape resilience to climate change playing a key role in preventing landslides and floods improving slope stability, and in striving land erosion and desertification, heightening biodiversity and generating adequate microclimatic conditions for agriculture. This is the leading reason of the recent inscription (2018) of the art of dry-stone walling comprising knowledge and techniques in the List of Intangible Cultural Heritage of UNESCO and it should be kept alive and transmitted by performing courses like the one described within the present contribution.

Such courses will contribute to boost the agricultural activity by recovering the cultivation of the products of the past as a potential resource for the social and economic development of the Aeolian territory as well as to protect the territory and the cultural landscape from social and economic point of view by creating new professional skills and retraining of artisanship in danger of extinction. In addition, by transmitting the traditional building techniques, they will facilitate the promotion of intervention on the existing terracing, improving consequently the resilience of the Aeolian landscape to climate change.

The overall objective is to create a continuous activity of training and capacity of building over time involving local stakeholders aiming at [3,4]:

- keeping alive a traditional craft in danger of extinction, characterized by high professionalism and quality of the products;
- encouraging generational turnover, through the transfer of skills acquired by craftsmen during their professional experience;

- giving participants the opportunity to obtain placements, ensuring the necessary tools and theoretical and practical skills;
- encouraging the creation of craftsmen small enterprises (SMEs);
- providing more cultivable land surfaces for the development of sustainable agriculture;
- protecting and enhancing the rural landscape as a leading resource for the promotion and improvement of local economic development;
- improving the hydrogeological features of the area.

A future step is to create the necessary expertise that will be acquired for the creation of an Aeolian Rescue Team for recovering and maintenance of dry-stone walls on abandoned terraces with high degree of deterioration. Educational initiatives for scholarships and citizen are also planned to increase awareness on the significance and value of cultural landscapes.

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Chapter 2 – Climate Change and Natural Catastrophes[4]

Impact of Climate Change on Cultural Heritage and Cultural Landscape

Climate change-induced hazards put cultural heritage worldwide under constant pressure with increasing daily frequency. Research dedicated to risk assessment, sustainable solutions for strengthening preparedness and mitigation and adaptation strategies, specifically dedicated to the protection of cultural and natural heritage, are fundamental. In fact, over the past 20 years, research in the field of assessing the impacts of climate change on cultural and natural heritage and related risks has achieved important milestones thanks to the support of European and national projects [1]. Research conducted up to now on climate change impacts on built heritage provides evidence of the driving role of climate parameters in determining forthcoming decay processes [2-3].

In a recognized situation of climate change, understanding what to expect in terms of degradation of cultural heritage in the future is of crucial importance, especially when considering effective preventive strategies for the conservation and protection of historical monuments and buildings. Maps have been developed on a European basis depicting future trends in the different damage processes of building materials [4-6], and several papers have been published that provide more detailed results with intra-regional resolution on specific European areas [7-11]. These research works have a fundamental common line that indicates that in the future, climate is likely to prevail over pollution in causing overall damage to historic monuments and buildings, implying a change from the well-known dominant blackening of architectural surfaces in urban areas [12].

However, scientific results do not find adequate operational translation in national climate change adaptation and disaster risk reduction and management plans, which lack safeguarding measures specifically dedicated to cultural heritage. This gap is clearly highlighted in the document "Strengthening Cultural Heritage Resilience for Climate Change" (2022) prepared by the EU Open Method of Coordination (OMC) experts group of Member States, which points out that only 12 of the 28 participating countries include cultural heritage in their climate change policies, while merely 7 are the countries with available plans to coordinate climate change and cultural heritage (Ireland, Greece, Italy, Cyprus, Slovenia, Finland and Sweden) [13-15].

The current challenge is therefore to facilitate the concrete application of findings from scientific research to policy actions. One of the reasons for the still ineffective transfer of research results to the policy sector in the field of cultural heritage protection is certainly the inadequate concretization of research results into tools and solutions to meet the needs of stakeholders and solve existing challenges at territorial level [16].

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Methodological Approach for Risk and Impact Assessment of Climate Change on Cultural Heritage

In dealing with the impact evaluations of cultural heritage induced by climate change, the following key steps are recommended:

1) Identification of environmental (climate and pollution) parameters with priority in causing deterioration in relation to the heritage under threat, by considering the building material, environmental context, exposure, cultural and socio-economic value. Appropriated spatial and temporal resolution of monitoring should be determined and selected.
2) Assessment of the potential synergic actions of different atmospheric forces and on the consequent deterioration induced over time on cultural heritage.
3) Identification of the chemical-physical, cultural, economic and social factors determining the vulnerability of diverse cultural heritage categories (such as monumental complexes, archaeological sites, terraced landscapes, underwater heritage).
4) Formulation of damage functions and risk expressions is necessary.

Sustainable Strategies for Preservation and Environmental Technologies for Risk Assessment and Management

Despite the substantial European resources committed in recent years to research and policy development aimed at strengthening the protection of cultural heritage against the impacts of climate change, further steps are undoubtedly needed to ensure sustainable management and safeguarding of sites at risk. Slow and extreme climate change imposes continuous and new challenges to the effective conservation of cultural heritage, particularly in climatically warm areas (e.g. the Mediterranean basin and Alpine region), where the effect of multiple pressures is amplified [12].

There is an urgent need for user-oriented adaptation strategies, solutions and tools, based on sound scientific studies, capitalisation of acquired knowledge, transfer and dissemination of results, and coordinated actions between the different actors involved in decision-making for the protection and management of cultural and natural heritage (public authorities, scientific community, private sector, rescue organisations).

As highlighted in the European Agenda for Culture, cultural heritage has been a priority for European cooperation on cultural policy since 2007. Cultural heritage is also considered a strategic resource for a sustainable Europe, as stated in the Council conclusions of May 2014. As a value to society from cultural, environmental, social and economic perspectives, its sustainable management emerges as a strategic need in the 21st century. In 2018, as part of the European Year of Cultural Heritage, cultural heritage was finally recognised as an incentive to strengthen society's resilience in the face of the impact of catastrophic events, and its protection was highlighted as playing a key role in supporting socio-economic development and sustainable tourism [13].

At the global policy level, the Sendai Framework for Disaster Risk Reduction 2015-2030 was a significant turning point, including the protection of cultural heritage among its key priorities and calling on national authorities to cooperate to raise awareness of the impacts of cultural heritage in the context of hazard exposure. This framework was followed by the Action Plan on the Sendai Framework, published in 2016 by the European Commission and covering a five-year period, which envisages a more systematic disaster risk-informed approach in EU policymaking. To support the implementation of Sendai Priority 4 (Improving Disaster Preparedness for Effective Response and 'Rebuilding Better' in Recovery, Rehabilitation and Reconstruction), implementation measures include the development of good practices on integrating cultural heritage into national risk reduction strategies to be developed by EU Member States (Key Area 4) [17,12].

The recent Interreg Central Europe project "Risk assessment and sustainable protection of Cultural Heritage in changing environment" (2017 – 2020), aimed to strengthen the resilience of cultural heritage (monumental complexes with their collections) to extreme climate change through the development of feasible and customised solutions to support regional and local authorities with preparedness measures and evacuation plans in case of emergencies. In this project, twelve different combinations of six global forcing models, driving five regional models, were considered for the development of a Web GIS tool for mapping the risk of cultural heritage in Europe and the Mediterranean basin exposed to extreme events related to climate change, in particular heavy rainfall, floods and fires due to droughts [18, 19]. The results of ProteCHt2save were further developed within the recently concluded Interreg Central Europe project 'STRENgthening resilience of cultural heritage at risk in a changing environment through proactive transnational cooperation, STRENCH' (2020 – 2022), which also included the application of satellite data from the services of the EU's Copernicus programme for the protection of cultural heritage at risk in a changing environment [20-23, 16].

Protection of Cultural Heritage and Landscape from Extreme Events

Despite the abovementioned international evidence of the increasing impacts of climate change on cultural heritage, the latter is still not comprehensively considered to be affected by climate change and thus deserving of protection. There are still few examples of national adaptation and mitigation plans that include specific measures for its protection based on damage quantification.

Therefore, research should go in the direction of developing damage functions for the quantitative assessment of climate change impacts on specific heritage materials and multi-hazard scenarios for complex systems such as historic centres, archaeological sites, underwater remains, terraced landscapes. On the other hand, special attention should be paid to the proposal of preparedness strategies in response to extreme climate change-related events (heavy rainfall, flooding, droughts) by mapping risk areas at high spatial resolution. New investigations should be based on existing knowledge and the needs of stakeholders involved in the protection and management of cultural heritage at risk due to climate change.

One of the most urgent requirements for policy and decision makers is undoubtedly the availability of quantitative data on the observed and projected impacts of different scenarios on cultural and natural heritage, which is crucial for establishing acceptable risk thresholds and setting adaptation and mitigation strategies [24-28].

Urgently needed is the development of projections that provide assessments of impacts in the near and far future of climate change on outdoor cultural heritage, both in terms of slow cumulative damage due to ongoing climate change and air pollution, and risks associated with extreme hydro-meteorological events related to changes in temperature and precipitation.

Fundamentally the focus must be on methodological approaches applied to attempt to quantify damage and the development of risk indicators in the context of the protection and management of the built heritage, in stone and stone materials.

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Chapter 3 – Built Heritage[5]

Preventive and temporary measures against impact of climate change or natural disasters are typically sorted into two categories: structural and non-structural, i.e. organizational or operational (Drdácký et al., 2007). Materialization of structural measures is problematic in the case of cultural heritage protection because they may affect perception of cultural heritage values due to their disturbing visibility. Moreover, they are often cost demanding. As far as non-structural measures are concerned, they mostly include application of various standards and recommendations for preventive processes and procedures, such as mapping and monitoring or identification of shortcomings and deficiencies. However, even here the originality, authenticity and aesthetic qualities and values of historic monuments should not be compromised. Increased numbers of climate induced natural disasters or damaging events improved the understanding to the problems and generated best practice examples enhancing resilience preparedness and damage mitigation of cultural heritage endangered by them. Some basic principles which have proved to be efficient remain highly important. They are based on four pillars:

i. regular inspection and careful maintenance of the historical stock & improved land use planning and management;
ii. raised awareness and regular coordinated training;
iii. international cooperation and availability of funding, and;
iv. legislative support.

Structural strategies and measures reducing climate induced harming action are suggested and designed selectively according to ranking of structures and elements vulnerable to them as defined elsewhere (Drdácký et al., 2011). There were accepted five levels of vulnerability which exhibit similar damage and therefore can also group standardized resilience or protection measures. We present examples for wind, landslide, flood and harsh weather.

In the past, serious damage to buildings caused by climatic effects - windstorms, hurricanes or floods - attracted the particular attention of writers, and references can be found to calamities in chronicles and other written sources. Together with large fires, often started by thunderstorms, **strong winds** feature prominently in the records in chronicles. Historical research has shown that windstorm damage to roofs was recorded relatively frequently in the past. Churches, with their high roofs and in particular their steep spires, are the largest group of buildings mentioned in written sources. Outlook towers built of timber and standing on hilltops, separated from traditional settlements, were the most endangered type of structure, especially around the beginning on the 20th century. Another category includes failures of freestanding walls, e.g. attic gables, ruins, fencing walls, etc. Most of the damage caused by strong winds was to roof coverings. Wooden shingles were much more resistant than, e.g. ceramic or slate tiles. There were also

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serious problems when copper sheets were used on extensive pitched roofs. The total collapse of an all-timber roof spire structure was often connected with longer-established existing problems, e.g. rotten wall plates or roof leakage. Periodic monitoring of the condition of the wood in the structures is therefore essential for preventing future damage. In combination with other structural failures - cracks in the masonry or in the vaulting - rotten timber can be very dangerous and can lead to the collapse of the building as a whole. Ranking of structures and elements vulnerable to wind effects includes the following grades:

- W0 - Wind resistant structures and elements;
- W1 - Vibration prone elements and structures, e.g. windows and window glazing, architectural elements (e.g. pinnacles);
- W2 - Wind releasable elements, e.g. roof coverings;
- W3 Structures susceptible to partial wind damage, e.g. roofs, windmills, tall sculptural works;
- W4 Structures and elements vulnerable to overall collapse due to wind action, e.g. free-standing walls and elements (attic gables, walls of ruins, fencing walls, chimneys, menhirs, poles, etc.), light and tall buildings (towers, timber houses, etc.), trees.

Mitigation of wind action on historic buildings and art objects includes:

- making regular inspections of structural health (all vulnerability categories)
- carrying out long-term monitoring of structural health (W3, W4)
- installing warning systems in special cases of W3 and W4
- conducting regular maintenance (all categories)
- changing the tuning of structures or elements (W1)
- improving the anchoring of the building envelope (roofing, facade) (W2)
- improving the anchoring of sensitive structural parts into the supporting structures (W3)
- changing the effect of wind on the element or building, (including changes to the wind flow conditions) (W1, W2, W3)
- strengthening the structure and/or providing additional supports for the whole structure (W4).

A l**andslide** event is usually caused by a combination of factors, the most important of which are:

i) the material properties of the soil/rock massif,
ii) geological composition,
iii) precipitation and water saturation,
iv) slope inclination and
v) technical disturbance of the slope.

In general, fine-grained soils are more susceptible to failure. They are characterised by significantly lower friction angles (Φ) compared to coarse-grained materials (the typical critical state friction angle of clay is of the order of 22°, whereas the friction angle of sands is of the order of 35°). The stability of the slope may be further reduced by unfavourable geological conditions. A typical unfavourable example is flysh material, with interchanging layers of sandstone and clay stone. During rainfall, the sandstone layer quickly becomes saturated due to its high permeability. This reduces the effective mean stress in the impermeable layer of clay stone, which is then susceptible to failure. Another example of geological conditions leading to the collapse of a slope is a rigid rock stratum lying on a highly plastic fine-grained material. The rigid blocks load the slope, which can fail when there is high precipitation. This is one of the most important causes of landslides. From the point of view of landslide hazards, an extreme climatic event is the most critical, e.g. a strong rainfall, or quick snow-melting in spring. This causes a sudden increase in the pore pressure and for this reason a failure condition may be reached. In general, slopes with medium inclination (15°-30°) are the most problematic. Slopes with a smaller inclination are usually stable, due to small shear stresses acting in the ground. Statistics have shown that slopes with higher inclination than about 35° are usually also stable. If such a slope were susceptible to failure, it would already have failed in the past. Slopes with high inclination are often made up of rigid rocks, where other types of instabilities, e.g. rock falls, may be expected. Incorrect geotechnical works or protective measures can worsen the threat of landslides. The probability of failure is increased by cuts (unloading) in the slope toe and by loading of the crest. Insufficient water drainage causes infiltration of water and an increase in pore pressures, which is the case of retaining wall without sufficient drainage, etc. In the case of landslides, no ranking of structures and elements is made, because any ranking would make little sense. However, the dangerous geological situations prone to landslides that have been described above can be summarized and ranked as follows:

- G0 Landslide-proof geotechnical conditions;
- G1 Areas under landslide-prone situations (threatened by flow);
- G2 Landslide-prone slopes - with an angle between 15° and 35°;
- G3 Highly landslide-prone soils;
- G4 Landslide-susceptible geotechnical conditions, e.g. natural (layers, etc.) or man-made errors.

Mitigation of heavy rains and of the impact of flooding on cultural heritage initiating landslides includes:

- making a survey and a GIS inventory of landslide-prone territories (all categories)
- conducting long-term monitoring of landslide-prone areas (G2, G3)
- installing warning systems (special cases of G3)
- checking construction works in landslide-prone territories (G4)
- protecting the area from water inflow (G2, G3, G4)
- planting trees and bushes to decrease erosion and to slow down infiltration (G2,G3)
- lowering the level of the water table (in combination with installing a warning system and water pumps, in special cases) (G2, G3)
- decreasing the load above the slope (by removing soil) (G3)
- conducting geotechnical measures (dowelling or nailing the slope, installing piles and pile walls, etc.) (G1, G2, G3).

Historic materials, structures and territories (landscapes, gardens etc.) are subjected to unusual loads and actions during **flood events**. First, we should bear Archimedes' law in mind. It states that all flooded objects are uplifted, and some can even flow away from their original position, even inside interiors, where streams can also occur. Static and dynamic pressures can of course destroy structures and trees. This phenomenon can be supplemented by the impact of floating objects, by the formation of barriers of floating objects, or by erosion of the subsoil beneath foundations. Wet materials and structures mostly lose their strength and stiffness characteristics, and they exhibit substantial volumetric changes. In addition to mechanical actions, there are also substantial chemical attacks during and especially after floods. These are mostly due to water pollution and to salt efflorescence during drying processes. It is therefore more difficult to make a general ranking of structures and elements according to their sensitivity to flooding than according to their sensitivity to other situations. Generally, many effects occur after a flood, e.g. compacting of infill, which can cause partition walls to fail and floors to buckle because of the uplift forces. Cracks can appear in vaults due to uneven settlement after the flood, and many other effects can occur. For the ranking of structures and elements according to their sensitivity to flooding the following scale has been developed:

- F0 Flood resistant objects and structures;
- F1 Objects and structures from materials with a high moisture volumetric change, e.g. timber structures and elements, combined structures from different moisture expansion materials, some soils;
- F2 Structures from materials of strength highly degrading due to moisture, e.g. dried brick (adobe) masonry, masonry with clay (low lime or cement contents) mortars, decayed timber structures and elements, infill subsoil and fine particle subsoil;
- F3 Structures susceptible to partial damage due to flood, e.g. timber parts prone to uplifting and floating away, large bridges, pavements;
- F4 Structures and elements vulnerable to overall collapse or displacement due to flood, e.g. small bridges and walkways, free standing walls, light improperly anchored objects (summer-houses, etc.).

Mitigation of heavy rains and consequences of floods on cultural heritage exploits:

- making regular inspections of structural health (all categories)
- making emergency plans and establish guidelines (all categories)
- installing an early warning system and provide information systems (all categories)
- preparing technical measures against flooding – permanent measures or easily-installable temporary measures (all categories)
- providing temporary strengthening and additional supports (F2, F3, F4)
- taking measures to decrease loads (dismantling bridge parapet walls, making openings to balance the water pressure) (F3, F4)

- improving the anchoring of sensitive structural parts into supporting structures (F3, F4)
- removing floating objects and “dams” from the stream (F3, F4)
- publishing guidelines for “after the flood” activities, e.g. how to prevent damage due to rapid material disintegration, rapid salt crystal growth, pollution and climatic effects, etc. (all categories).

Considering the sensitivity of structures and elements to **weather effects**, irrespective of the materials that they are made of, we can logically categorize structures according to their exposure conditions and the morphological characteristics that influence water retention or the eddies and flows around monuments. Morphological characteristics are reflected in the robustness categories, where the material types are also mentioned. Ranking of structures and elements vulnerable to weather effects therefore involve three groups of exposure. First, the surfaces of sculptures and building structures **exposed to rain** are divided into five categories:

- R0 Sheltered from rain;
- R1 Partly exposed to rain and/or moderate rainwater runoff, e.g. vertical surfaces moderately exposed to winds;
- R2 Exposed to rain and/or heavy rainwater runoff, e.g. roofs, inclined surfaces of sculptures, vertical surfaces exposed to prevailing and strong winds;
- R3 Complex shapes with horizontal surfaces, e.g. cornices, balconies, decorative architectural elements; R4 Complex shapes with water traps, e.g. roof and façade details.

Second, the structures and elements exposed to the threat of **rising damp** are classified according to:

- D0 Natural moisture content;
- D1 Occurrence of occasional moisture, e.g. walls that are damp due to water splattering (e.g. bridge parapet walls), structures occasionally affected by an elevated water table;
- D2 Permanent moisture content, e.g. masonry that is highly contaminated with hygroscopic salts or materials, masonry covered with damp-proof layers;
- D3 Permanent high moisture content, e.g. buildings in lagoons, cellars or caves;
- D4 Cyclical alterations below water/in the open air, e.g. bridge piers, watermills, marine structures.

Last the structures and elements **exposed to sunshine** (heat and light effects) are categorized in groups of:

- S0 Sheltered from light;
- S1 Sheltered from direct sunshine;
- S2 Partly exposed to sunshine, e.g. buildings shaded by trees;
- S3 Fully exposed to sunshine, e.g. south-east oriented façades;

Erasmus+

- S4 Fully exposed to sunshine with elevated heat exchange, e.g. S + SW +W oriented facades or roofs, flat roofs and pavements.

Weather effects further endanger not sufficiently robust structures and materials. Robustness is dependent on the volume of mass, detailing and material characteristics and the ranking considers elements and structures:

- M0 Robustly resistant to weather effects;
- M1 Robust in form made of sensitive materials, e.g. porous materials, materials with low freeze/thaw resistance, water-soluble materials, corrosion-prone materials (alterations, crust formation);
- M2 Resistant materials but sensitive details, e.g. details with notches (stress concentration, manufacturing defects, etc.);
- M3 Form prone to uneven strains and gradients, such as edges, corners, protuberances or subtle elements fixed to massive parts;
- M4 Sensitive material & sensitive details. Weather effects are among the main causes of deterioration to cultural heritage, above all architectural heritage. It is beyond the scope of this short summary to deal in detail with all possible strategies and measures for mitigating these effects.

The main categories are listed here to emphasize the importance of detailed studies of combined weathering effects that increase deterioration and require specific preventive measures. The preventive strategies and measures against weathering are based on:

- making regular inspections of structural health
- conducting long-term monitoring of structural health (selected)
- installing warning systems (typically in moisture-sensitive roof lofts and timber)
- conducting regular maintenance
- ensuring that water is carried away rapidly and effectively (outlets, adequate, unblocked gutters, etc.)
- preventing water penetrating or soaking into material (coatings, barriers, etc.)
- providing protection against excessive variations in heat and light (shelter, coatings, etc.)
- conducting architectural improvements (details, cornices, etc.)
- replacing originals by replicas.

Natural disasters pose a major threat to cultural heritage. Hurricanes, floods, earthquakes, landslides, volcanoes, wind effects, fires, environmental fatigue and similar long-term climate effects and other disasters can cause irreversible damage to cultural heritage or can destroy entire areas of movable and immovable cultural heritage. Many heritage objects are further damaged by inadequate emergency interventions because urgent responses to basic needs may lead to ill-considered emergency measures and to planning and rehabilitation schemes for recovery that are insensitive to cultural heritage. There are considerable shortcomings and mistakes in preventive measures and actions, e.g. inappropriate hydrological predictions, insufficient knowledge about cultural heritage at risk, and about the state and condition of the assets. Recent disasters have confirmed the crucial role of coordinated knowledge-based crisis management. Losses of cultural heritage assets could have been much lower if human error had been minimized. Inadequate maintenance of old buildings and materials has increased the extent of damage suffered in all types of disastrous events, floods, windstorms, earthquakes and heavy snow events. Maintenance methods are not always appropriately accommodated in design standards and recommendations. Cultural heritage stakeholders may not be well informed about maintenance and are often not educated to design and implement protective or mitigation measures. Therefore, they need education as well as support for adequate approaches and behaviour in case of critical situations. Standards and guides are the most appropriate tools which can be widely distributed, digitized and available in the media space for free and in-time application. Recent examples are represented by the "Manual for Owners and Managers - Vulnerability self-assessment, criticality identification and resilience focused measures in emergency and disaster situations" (Drdácký, Cacciotti, Kopecká, 2020) or "Sustainable Conservation of Danube Limes Sites" (Drdácký et al., 2022).

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Chapter 4 – Conservation and Restoration

4.1 Assessments on Conservation and Restoration Issues regarding artistic and cultural Treasures. Preventive and long-term Preservation Strategies in the outdoor Environment and in Collections[6]

Monitoring

In the field of conservation, several methods exist that are particularly valuable as we face a future with a changing climate. With the goal of long-term preservation, these approaches can assist dealing with future challenges. Such methods are for example monitoring and maintenance. When creating a future preservation strategy for an object/heritage asset, these two methods are optimally interwoven and mutually supportive in the long term. Monitoring and maintenance are forward-looking and sustainable ways to preserve heritage.

Monitoring is based on the approach of systematically comparing phenomena and measurements that are observed and recorded at regular intervals. The aim demonstrates making processes recognizable; hence measures can be taken to stop negative changes. In the field of conservation, monitoring is defined as the continuous study, documentation, and evaluation of certain parameters, not involving direct treatments of objects, and aiming at the long-term preservation of cultural heritage. Parameters that can be studied are, for example, the measurement of an object's material properties or environmental factors, or changes in the condition of the heritage asset, as well as the effects of conservation measures. For example, after a conservation treatment, monitoring can be installed to determine when the conservation media is losing its effectiveness.

Monitoring is characterized by continuous or cyclic data collection. It requires the performance over a long period of time. It is not to be confused with activities such as single investigations of an object, e.g., condition assessment or evaluation of conservation treatments. These approaches do not fit into the field of monitoring. Another characteristic is that monitoring itself does not involve any direct action on the object. However, actions can be initiated based on the results of monitoring. By analysing the collected data targeted action can be performed. One of the positive effects of a well-functioning monitoring system is that damage can be detected at a very early stage and, as a result, it is possible to react quickly with minor interventions. On the other hand, a lack of monitoring can lead to damage that is not noticed for a long time, resulting in the need for major repair work, which can be very extensive and costly. Monitoring requires the collaboration of many cultural heritage professionals, such as conservators, natural scientists, and technicians. Therefore, monitoring is an interdisciplinary field involving many different experts.

The starting point for any monitoring action is always an initial investigation. Depending on the monitoring concept, it may involve inventory and condition report, climate measurements, archival research, consultation of old restorations, object inspection, and material scientific investigations. Afterwards the

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parameters, which should be monitored, must be selected. This means choosing exactly what information should be recorded. Defining methods or tools capable of collecting the selected parameters to be monitored demonstrates the next step. Methods should be defined that either continuously collect data or repeat collecting data at regular intervals. It is important to consider validity and repeatability over time when selecting methods. They should be viable in the decades to come and have no technical limitations, such as software-based monitoring. They must be performed under the same conditions, e.g. with the same equipment, every time. The methods should be based on non-destructive or, in exceptional cases, low-destructive investigations. After selecting the parameters to monitor and the methods for collecting the data, the definition of the intervals and the frequency with which to examine these parameters is essential. In many cases the definition of reference areas (in the case of large objects) is needed. These should be representative of the object and, for example, contain the conservation measures that you want to monitor. It is also important to select the areas in such a way that they are accessible for further cycles, so that scaffolding is not required, for example.

The next step is the actual data collection / documentation of the reference area; hence applying the chosen investigation methods. This can include mapping, description and assessment of condition, photographic documentation if necessary scientific investigations. This step is essential, it should be comprehensible and repeatable, the values/parameters should be as exact as possible and as little subjective as possible. Finally, the documentation of the data collection itself shall not be forgotten, preferably in a uniform way, which shall be done in the same manner in all the investigation cycles. The next critical step is the evaluation of the data gathered. Without the interpretation of the data no output, no conclusion can be drawn. The last step is the communication of the results to relevant stakeholders, for example those responsible for the preservation of the heritage asset. The results of the monitoring can, if necessary, lead to conservation actions and thus help preserving the objects.

At the next investigation date the monitoring action starts again with the data collection. The exact same investigation methods will be carried for comparison.

Maintenance

In the discipline of conservation, maintenance demonstrates a continuous process involving direct and indirect measures for prevention and / or early remediation of damages, consequently a long-term preservation effort. Maintenance wants to achieve with direct and indirect measures keeping an object in a good state of preservation over a long period of time so that it is protected from deterioration. It is a continuous process and not a result or product. Essential to maintenance is that it needs commitment over a long period of time. Small interventions at regular intervals should keep the object in a good condition for a long time. Maintenance can be a very simple and careful way to preserve cultural assets because it either prevents damages completely, eliminates or reduces them at a very early stage. In principle, maintenance concepts can be drawn up after an inventory and condition survey, developed and launched after a restoration project, or linked to monitoring, so that the results of the cyclic inspection of the monitoring processes are incorporated into the ongoing maintenance. A maintenance concept contains the definition of measures and personal conducting the measures, setting up a timetable for the tasks as well as a documentation format. Typical measures in the maintenance of historic buildings in the exterior include the cleaning of gutters, replacement of tiles, renewal of window coatings and seals. For these measures, the original materials of the building should be used in the historical execution.

Maintenance on archaeological sites demonstrate a special case. Excavated monuments often do not have a roof on top of their walls. As a result, the top of the wall and the walls themselves are vulnerable zones that will deteriorate rapidly without a protective roof. For the long-term preservation of exposed architectural-archaeological heritage exists so far two options: Either to install a protective roofing or to install regular maintenance. This is the only chance to delay the decay of freely weathered structures. Typical maintenance measures of architectural-archaeological heritage assets include the removal of vegetation or the maintenance of joint mortar.

Preventive Conservation

Another strategy for long-term preservation is preventive conservation. Preventive conservation includes all measures and actions aiming at avoiding or minimizing future deteriorations or loss of tangible cultural heritage. They are conducted within the context or surrounding of the objects/assets. So, they are indirect, they do not interfere with the item or its appearance. Preventive conservation deals with the registration of items, the storage, the handling of objects, the packing, the transportation. Further it also includes security issues of facilities, environmental managing, e.g., light, humidity, pollution, pest control. Also, emergency preparedness, training of personal and so on.

Case Studies of preventive conservation activities in the outdoor environment will be demonstrated by summarizing a publication of UAA: “Marija Milchin, Martina Haselberger & Gabriela Krist (2020) Preventive Conservation Measures for Stone Statuary in the Outdoor Environment: Three Case Studies from Austria, Studies in Conservation, 65:sup1, P233-P236“.

<u>Sculptures in the Gardens of Schönbrunn Palace</u>

Over forty marble sculptures from the eighteenth century are part of the statuary of the Schönbrunn Gardens in Vienna, Austria. The search for suitable protection for the statues over the winter period included different approaches; hydrophobic coatings have been evaluated as well as different temporary shelters over the last decades including wood, Plexiglas sheet (PMMA), geotextile and soft wrap shelters made from a coated woven textile acting as a semi-permeable membrane. In 2012 the Institute of Conservation, University of Applied Arts Vienna, conducted an evaluation within the framework of a pre-diploma thesis (Haselberger2011). The climate inside and outside the soft wraps was monitored over one season (October until April) for three sculptures. Additionally, the material used for the shelter was investigated. This proved that the shelters achieved their primary goal, to buffer the climatic extremes and to keep rain and snow away from the surfaces during the first year of their use. This effect dropped radically once the shelters were reused for the second or third time. Holes and wear allowed water to penetrate the shelter. The experiment showed that the geotextile performed as a semi-permeable membrane if it was new and sound. As soon as the material was folded to store it in the summertime, the surface was damaged, which resulted in water penetrating the shelter. As result of the evaluation the use of the soft wrap shelters was abandoned.

Sculptures in the Garden of Langenzersdorf Museum

The small Museum of Langenzersdorf in Lower Austria specializes in sculpture from the twentieth century. Stone, brick and concrete sculptures as well as some metal artefacts are presented in the museum garden. The University of Applied Arts Vienna has been active in the museum and its garden since 2017, when an inventory was made and a plan for the conservation of the different material groups was developed (Milchin and Sandner2017). To be able to keep the sculptures in position in the garden, shelters have been planned from the beginning. A permanent shelter in the form of a roof was not considered because of the aesthetic impact it would have on the garden and the surrounding landscape. Instead, low-budget winter shelters that can be set up by the museum staff or the craftsmen of the municipality were chosen. Two different systems were evaluated. The first was a soft wrap with spacers made from Tyvek (DuPont, a breathable but water-resistant polyethylene material) (Franzen2018, 25). The second system was a traditional wooden shelter, made of uncoated wood, with big gaps for air circulation. The climate was monitored over a year in both systems and compared to climate data from an unsheltered sculpture. The measurements consisted of air and surface temperatures accompanied by relative humidity. The stability of the shelters and their estimated life time were also taken into consideration. This, together with the workload for the mounting and demounting and the space needed to store the shelters in the summer months, helped the decision-making. Both systems could buffer weather extremes. After one winter the wooden shelters showed no signs of decay, but the Tyvek wraps were worn out and could not be used for a second season. The harsh winter climate is responsible for this phenomenon. Most of the Tyvek covers showed serious damage, with the development of large holes as quickly as a month after they had been installed. The risk of the soft wraps in connection with strong winds and their sail-like form should not be underestimated. The close contact to the surface of the sculpture adds to the damage to the cover, also making surface abrasion of the sculpture a plausible risk. The wooden shelters are initially more expensive than the soft wrap. Taking the expected life span–wood, 10 years, Tyvek, 1 year–into consideration, the Tyvek covers prove more expensive in the long run and are less environmentally sustainable. Considering the workload involved, the production of new Tyvek covers adds up to more working hours than the mounting and demounting of the wooden shelters.

The only disadvantage of the wooden shelters is that they require more storage space in summer. As a result, all the artefacts in the garden of Langenzersdorf Museum were sheltered in the winter 2019–20 for the first time, following the trial periods in 2017–18 and 2018–19.

Permanent shelter in the Archaeological Park of Leithaprodersdorf

In the archaeological park of Leithaprodersdorf a permanent shelter (roof) was designed to protect Roman gravestones and sarcophagi on display. The roof offers protection from rain, snow and direct sun for the stone artefacts. Unfortunately, birds and the local youths also appreciate the sheltering effects. At present the stone artefacts are soiled and covered with bird droppings. Rubbish (food and drink containers as well as cigarettes) can also be found around and inside the artefacts. Youngsters are using the artefacts to sit on while meeting in the evenings as a result recent mechanical damage can be seen on most surfaces. Therefore it can be argued that the well-intended structure that was supposed to protect the objects from the slow but steady decay due to weathering caused more aggressive mechanical damage due to anthropogenic factors, as well as a new problem with bird droppings. This should not mean that permanent roofs are problematic altogether, but that one should evaluate and modify all conservation measures, including those that seem as simple and straightforward as roofs (Curteis 2018,47). In the case of Leithaprodersdorf, different approaches could be used to deal with the anthropogenic part of the problem, such as the installation of benches and/or fencing the area. At present two Plexiglas covers and one dome are planned for three artefacts as a trial solution. However, the concentration of birds and therefore bird droppings under the roof is a problem often encountered with permanent shelters. Similar situations have been reported from the shelters in Caeserea, Israel (Alef2018, 95), Um er-Rasas, Jordan(Ha'obsh2018, 118) and Terrace House 2 in Ephesus, Turkey (Bellibas2018, 141). There is no satisfactory solution for this problem yet.

Conclusion

There is no perfect solution for sheltering stone statuary in an outdoor environment. For the eastern part of Austria, temporary shelters made of wood prove to be a good and simple option. Given that there is available space for the storage in summer, this also proves to be the best solution regarding the financial and sustainability aspect. Soft wraps made of different geomaterials are not suitable for the outdoor environmental conditions in Austria. Roofs offer a good protection from the elements and the costs involved can be low if looked at over the life span of the protection itself. The installation of a permanent roof can reduce the yearly workload involved, although maintenance and security must be planned up front (Pesaresi and Stewart 2018, 70). The side effects include aesthetic changes to the site as well as unexpected shifts in the circumstances and decay patterns. The evaluation and repair and/or modification of all these measures, permanent and temporary, are essential for their success.

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Collection Care

In the interior of historical buildings, which are used either privately or as museum, or even religiously, maintenance is equally important. For historic houses not only regular maintenance of the room shell but also the equipment in the interior is important. In the literature the term "care" is communally used for those activities. The tasks vary, depending on the type of object. For example, in the case of canvas paintings, maintenance or care activities may include regular cleaning, stabilization, adjustment of the frame, mounting, and so on. If you have metal objects, for example an iron fence, regular maintenance of protective coatings would be regular tasks.

In the museum context the term "collection care" is used. This comprises a continuous process, which includes indirect and direct measures to preserve a collection over time. Collection care can be compared to the terms "monitoring" and "maintenance" used in the field monument protection.

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4.2 Historic and heritage buildings[7]

Heritage and historic buildings (HHBs) are unique buildings that characterize the skylines of cities and landscapes in the world. They are considered landmarks because they are familiar to citizens and tourists that live with them or that have seen them often on media. These unique buildings have the power to evoke historical times and events, they have recognized aesthetic and architectural value that contribute to revealing the story of a nation, a city, or a district. They are irreplaceable as an economic capital, but above all for their socio-cultural values as they create a sense of community and cultural identity [1-5]. Although heritage and historic buildings can help boost local (or national) economies and the tourist sector, these buildings require special care and restoration solutions due to their construction techniques and original aged materials that must be preserved in the long-term. Nowadays these requirements represent many challenges because 1) the vulnerability of historical and heritage buildings has increased over time, HHBs being exposed to a range of slow- and sudden-onset natural and human-induced hazards; 2) even given the necessity of preserving HHBs to maintain each city's individual character and cultural identity, the rapid change which is being implemented in the built environment and the way how districts are changing, pose threats to such preservation; 3) the environmental, economic, and socio-political changes in times of climate change and energy crisis furthermore request a HHB protection driven by responsible choices which may last and be effective in the long-term.

Long term HHB management in the light of sustainability

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It becomes critical to understand what long-term HHB management means in the optic of the above challenges and in the light of sustainability.

"Long-term" management means to preserve HHBs from the natural ageing and the natural catastrophes or the anthropic impacts for long enough to be transferred to the future generations; to be concerned with the impacts of changing energy retrofitting interventions and renewable energy sources; or to be concerned with a changing user community. This "long-term" period could be of several decades but ideally should extend indefinitely into the future. Therefore, the long-term management of HHBs aims to keep the HHBs, make them usable nowadays, preserve their tangible and intangible significance for the future. The key risks to take into considerations are therefore:

1. Decay and/or low thermal insulation performances of the HHB envelopes;
2. High energy consumption and climate induced decay indoors of HBBs;
3. Low effectiveness of the ongoing risk assessment tool and management strategies in the light of the sustainability goals;
4. Risk of loss of significance of HHBs during their long-term management and/or the risk of obsolescence of nowadays common energy retrofitting interventions

Doing long-term management it is important to implement the necessary means to mitigate the impact of these threats.

Reflection on degradation and aging of historic materials

Against the degradation and aging of the historic material caused by slow- and sudden-onset natural and human-induced hazards, it is safer to apply early warning and precautionary principles. Nowadays technologies that support predictions on decay on HHB envelopes are hazards risk scenarios created by institutions in charge of mapping hydrogeological and climate risks at high resolutions; structural health monitoring and condition monitoring obtained by using nondestructive techniques (NDTs), and/or by satellite products that - although having a lower spatial resolution - offer continuous high resolution global monitoring of decay triggering parameters. The diagnosis on damage is not feasible without sensing. When dealing with HHB the sensing needs to be nondestructive and capable of detecting an onset of decay on the building structure. To this purpose, it is critical to test NDTs, remote sensing technologies, or mapping tools towards HHBs data collected in situ or in the laboratory to prove their detection reliability and thresholds as these depend on the type of HHBs materials (less or more vulnerable) and/or on the type of surrounding landscape. At present, accurate 2D or 3D models obtained by NDT i.e. photogrammetry are used integrated in Heritage Building Information Modelling (HBIM) which acts as a database to show the evolution of the damage and of the maintenance and restoration interventions [6,7].

Reflection on energy retrofitting interventions applied on HHBs

Against the energy retrofitting interventions applied on HHBs, new methods which better connect and integrate "old" and "new" materials and that synergistically evaluate the visual significance of the intervention, are needed. This is due because (standard) energy retrofitting solutions commonly applied to existing and recent buildings cannot be adopted instead to HHBs because of their aesthetic and architectural value in the envelope that cannot be modified or negatively affected.

The HHB envelopes outdoors as well as indoors undergo ageing and are vulnerable to climate-driven deterioration mechanisms. These building materials (e.g. masonry, wood, stones) respond to the variations in relative humidity (RH) (and temperature [T]) with changes in dimensions and mechanical properties [8] [9] induced by natural climate variability and/or using HVAC systems for artificially controlling the indoor conditions. To limit the arising of damage-favourable conditions, a damage tolerant-like design approach should be preferred [10] and reliable risk assessment tools (RATs) should be considered. At present, there are still inadequate tools for the climate-induced risk assessment. To limit the fluctuations of T-RH in indoor environments, standards of the technical committee CENT-TC 346 Conservation of Cultural Properties [11-13] have been developed during the years for establishing the allowable climatic variations ranges for art objects, which are susceptible not only to physical/structural damage [14], but even to chemical [15-17] and to biological ones [18-19]. Results in literature [20-26] have highlighted that the indoor environmental conditions in HHBs do not always meet these requirements through passive control. This means that active climate control techniques need to be implemented to resolve the hygrothermal deficiencies at cost of a certain budget availability that due to the ever-increasing energy prices, is becoming less and less economically sustainable for HHB owners and managers. Limiting the energy consumption is therefore a delicate issue affecting two needs: historic heritage preservation from the climatic variations and save energy consumption.

Reflection on energy consumption and climate-induced decay indoors of HHB

The standards and the RATs that are currently adopted are alerting in case of occurrence of past risky events. Against the high energy consumption and climate induced decay indoors of HHB, as well as against the low effectiveness of the ongoing risk assessment tool and management strategies, these tools should rather be updated and reformulated to become tools with future predictive capacity once having analysed the past and present climate conditions. This may improve both the dynamic climate control with energy use reduction and preservation capabilities. Nowadays this revolution can be feasible taking advantage of the huge predictive potentiality the machine learning algorithms have. Notwithstanding large existing and available datasets need to be reanalysed to warrant the quality of the timeseries e.g., filling gaps, reconstructing original climate signals by corrected timeseries and so on. Machine learning algorithms can support these types of reanalyses too. Finally, it is critical to reanalyse the existing RAT and standards on climate control in CEN-TC346 at the light of the sustainability goals as these tools do not answer properly to the ongoing needs of warranting optimal HBB conservation and use while facing challenges of energy poverty and/or of facilitating renewable energy resources installations in proximity of HHBs.

Reflection on risk of loss of significance of HHB

Against the risk of loss of significance of HHBs during their long-term management, the solution lies in documentation of HHB significance and metadata concerning the past and present management. Metadata is literally “data about data” and represents all the information necessary to describe the activities that have been put in place over decades to effectively monitor and preserve the heritage and historic buildings. These data help in understanding which aspects of the management can be modified to continuously improve in facing the identified challenges, as well as in understanding how these choices over the years have or have not influenced the preservation of the significance and intangible value of the HHBs. Metadata must be retrieved and preserved along with the monitored and survey data because they offer important milestone information to detect and explain changes during the HHB lifetime, to investigate durability and effectiveness of energy retrofitting solutions, and/or of changes in indoor climate control.

Transdisciplinary training: actions needed

Some of the actions that should be pursued to address the existing gaps in knowledge and practices are summarized as follows:

- Actions targeting the development of robust methods based on machine learning algorithms for studying and predicting the indoor microclimate of historical buildings with the purpose of guiding smarter choices for the management of the indoor microclimate, in the framework of preservation and conservation. These algorithms can be synergistically used to find patterns for reducing time and money consumption when both carrying on-the-field monitoring campaigns and the climate control indoors. Similarly, they may be used to accurately track visitors' presence thus contributing to improving metadata quality and in identifying causes of microclimatic variations.
- Actions targeting the development of robust risk assessment tools (RATs) focused to heritage and historic buildings exposed to extreme events and/or natural hazards. As stated in [27], part of these tools requires to conduct updated documentation surveys on original and restored materials, their state of conservation, as well as the significance of the cultural heritage under examination. These data are collected and organized in data inventories relevant for the RAT to predict heritage buildings at risk. Data on vulnerability and hazard are nowadays obtained by existing danger maps or by large-scale satellite images.
- Actions targeting the development of adequate energy and carbon savings retrofit interventions on historic buildings. These interventions are difficult to standardize because the historic building stock is extremely variable and strictly intertwined with the range of baseline conditions of such dwellings. In addition, in the historic building stock the authenticity and significance must be preserved, and the adaptive re-use after the intervention should consider the history and original function of such dwellings for stimulating creativity.
- Actions targeting the development of adequate energy and carbon savings retrofit interventions at district level. It is needed to develop methods capable to assess the performance of distinct solutions

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in digitally simulated climate conditions (design scenarios) considering different criteria weights for understanding if the proposed energy retrofit measures are effective in facing future climate changes. In these actions it is also important to avoid as much as possible the replacement of existing materials and components to limit the carbon footprint taking advantage of the pre-existent historic materials.

- Actions targeting the development of standardized approaches in testing mechanical properties of material resembling heritage building materials to understand what are the load conditions which may cause crack initiation and propagation. It is fundamental, when dealing with laboratory testing in the heritage field to use non-destructive techniques as infrared thermography, photogrammetry, digital image correlation, and acoustic emission. All these methods acquired information on material reactions to stress conditions without the need of a direct contact with the material itself and for this reason they can be used to monitor the response of original historic material in situ during monitoring campaigns. In this way the laboratory tests become fundamental for validation purposes.

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4.3 Case Study: Wooden Historic and Heritage Buildings: The 28 Medieval Stave Churches in Norway[8]

The Stave Churches and the SyMBoL Project (2018-2022)

The SyMBoL project "Sustainable Management of Heritage Building in a Long-term Perspective" (project number 274749, funded by the Norwegian research Council) was coordinated by NTNU and offered the opportunity to conduct research on the Norwegian Medieval Stave churches. These outstanding HHB constitute a perfect case study for the purpose of this concept.

The main objectives in SyMBoL were:

I. To better understand the mechanical decay on heritage assets made of pine wood which may be caused by hygric change. This is because the main constructive material in stave church is of pine wood.
II. To adopt in experimental analysis two non-destructive techniques (NDT): the micro-indentation and the acoustic emission (AE) techniques. While the first technique is still not commonly used in

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heritage science; the second one is more common and in SyMBoL, the AE NDT has been used both during tests and on site.

III. To support laboratory experiments with in-situ monitoring campaigns in two churches with different heating strategies.

The expected outcomes were to provide science-based advice for the indoor climate management especially for the two stave churches monitored in situ (i.e., Heddal and Ringebu, Norway) but not limited to them and then to analyse the possible impact of climate change to ensure to give advice for a long-term preservation. Concerning the achievements based on the use on non-destructive techniques (NDT) in experimental analysis, SyMBoL has worked extensively with:

The micro indentation technique

It was used to estimate the mechanical properties and dimensional response of distemper paint micro-samples. Micro-sensitive techniques – nanoindentation, dynamic water vapor sorption, and X-ray microtomography – were used to examine the physical properties of small volumes of these samples which became key parameters used to inform macro-sized mock-ups (i.e., mainly used in the laboratory for tests) mimicking physical and mechanical behaviour of “real” artistic materials. The results published in [28] report the novel method proposed, tested in laboratory prepared chalk-based ground samples and on distemper paint micro-samples taken from polychrome walls of Eidsborg Stave church, Norway. Very recently results of the experiments conducted at the Norwegian University of Science and Technology, examining the effect of indentation separation on the mechanical properties of proteinaceous adhesive films made of gelatine-based films typically used by artists and conservators, were published in [29]. This work focused in addition on the process of selecting optimal indentation separation for proteinaceous adhesives derived from mammalian and fish sources: rabbit hide, bovine hide, bovine bone, and swim bladder of fish. Beside nano-indentation tests, multi-techniques (i.e., x-ray diffraction (XRD), environmental scanning electron microscopy (ESEM), energy dispersive x-ray spectroscopy (EDS), Fourier-Transform Infrared (FT-IR) spectroscopy, enzyme-linked immunosorbent assay (ELISA), gas chromatography-mass spectrometry (GC-MS)) have been applied to study the chemical characterization of the analysed 17th century distemper paint micro-samples. Results published in [30] allowed for the identification of red ochre as the main red pigment within the topcoat, confirmed that a chalk basecoat was used, and permitted the recognition of alteration phases. In addition, throughout the stratigraphic layers of both churches, markers of proteinaceous material attributed to the use of animal-based glues were detected, linseed oil in some locations as well as the wooden specie (pine tree) of the wood substrate with contamination of wood fractions being detected in some of the paint samples from Heddal and Eidsborg stave churches. In conclusion this research has contributed to a better understanding of the current preservation state of Heddal and Eidsborg, and ultimately assisted in developing a deeper comprehension and awareness of materials used in Norwegian stave churches. Recently in 2022 – during the extension of the SyMBoL project, GCI performed a work [31] to compare the mechanical properties of seven animal glues commercially available for conservation practice. The performance of these materials within ranges of temperature and relative humidity commonly found in uncontrolled environments was quantified on cast glue films using dynamic mechanical analysis (DMA) and tensile testing. The applied experimental protocol resulted in the identification of phase transitions between the glassy and rubbery states and the evaluation in those states of the stiffness, viscoelasticity, strength, and strain at break of each tested adhesive. The presented results allow for the prediction of environmental conditions at which specific glues may fail and may help to select the most appropriate adhesive, from a mechanical point of view, for applications.

The acoustic emission technique

The laboratory tests conducted at NTNU have constituted the main experimental task of the project that allowed to characterize the mechanical properties of the Stave church constructive material i.e. the Scots pine and allowed to create a novel RAT to estimate the risk of mechanical decay on a cylindric Pine element (diameter of circa 16 cm) when subjected to (natural and artificial) environmental hygric change as those existing in the Stave churches (e.g. Ringebu and Heddal) [25;32-37]. Beside the mathematical formulation of this RAT published in [25], its use with the monitored microclimate data measured in Heddal and Ringebu has been recently reported in a book chapter published in 2022 highlighting the risks induced by the use of three common heating strategies existing in the monitored stave churches i.e., the continuous mild heating, the sporadic intermittent heating, and the no heating strategy which consists in keeping the climate as it is. In [38] additional tests with the combined use of AE system, digital image correlation and a uiversal testing machine were conducted at NTNU and explored the early warning capability of the technique in detecting mode I and mixed mode fractures in Scots pine samples. The acoustic behaviour of the specimens, being different for tree rings number (high and low) and grain angle (0-20-40-60°), was investigated while undergoing an external tensile load. The threshold value of 51.9 dB was found as an early warning indicator for Scots pine samples with mixed mode fractures. While in the case of Mode I fracture, as cracks occur instantaneously, the oncoming fracture could not be predicted.

The Finite Element Modelling (FEM)

In SyMBoL, numerical modelling has been used to model the properties of the Scots pine wooden samples based on data retrieved during the fracture tests at NTNU. Simulated and experimental properties were compared in [32, 33].

The FEM has been used recently by the Polish Academy of Science within SyMBoL to assess risks of fracture in massive wooden cultural heritage object and to model the risks due to idealized RH variation [39]. Where the assumption of no hygrothermal equilibrium of the object with the surrounding environment is investigated as this is a common situation in case a church has sporadic use of a HVAC system for comfort purposes with dynamic temperature and relative humidity (RH) variations. The PAS contribution analyses the risk of fracture in massive wooden cultural heritage objects, particularly endangered by gradients of moisture forming in their volume due to dynamic environmental variations. The study aimed at elucidating general trends as both crack formation and propagation depend on material parameters of a specific wooden element, which can vary even within the same wood species. A two-dimensional elastic model of a massive object made of pine wood was subjected to two types of RH variations: step and sinusoidal. The critical amplitude and duration of variations inducing crack propagation were determined for both variation types. The modelling showed that the risk of fracture was significantly higher for a sinusoidal variation than for a sudden RH drop. Therefore, sinusoidal variations should be considered the worst-case condition when analysing risks of fracture in wooden objects. The numerical approach that is based on experimental results is powerful as it allows to extend experimental results validity thanks to the parametrization. In addition, such novel results have been inserted in Herie existing tool at PAS (link: https://herie.pl/Home/Info). The results achieved within the SyMBoL project have been integrated in the module for “incorrect relative humidity>mechanical decay”.

The machine learning application to microclimate studies

Several Stave churches in Norway have been studied in detail during SyMBoL. The two main case studies have been Heddal and Ringebu. For these churches microclimate campaigns have been carried out with thermo-hygrometers. In [40] the analysis of the several existing guidelines provided by standards and protocols about the optimal microclimatic conditions that should be ensured to avoid the decay and the eventual catastrophic failure of heritage objects and buildings, have been published. The criticalities of the existing protocols have been pointed out, emphasizing the need for systematically and periodically updated specifications, tailorable to a given case study of concern, without forgetting the ever-present needs of energy- and money-saving approaches.

What is worth to highlight in term of novelty of the SyMBoL results is that for the first time extensively, the machine learning algorithms have been applied to microclimate studies of the indoor environment of the stave churches to analyse the risk of climate-induced mechanical decay on valuable heritage objects.
In fact, the microclimate strongly influences the mechanical decay and properties of the constituent materials, especially if they are susceptible to fluctuations of temperature and relative humidity as the case of Scots pine elements. In this framework, NTNU has produced a novel simple strategy [41], named Median of Data Strategy, for identifying RH drops; the new approach, by scanning the RH time series. Then a machine learning approach for predicting whether climatic fluctuations which may have catastrophic effects on the historical wooden materials is presented that opens a pathway for future investigations in the fields of fracture mechanics, fatigue behaviour and smart timeseries prediction for conservation and preservation purposes.

The outdoor climate, natural hazards, and climate change impacts

Very recently an algorithm to assess the risk of freeze-thaw decay on the foundation stones of the whole group of the 28 Stave Churches have been developed and published [42]. This algorithm is developed by a single climate input parameter i.e., the land surface temperature, extracted from the Global Land Data Assimilation System GLDAS which integrates satellite- and ground-based observational data products. Thanks to this algorithm the impact on the foundation stones of the land surface temperature variability over the last 70-year (1950-2020) at the 28 locations has been made visible. The outcome has been further used to evaluate the average lifetime (half-life time) of foundation stones as well as the number of interventions necessary to guarantee their long-term structural soundness.

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Chapter 5 – On-site hands-on Training[9]

On-site hands-on training can take fundamentally different forms, ranging from guided assessments of heritage sites and materials to full-scale exercises. CHePiCC's test version of the summer university concept focused on the former, on guided assessments and follow-up syndicate working groups tasked with developing tailored solutions for challenges presented during the guided assessment phase. These solutions were then discussed with experts and the other syndicate working groups. For further information on this version we refer to the detailed documentation of the 2022 summer university in Norway.

Full-scale exercises as parts of summer universities have been developed and assessed in research projects that form the solid basis for the CHePiCC project. In addition to the documentation of the 2022 summer university in Norway we would like to present this form of on-site hands-on training in more detail.

One key challenge in cultural heritage protection is that the varied experts involved do not work together consistently and are, therefore, often unaware of what the other parties need to facilitate the protection of movable or immovable cultural heritage. The two sides often involved in the protection of cultural heritage are the heritage specialists, mostly civilian experts who rarely have military or disaster management experience, and the military or first responders who engage in managing man-made or natural catastrophes that threaten cultural heritage, including law enforcement and security personnel. These experts, conversely, rarely have a heritage background, though there are striking exceptions, like the Italian Carabinieri Tutela Patrimonio Culturale (Rush / Benedettini Millington 2015).

To establish effective cooperation in an emergency, both sides must understand how their respective counterparts operate and what they need to be able to cooperate. Military and crisis response staff are used to well-focused and strictly organized ways of working, which might seem quite alien to someone who has never encountered such procedures. The military and other emergency responders, i.e., civil protection and fire brigades, are not likely to change their established and ingrained procedures. Hence, the civilian experts should at least know how the military procedures work and how best to integrate themselves and their knowledge into this rigid system. However, all sides benefit from learning what the other actors in the field need, what their capacities, capabilities and standing operational procedures are.

The principal purpose of the training exercises and hands-on training is to facilitate the cooperation of the primary actors involved in heritage protection in crisis– the "heritage side" and the "emergency response side" and to create interfaces for successful collaboration. The focus of instructions in the staged exercises within several summer schools was on heritage professionals, exposing them to how emergency responders--in this case, the Austrian Armed Forces--work. This included acquainting them with the strict military decision-making processes and related procedures typical of military entities and educating heritage professionals about how to best communicate critical information regarding cultural heritage to

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the right person at the right time. It should be noted that these exercises did not aim to train heritage professionals or emergency responders about how to treat impacted cultural heritage and materials. However, the treatment of these mock cultural heritage items was by no means haphazard or blatantly wrong. The scenarios developed for the exercises were designed to be overcrowded with information and adversary scenarios on purpose, stressing the necessity of a complex evaluation of needs in cooperation with emergency responders. Director's guidelines were issued regarding the affected cultural heritage, which had to be recovered and moved, with no option to leave items behind.

Three exercises were conducted and analysed in detail for a master's thesis (one of them is described in detail below). The question was whether table-top and live exercises were valid tools in effectively preparing civilian heritage professionals to cooperate with emergency responders. The analysis was focused on cooperation with the military and considered the impacts of time constraints on the validity of these training endeavours. Expanded training in military staff work is typically unavailable to civilian heritage professionals who do not normally need this type of expertise in executing their day-to-day professional duties (Schramm 2019, 13). Thus all scenarios were conducted under time pressure: in the scenario on the default setting and outside the scenario as the time allocated for pre-learning was also limited. Staff work and decision-making processes were aligned to the format used by the Austrian Armed Forces since they supported the exercises, but also as a means of benefitting their personnel as they were able to train their teams in cooperation in cultural heritage protection. It is also important to note that with only slight modifications the same system is used in civilian disaster management on the national level (BMI 2007).

The exercise TRITOLIA18 was a combination of table-top and live exercise in which the scenario involved an earthquake that had impacted the eastern part of the country, destroying a castle listed as a UNESCO World Heritage site. The exercise was called TRITOLIA18, as it took place in the Austrian Armed Forces' disaster relief training area also known as "Tritolwerk", a former ammunition factory dating back to before World War I. The principal purpose of this training exercise was to facilitate the cooperation of the primary actors involved in heritage protection in crisis – the "heritage side" and the "emergency response side" and to create interfaces for successful collaboration. On the first day of the exercise, the participants planned the deployment of cultural heritage experts while embedded in urban search and rescue platoons. In other words, during this first stage, the heritage professionals were tasked with working in tandem with battalion staff officers, but at this stage deployed as staff officers and not as heritage experts. On days two and three of the exercise, the heritage sector participants took over the role of subject matter experts, following the plans they helped to develop during day one. They conducted reconnaissance in the affected area and recovered cultural heritage on-site in cooperation with an urban search and rescue platoon, again, as planned during day one of the exercise. This mixture of table-top training for the planning and decision-making components followed immediately by the hands-on recovery of cultural heritage and application of the participants' inherent expertise in correctly handling cultural heritage items was highly appreciated. The TRITOLIA18 exercise was conducted as part of the Interreg CE project ProteCHt2save, for which a novel approach was developed and evaluated to bridge the above-mentioned gap. This approach takes the form of so-called Cultural Heritage Rescue Teams (CHRT).

Ideally, these teams are composed of a mixture of heritage experts and personnel from emergency units or the military, but a team composed solely of heritage experts could do the job as well, provided they understood how the military and emergency units plan and operate (Kaiser 2019).

All participants of the three exercises analysed in detail for the above-mentioned master's thesis listed three main takeaways:

1. Speaking the same language is of paramount importance. The participants stressed that they only realized this during the exercise phase, not understanding the necessity and the implication in the lectures before participating in the exercises themselves.
2. Coordination between the heritage side and emergency responder side is vital. Having worked together before, i.e. during training exercises, is of immense help in ensuring successful coordination. The civilian heritage professionals stated that considering the highly structured staff work and procedures that are firmly in place in emergency responder organizations, it would be the civilian heritage professionals who must learn how to best cooperate and communicate with emergency responders.
3. When working under time constraints and in emotionally stressful situations (that could not be fully simulated), it was crucial to have clearly stated responsibilities and work according to a fixed scheme. In this case, the decision-making process and related procedures relied on military staff who enabled the development of effective courses of action (Schramm 2019, 52-53).

In conclusion, the set goals of the training events were met -- the participating civilian heritage professionals were empowered through their understanding of first responders' staff work and decision-making processes and were able to contribute their expertise on cultural heritage where, how, and when it would be best received by their partners, even under the immense pressures of these intense scenarios. Table-top and live exercises are valid means by which to reach this learning outcome in a short time frame, understanding that participants who are not active members of emergency response services or the military and who have an in-depth understanding of these procedures, will not be able to take over parts of that process, but can still gain a basic level of understanding of these structures – thus enhancing future cooperative possibilities in emergencies that put cultural heritage in danger.

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Closing Remarks

The feedback received from the participants of the summer university showed that the expected impact was met. They students did learn to follow a transdisciplinary approach in dealing with the subjects of cultural heritage, cultural landscapes, climate change and the projection of the former from the latter. They were able to take this approach with them and establish at their working places (in the cases in which this was applicable) a behavioural change towards cultural heritage protection. The envisaged peer-learning processes, built on the transdisciplinary setting of the summer university and the background of the students, was fully accomplished and the participants were enabled to build a high capacity in climate change effects on different climate zones, landscapes and types of cultural heritage, also based on the prior information they received in the mandatory completion of CHePiCC's Massive Open Online Course on Cultural Heritage Protection in Climate Change online.

The participating students came from different backgrounds, some of them also having an impressive amount of working experience in their individual disciplines. What they stressed regarding the hands-on approach and the syndicate working groups was that they benefited from the different background of the participants, which challenged them, but also allowed them to collaborate in a constructive way, developing a common project with common objectives. Each of them was not only sharing his or her ideas and opinions, but the interdisciplinary set-up also allowed the students coming from other disciplines to learn from practitioners of i.e. architecture, engineering, and conservation science.

They rated the site visits during the week as highly important and beneficial, allowing them to step out of the theoretical setting of online and on-site lectures and to assess and experience the challenges the Bakklandet Warehouse District, the Nidaros Cathedral and the Dora Archives in the Nyhavna District face. All three of these sites face different challenges, first and foremost because they are built of different materials and serve different purposes – some of them being actually out of commission in neglected (some of the Bakklandet Warehouses), for which the development of future projects to revitalise them is of paramount importance.

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CHePiCC Summer School

"Cultural Heritage Protection in Climate Change"

Trondheim, Norway

30th May 2022 – 4th June 2022

Chiara Bertolin **America Califano** **Markus Schwai**

CHePiCC Summer School

May 30 – June 4

2022

INDEX

PART I

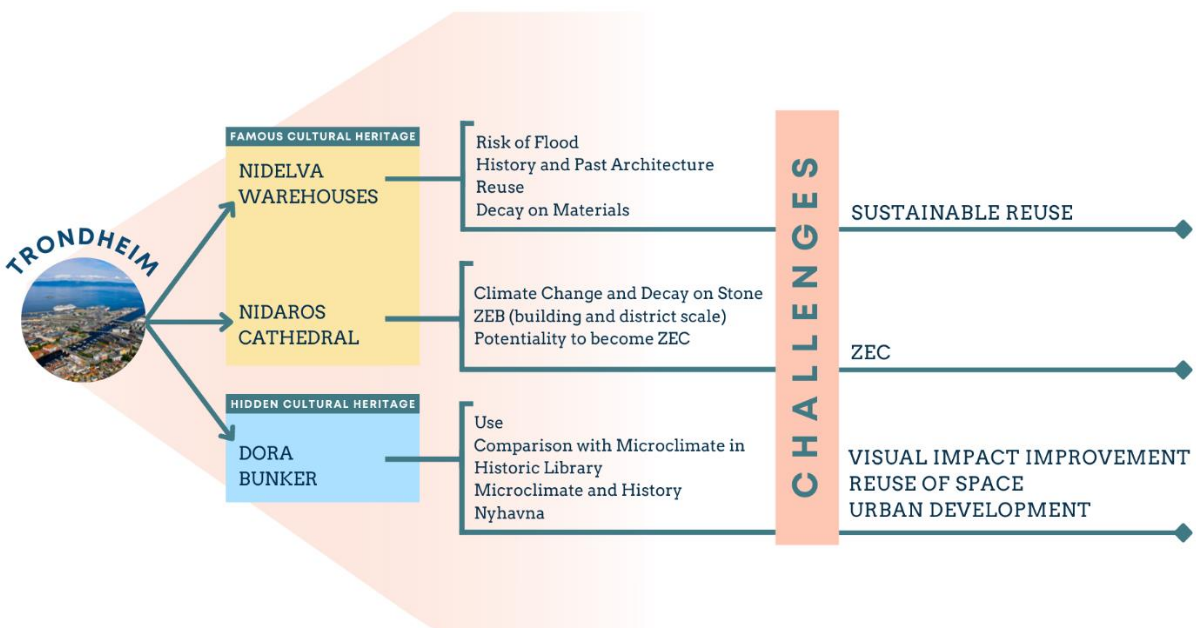
C. Bertolin, A. Califano, M. Schwai

CHePiCC SCHOOL CONCEPT

[MAIN IDEA]

The concept of the Cultural Heritage Protection in Climate Change (CHePiCC) School focuses on built cultural heritage as integral part of cultural landscapes and vice versa, both seriously affected by climate change and related natural catastrophes. Climate change itself is the connecting element and affects both cultural landscapes and cultural heritage. Higher Education (HE) students are given the chance to learn about applicable maintenance, preparedness and preservation measures by developing tailored measures for a given site and by implementing and actually testing their ideas. The concept focuses on the effects of climate change in a certain climate zone, and develops possibilities to teach sustainable, eco-friendly and cost-efficient preparedness measures for built cultural heritage and maintenance measures for cultural landscapes. The whole concept is hybrid, student-centred, following a strict hands-on approach and is research based. The entire concept of the School can easily be transferred to other frameworks. As a matter of fact, the idea of the School is summarized as follows:

- choosing a city (Trondheim, in this case);
- selecting the points of interest (both touristic and hidden cultural heritage) according to the School's topics;



(Credits: Giulia Boccacci, "La Sapienza" University, Rome – Italy)

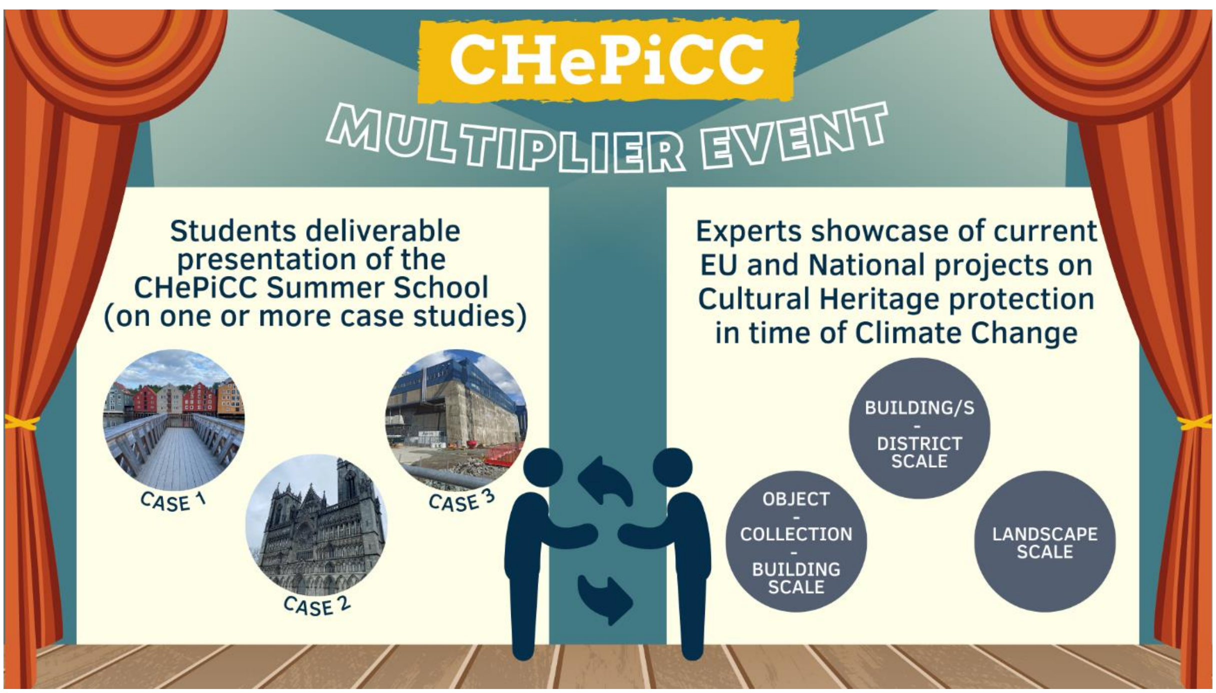
- engaging the local and international experts in the field (academics, stakeholders etc.) for the organization of high-level lessons and on-the-field activities;

Expert contributions and structure of the CHePiCC Summer School

MAIN TOPICS	CASE STUDIES: Warehouses	CASE STUDIES: Nidarosdomen	CASE STUDIES: Dora archives
History	Professor in Architecture Trondheim municipality delegate	Professor in Architecture	Professor in Cultural Heritage Preservation and Historic Climatalogy
Landscape	Professor in Urban Design and Planning	Professor in Urban Design and Planning	Professor in Urban Design and Planning Professor in Architecture
Conservation in Climate Change	Professor in Cultural Heritage Preservation and Historic Climatalogy Professor in Architecture	Nidaros Workshop staff Researcher in Architecture, Materials and Structures Researcher in Physics and Astronomy Researcher in Conservation	Researcher in Environment and Cultural Heritage Professor in Cultural Heritage Preservation and Historic Climatalogy Professor in Building Engineering

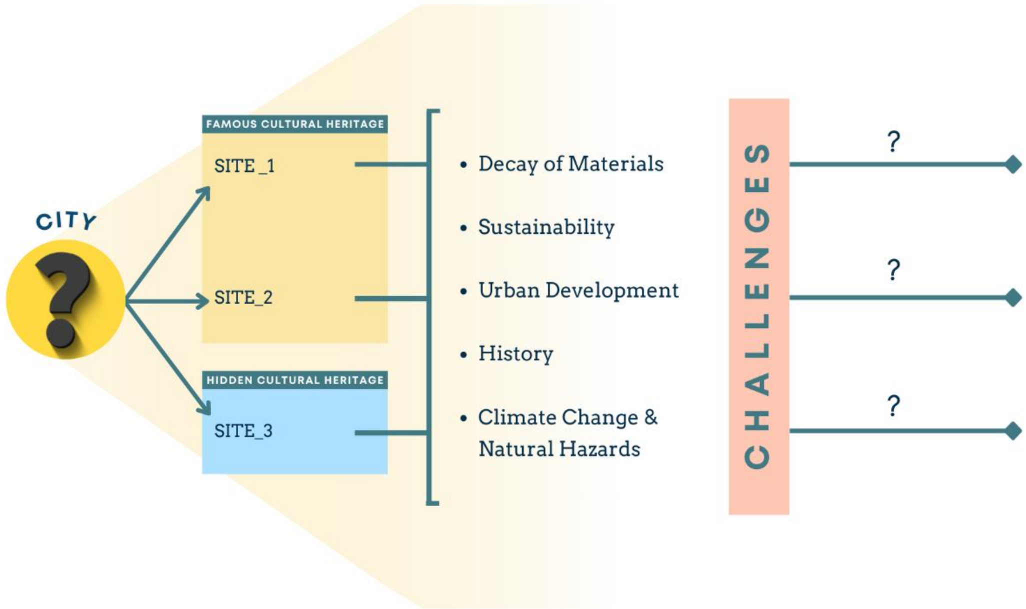
(Credits: Giulia Boccacci, "La Sapienza" University, Rome – Italy)

- dissemination of the students deliverables and of the main international research projects and activities focused on the School topics through a dedicated Multiplier Event.



(Credits: Giulia Boccacci, "La Sapienza" University, Rome – Italy)

For the above reasons, the School main concept has a high potential and can be ideally adapted to other conditions, cities and situations that may be interesting to study in the framework of the Cultural Heritage Protection. The concept for the summer university is applicable to any cultural landscape and its built heritage in Europe. It functions as important medium to gather practical experiences and get to know the respective built heritage and cultural landscapes on-site.



(Credits: Giulia Boccacci, "La Sapienza" University, Rome – Italy)

[ACTIVITIES FOR TEACHING STAFF]

The CHePiCC School is a transdisciplinary summer university school on cultural landscapes in climate change. It was mainly focused on cultural and natural landscape in Norway and on the most used material constituting its heritage-built environment i.e., wood. Notwithstanding, per each day of lesson a comparison with other landscapes in different climate zones (e.g., central Europe or the Mediterranean area) and/or other historic materials prone to climate-induced decay is provided.
In addition to the topic of the climate change impact on cultural landscapes, several lessons are focused on the Norwegian research directions towards application of green energy (especially solar energy that is a challenge in Scandinavian countries) and the achievement of zero emission to the built environment (here included the sub-group constituted by historical buildings). The teaching staff is made up by experts from several fields that provide their guidance and support during lessons, activities and visits. All the activities are coordinated

through internal meetings carried out during the School. The activities described above and carried out by the teaching staff contribute to reach the project's objective by fulfilling the following duties:

- preparation of easily understandable lessons on the treated topics by means of presentations with both theoretical and practical aspects;
- delivery of lessons to a wide group of international students, providing them insights and food for thought about the topics of concern;
- provision of support during the students self-learning activities, giving the learners the possibility to raise questions, share ideas and improve the scientific communication between people with different backgrounds (architects, engineers, conservators, geologists…);
- provision of support during the on-the-field visits, giving the learners the possibility to always count on experts for possible questions and discussions.

This way it is possible to bring heritage back into higher education (HE) teaching and learning, to enable future generations to protect cultural heritage and to facilitate a behavioral change concerning cultural heritage protection and climate change, especially in the prospective professional lives of HE learners and teachers, and to enable HE teachers to build and deliver engaging and high-quality learning formats.

[ACTIVITIES FOR LEARNERS]

The summer university is primarily addressed to students of architecture, protection of built cultural heritage, archaeology, urban/landscape planning, mechanical engineering, restauration, and architectural heritage. The program for HR learners comprises an intensive mix of frontal lessons, on-the-field visits and self-learning activities based on stimulating the discussion on the topics of concern. The program is thought in order to give the HE learners the right time to acquire and assimilate the theoretical and practical aspects of the frontal lessons, to actually see the real case studies and the local points of interest and, then, to elaborate the acquired information by sharing ideas with the other learners and staff and by writing group reports on the School topics.

The activities described above and carried out by the learners contribute to reach the project's objective by fulfilling the following duties:

- Attending frontal lessons;
- Real-time training on the software presented and explained during the lessons;
- Collecting photographic material and information during the on-

the-field visits;
• Working in groups and collecting the acquired knowledge in written reports and power-point presentations.

The above activities help to bring basic, academic need concerning cultural heritage (tangible, whether movable or immovable, but also intangible) and its protection back into society and to foster the understanding of its importance, its shared values and identities. The more tangible needs of building inclusive, modular and transdisciplinary learning programs for higher education learners enabled them to include in their professional lives all necessary disciplines for enhancing climate protection means, preparing cultural landscapes and their built heritage for the immediate effects of climate change and natural catastrophes, and doing the same for movable cultural heritage.

PART II

C. Bertolin, A. Califano, M. Schwai

PRACTICAL INFORMATION

[COVID-19]

Since 12.02.2022 there are no requirements for testing, quarantine or registration upon arrival in Norway. Anyway, you are invited to behave responsibly, to wash your hands regularly, to keep the safety distance and to avoid crowded places when possible.

In order to enter Norway, beside your passport (and eventually VISA if you are from Extra EU countries) you need to have the green pass and use a face mask if needed.

Official updates available at

https://reopen.europa.eu/

https://www.regjeringen.no/en/topics/koronavirus-covid-19/id2692388/

[TRAVEL]

Upon arrival at Trondheim Airport (*Trondheim Lufthavn*, in Norwegian), it is possible to reach the city center via bus or via train.

Via bus (at any time): https://www.atb.no/en/trondheim-airport/

(timetable at https://www.atb.no/getfile.php/1394071-1646391897/Rutetabeller/21-22_by/AtB_Linje70.pdf)

Via urban ATB bus (in diurnal time): line 70 is recommended as it stops in Buran 1, which is only 750 m away from the students' accommodation, the Trondheim Vandrerhjem Hostel.
(See the walking itinerary from Buran 1 to Trondheim Vandrerhjem at https://goo.gl/maps/EBwpEnYDZJsyDeNW7)

Information about tickets and tickets purchasing available at: https://www.atb.no/en/ticket/#collapse-article_8

Make sure you have a valid ticket for the entire trip by purchasing for the right zone. For example, if you are traveling from the Airport to

Trondheim, you must purchase a ticket for two zones. The average price for an adult two-zones single ticket is 84 NOK (8.50 € circa). Additional info at https://www.atb.no/en/zones-and-zone-maps/#collapse-article_6

The trip from Trondheim Airport to Buran 1 via ATB bus lasts about 50 minutes.

Via train: https://www.vaernesekspressen.no.

The Vaernes Express from Trondheim Airport (Lufthavn) Vaernes to FB 73 Buran is recommended. The trip lasts about 27 minutes and the average ticket price is 189 NOK (19.20 € circa).

Information about timetables, fares and ticket purchasing available at https://www.vaernesekspressen.no/no/rutetider/

Please beware that the Vaernes Express website is in Norwegian.

IMPORTANT NOTE FOR PEOPLE HAVING CONNECTION FLIGHTS THROUGH OSLO: please be aware that, upon arriving at Oslo Airport, it is mandatory to pick up eventual checked-in baggage and go through the check-in and the custom controls again. In case you do not own checked-in baggage, you need to go through the custom controls again as well. This usually takes a long time, so please keep an eye on your time-schedule.

[ACCOMODATION]

Students and part of the Staff will stay at the Trondheim Vandrerhjem Hostel (https://www.trondheimvandrerhjem.no/home) located in Weidemanns vei 41 B, 7043 Trondheim.

Trondheim Vandrerhjem shared dorms/rooms/apartments are equipped with bed linen and towels. There are no bars or cafeterias within the building, but free tea and coffee are always available in the common area. Guests can make their own food in the fully equipped guest kitchen, order take-away food from food delivery services or go to restaurants. The closest restaurant is 3 minutes away from the hostel. However, by walking 10 minutes down to Solsiden, a wide selection of restaurants and cafes can be found. The hostel has free Wi-Fi, a laundry room and is facilitated for special needs. Smoking is strictly forbidden indoors, and the alcohol consumption is prohibited in the common areas.

From the hostel, the closest grocery stores are 5 minutes walking (i.e., Bunnpris supermarket), and 7 minutes to Rema 1000 supermarket at Rosenborg

Concerning the distance to other nice spots in the city:

- To the NTNU campus in Gløshaugen you can expect 30 minutes walking
- To the lovely cobblestone streets of Bakklandet, you can expect a 16 minutes walk.
- Torvet in the city center is situated 20-25 minutes walk from Trondheim Vandrerhjem.
  Please be aware that the return to the hostel might take longer, as Trondheim Vandrerhjem is placed on top of a hill.

If you do not prefer walking, there are tons of colourful electric scooters placed all over the city, which might be rented for a small fee.

[FOOD]

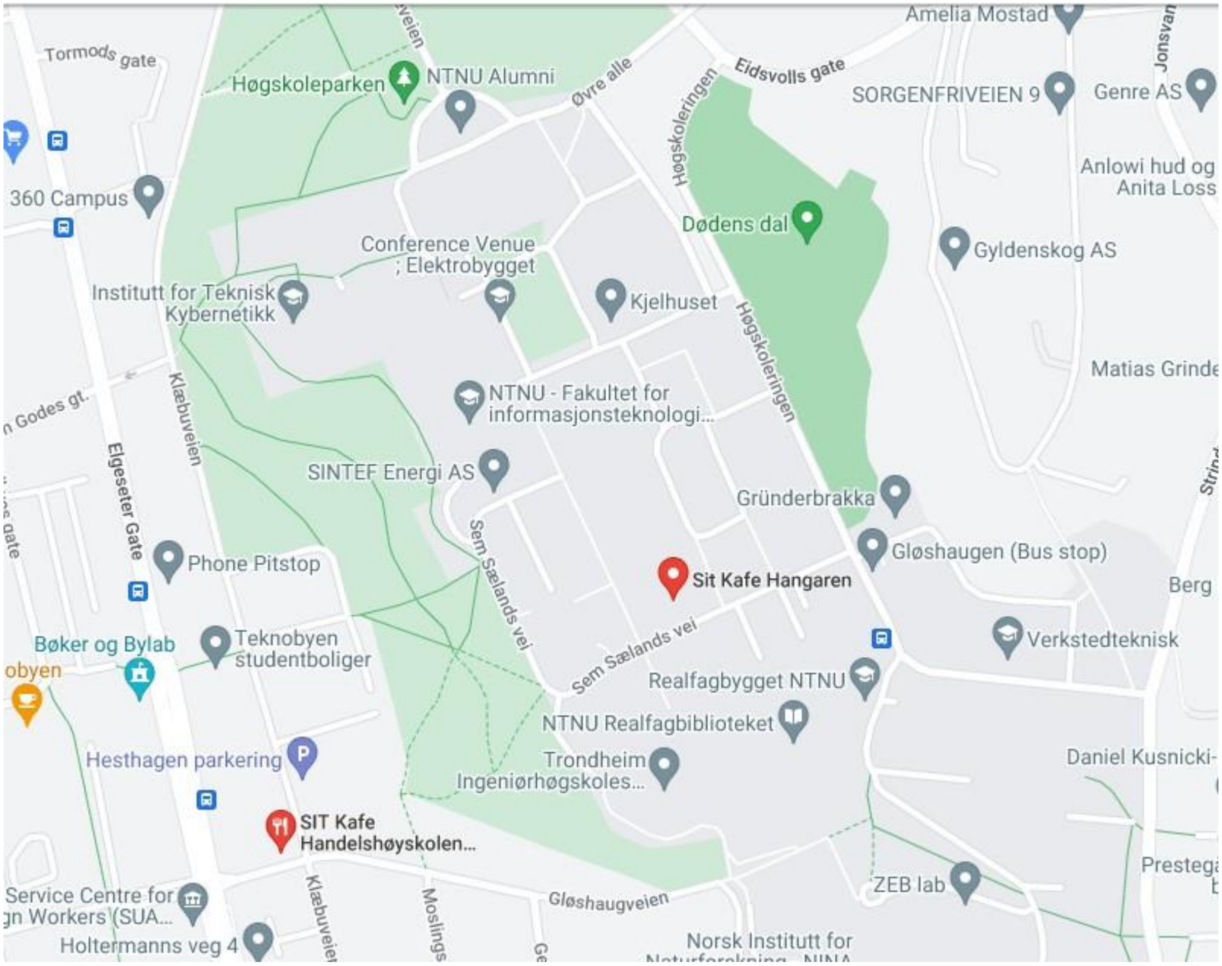
During lunchtime from Monday 30th of May to Friday 3rd of June, Students and Staff are on their own for the meals. On Saturday 4th of June, the lunch is offered from NTNU to students and staff.

After the morning lessons, students and staff will go together to have lunch to the cantina located in Sentralbygg 1 in Gløshaugen (Sit Kafe Hangaren). During the days with lessons and during the multiplier event of Saturday 4th of June coffee breaks will be organized by NTNU.

For the dinners Students and Staff are on their own.
An outdoor social evening event will be organized for students and staff if the weather will allow it during the week (based on nice weather forecast, during one evening from Monday to Thursday).

A social dinner will be organized for the teaching staff and guest lecturers on Friday 3rd June at 19:00 at the Olivia restaurant, Beddingen 16, 7014 Trondheim.
https://oliviarestauranter.no/restaurant/solsiden/

Please consider that the Campus is equipped with bars/cafeterias, the cantina in Sentralbygg 1, and a small supermarket (RAPIDO) in the same building.



[CURRENCY]

In Norway the official currency is the Norwegian krone (NOK). Please note that 1 € is about 10 NOK and that you can pay by card everywhere. Norway is expensive, remember to plan your budget accordingly. There is 25% VAT included in all prices and tipping is not customary.

[CLOTHING]

Pack warm clothing - there is a reason Norwegians are known for their wool sweaters! Trondheim’s average maximum temperature in June is 15°C/17°C, while the minimum temperature is 7°C/9°C. The following clothing items are recommended:

- cap (and gloves)
- waterproof jacket or umbrella
- proper footwear (sturdy hiking boots or rain boots)

- warm clothes if the temperature goes down

In addition, be aware that in Trondheim in May/June the sun rises at 3 AM and sets at 11 PM. The use of eye-masks for sleeping is highly recommended.

[MISCELLANEOUS]

It is recommended for students and staff to bring:
- sketchbook/pens/laptop/pendrive
- camera
- travel documentation (passport, health insurance, travel insurance, *etc.*)
- personal medicine

[USEFUL PHRASES]

There are many local dialects of Norwegian, but everybody can speak English. Here are some words to help you get by in the local language:
Thank you – Takk
Sorry – Beklager
Hello – Hei, god dag
Goodbye – Ha det
Yes – Ja
No – Nei
Excuse me – Unnskyld
Where is…? – Hvor er…?
Cheers! – Skål!

BACKGROUND INFORMATION

[ABOUT TRONDHEIM]

Trondheim is a city and municipality in Trøndelag county, Norway. It is the third most populous municipality in Norway, although the fourth largest urban area. Trondheim lies on the south shore of Trondheim Fjord at the mouth of the River Nidelva. Among the major technology-oriented institutions headquartered in Trondheim are the Norwegian University of Science and Technology (NTNU), the Foundation for Scientific and Industrial Research (SINTEF), and St. Olavs University Hospital. According to the sagas, the city was founded by king Olav Tryggvason in 997, but archaeological evidence suggests that there was already a settlement, or a seasonal a trading post on the left bank of the estuary. Olav Haraldsson ('the holy king') built a royal residence close to the settlement in the early 11th C, and served as the capital of Norway during the Viking Age until 1217, when the kings took residence in Bergen. Trondheim remained the clerical centre of Norway, where Olav Kyrre, the son of Olav Haraldsson's half-brother Harald Hardrada, established a see with resident bishhop and funded the building of a large stone-built church for this purpose. This was commenced around 1070 on the site of the present cathedral. From 1152/-53 the city was the seat of the Catholic Archdiocese of Nidaros until the Reformation in 1536-37; since then, it has remained the seat of the Lutheran Diocese of Nidaros. The current municipality dates from 1964, when Trondheim merged with Byneset, Leinstrand, Strinda and Tiller, and the municipality was further expanded 1 January 2020 when Trondheim merged with Klæbu. The main attractions of Trondheim are:

- Nidaros Cathedral and the Archbishop's Palace, located side by side in south of the city centre. The cathedral, built partly on the foundations of Olav Kyrre's church, is the most important Gothic monument in Norway and is said to have been the most important Christian pilgrimage site of Northern Europe during the Middle Ages. Today, it is the northernmost medieval cathedral in the world, and the second largest in Scandinavia;
- DORA 1, a German submarine base that housed the 13th U-boat Flotilla during the Second World War occupation of Norway. Today the bunker houses various archives, among them the city archives, the university and state archives. More recently, DORA has been used as a concert venue;
- Kristiansten Fortress, built in the 1682-84, extended 1740, located on a hill above the eastern bank of the river. It repelled the invading Swedes

- in 1718. Abandoned as a military fortress 1816 after the union of Sweden and Norway 1814.
- the statue of Olav Tryggvason, the founder of Trondheim, located in the city's central square, mounted on top of a column. The statue was made by the sculptor Wilhelm Rasmussen, who held a high artistic standing before World War II, and also made several sculptures on the Cathedral, a.o. the Calvary group above the central West door. His reputation became somewhat tainted after the war, as he was a member of the Norwegian Nazi party.
- the isle of Munkholmen, a popular tourist attraction and recreation site. The islet has served as a place of execution, a monastery, a fortress, prison, and a Second World War anti-aircraft gun station;
- Stiftsgården, built as aprivate residence for a wealthy widow 1774-78, sold to the Danish-Norwegian State 1800 and used as residence and office for the county governor and administration until 1906. It has been the royal residence in Trondheim since 1800, and is said to be the largest wooden building in Northern Europe.

Source: https://en.wikipedia.org/wiki/Trondheim

[SCHOOL OBJECTIVES]

The summer university school funded by the Erasmus+ project "Cultural Heritage Protection in Climate Change online (ChePiCC online)", will take place on the premise of the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway.

This will be a transdisciplinary summer university school on cultural landscapes in climate change. It will be mainly focused on cultural and natural landscape in Norway and on the most used material constituting its heritage-built environment i.e., wood. Notwithstanding, per each day of lesson a comparison with other landscapes in different climate zones (e.g., central Europe or the Mediterranean area) and/or other historic materials prone to climate-induced decay will be also provided.

In addition to the topic of the climate change impact on cultural landscapes, several lessons will be focused on the Norwegian research directions towards application of green energy (especially solar energy that is a challenge in Scandinavian countries) and the achievement of zero emission to the built environment (here included the sub-group constituted by historical buildings).

Finally, in term of preventive conservation of movable cultural heritage and preparedness in emergency, the University School will offer a set of lessons on climate-induced degradation processes and optimal microclimate for the preservation of paper and book collection kept in libraries and archives. This topic will be presented in the framework of a unique case study that exists in Trondheim i.e., the Dora archive into a IIWW bunker. This archive in addition of being unique for its way of re-using/re-thinking a IIWW heritage, it offers optimal natural conditions for preservation.

All these topics will offer food for thought to the students to see and experience the changes and, thus, absorb the necessity of climate change actions related to the preservation of cultural landscapes and their integral cultural heritage. Beside frontal lessons in the morning, a mixture of excursions and support during self-learning days through discussions will be offered to the participants. The afternoon excursions include the modern urban development of Trondheim laying its focus on the district of Nyhavna, the old harbor district with its historic wooden warehouses and the U-boat bunker "Dora" from World War II, which, as described above, is used to this day as an archive, among other things.

[STAFF EXPERTISE]

The teaching staff participates as experts on:

- cultural landscapes (from Scandinavian to Mediterranean countries e.g., NTNU, DUK, ISAC-CNR, ULPGC),

- preservation and preparedness measures, recovery of cultural heritage, cooperation with emergency responders in crisis situations (e.g., DUK)

- built heritage, material preservation and maintenance as well as preparedness measures for built and movable heritage and material handling (e.g., NTNU for wooden structures and ITAM for post disaster recovery)

- climate change impact, climate-induced risk assessment and material preservation in time of climate change (e.g., CNR-ISAC and NTNU)

- recovery and preservation of different types of movable heritage and material (e.g., UAA).

The summer university is primarily addressed to students of architecture, protection of built cultural heritage, archaeology, urban/landscape planning, mechanical engineering, restauration, and architectural heritage.

[SCHOOL EXPECTED DELIVERABLE]

It is expected that the 4 groups of students will deliver each a deliverable in form of:

- a working document as .docx and as .pdf file
- a presentation as .ppt file
- The presentation will be presented by the components of each group during the multiplier event, on Saturday 4th of June in the morning in the Auditorium R9 in the Realfabygget at the NTNU Gløshaugen Campus (see the detailed program below). The multiplier event has been organized by NTNU within the framework of CHePiCC and aims to cluster the research and networking projects in which NTNU is involved to optimize the dissemination of research results and activities.

The participants to the summer university school, following a successful completion of the above-mentioned deliverable, will obtain a certificate with the possibility to obtain ECTS at their own university.

[SCHOOL ORGANIZERS]

The school has been organized by Prof. Chiara Bertolin and Prof. Markus Schwai of NTNU within the framework of the Erasmus CHEPICC project, with the support of the Coordinator Universitat fur weiterbildung Krems (UWK), Austria, and the partners of the Erasmus project: Universitat fur Angewandte Kunst Wien (UAA), Austria; Ustav Teoreticke a Aplikovane Mechaniky Avcr (ITAM), Czech Republic; Consiglio Nazionale delle Ricerche – Istituto di Scienze dell`Atmosfera e del Clima (CNR-ISAC), Italy; Universidad de Las Palmas de Gran Canaria. Details of the staff directly involved in the lessons are reported on page 20.

[SCHOOL ACKNOWLEDGEMENT]

The organization of the University Summer School has been possible thanks to the economic support of the:

- Cultural Heritage Protection in time of Climate Change Online (CHePICC) Erasmus+ Project No. 2020-1-AT01-KA226-HE092550 funded by the EU commission

- Sustainable Management of Heritage Building in a long-term perspective (Symbol) Research Project n. 274749 funded by the Norwegian Research Council

- TC20 – Structural Integrity and Condition Monitoring of Historical Structures.TC 20 is an ESIS (European Structural Integrity Society) Technical Committee completely dedicated to the structural integrity and preservation of historical buildings.The evolution and impact of climate changes on past and recent structures together with the health monitoring of existing structures is also aim of this TC.

The organization of the Multiplier event on Saturday 4th of June 2022 has been possible thanks to the economic and scientific support of the:

- Cultural Heritage Protection in time of Climate Change Online (CHePICC) Erasmus+ Project No. 2020-1-AT01-KA226-HE092550 funded by the EU commission

- Sustainable Management of Heritage Building in a long-term perspective (Symbol) Research Project n. 274749 funded by the Norwegian Research Council

- Spara Och Bevara Project n. 50049–1 funded by the Swedish Energy Agency

- Enhancing optimal exploitation of solar energy in Nordic cities through the digitalization of the built environment (Helios) Project n. 324243 funded by the Norwegian Research Council

- Energy eFFiciency buIlding and CirculAr eConomY for thermal insulating solutions (Efficacy) EEA Bilateral Initiative funded by EEA and Norway Country

- Protecting our industrial heritage: preservation and new uses for traditional warehouses (PROTIND) EEA Bilateral Initiative funded by EEA and Norway Country;

- - TC20 – Structural Integrity and Condition Monitoring of Historical Structures, belonging to ESIS.

The scientific dissemination of the presentations at the Multiplier Event on Saturday 4th June 2022 is possible thanks to the help and support of the:

- Symbol Research Project n. 274749, funded by the Norwegian Research

Council

- Italian Group of Fracture (IGF);
- - TC20 – Structural Integrity and Condition Monitoring of Historical Structures, belonging to ESIS.

Acknowledgements go to guest lecturers that have become available during both the University summer school and the Multiplier event to present their work and research projects. Special thanks to the Norwegian Research Council and the Symbol project that have allowed the economic support to have NTNU students and staff during the University school and the Multiplier Event.

PLACES

[NORWEGIAN UNIVERSITY of SCIENCE and TECHNOLOGY – NTNU]

Gløshaugen Campus

Almost all activities of the School will start in the morning at the Gløshaugen Campus of NTNU. A walking itinerary from the Trondheim Vandrerhjem Hostel to the Campus is available at https://goo.gl/maps/D6W2hdUtJtNBFQLA6 .

Logistical information about the Campus available at https://www.ntnu.edu/gloshaugen

Gloshaugen Campus Picture by Gunnar K. Hansen/NTNU

The lessons/activities held in Gløshaugen Campus will follow the subsequent room schedule

Date	Building	Room	Time
30.05.2022	Sentralbygg 1	S1	All day
31.05.2022	Kjelhuset	KJL2	All day
01.06.2022	Kjelhuset	KJL21	All day
02.06.2022	Sentralbygg 1	S1	All day
03.06.2022	Kjelhuset	KJL21	All day
04.06.2022	Realfabygget	R9	All day

The internal CHePiCC staff meeting will be held according to what follows

Date	Building	Room	Time
01.06.2022	Sentralbygg 1	265	13:00 – 15:00

For the buildings locations please refer to the Gløshaugen Campus map below and to the map locator site of NTNU: https://www.ntnu.edu/map
Through this website, it is possible to search rooms within the NTNU Gløshaugen campus in the dropdown-menu on the left.

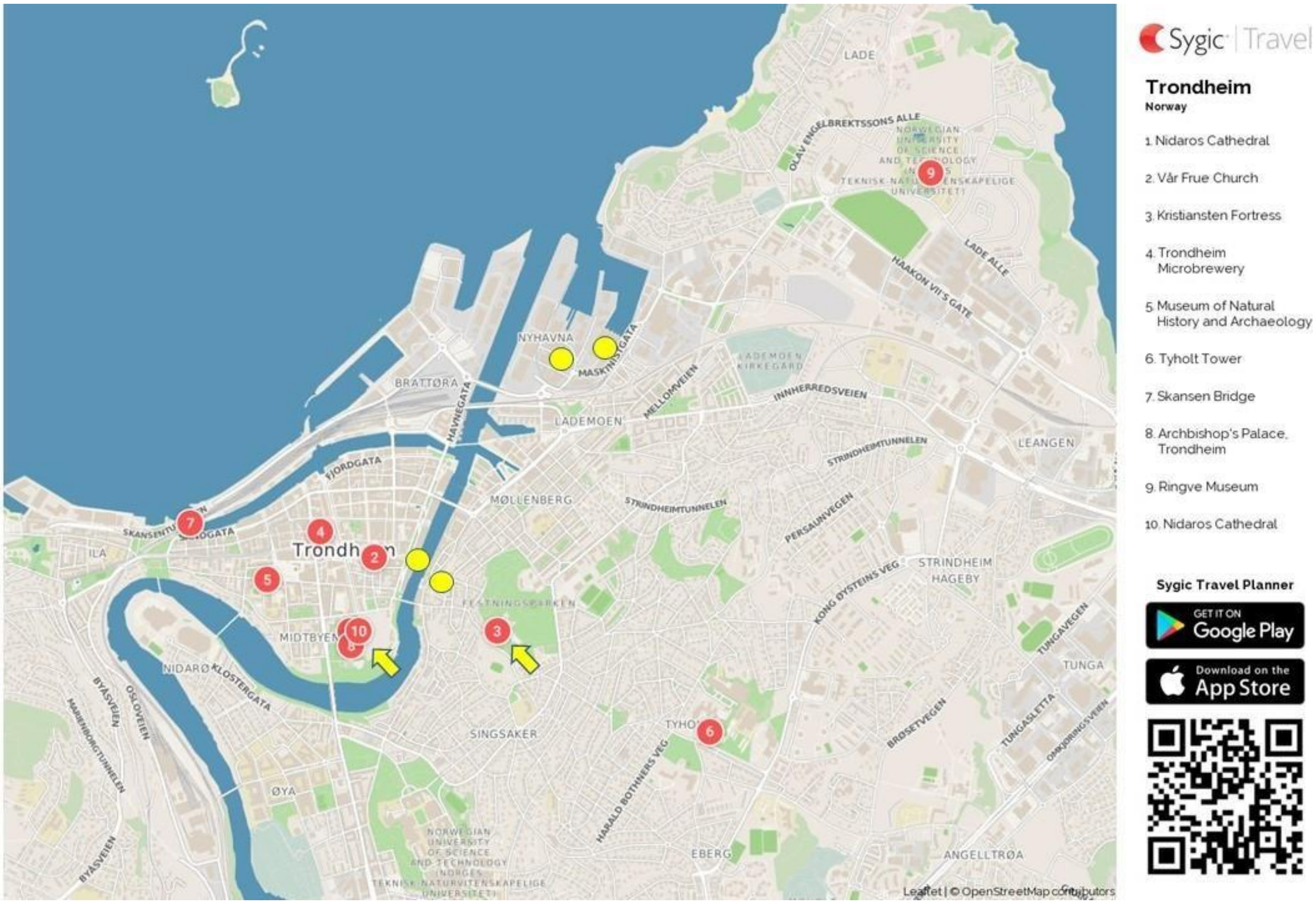
[TRONDHEIM CITY CENTER]

During the School several on-the-field visits will be arranged. They will be focused on exploring the following sites located in Trondheim:

- Bakklandet
- the Warehouses
- the Nidaros Cathedral
- the Cathedral Stone Workshop
- the Fortress
- Nyhavna

Places

- Dora
- Dora Archive



PEOPLE

[STUDENTS]

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Vergelli	Lisa	NTNU	lisa.vergelli@uniroma1.it

[STUDENTS' GROUPS]

The students have been divided in the following groups for carrying out self-learning activities.

Group 1	Group 2	Group 3	Group 4
Afonso Santana J. E. Calapiña Arriaga C. Klinkert M. Higgins P. Vergelli L.	Bartolucci B. Grabner C. Kocabas E. Parracha J. Trujillo Cabrera L.	Dietrich F. Jokin I. Moreno Falcon M. Ogut O.	Aguiar Botello C. Barakat I. Boccacci G. Panahifar M.

[STAFF]

Surname	Name	Affiliation	Email address
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Woller	Raffaela	UWK	raffaela.woller@donau-uni.ac.at

IMPORTANT NOTE: The Staff needs to be available for counseling and supporting the students self-learning activities on June 1st 2022 and on June 3rd 2022 from 10:00 to 12:00 and from 13:00 to 15:00. In addition, the Staff will always follow the students during their walking visits.

[CONTRIBUTORS]

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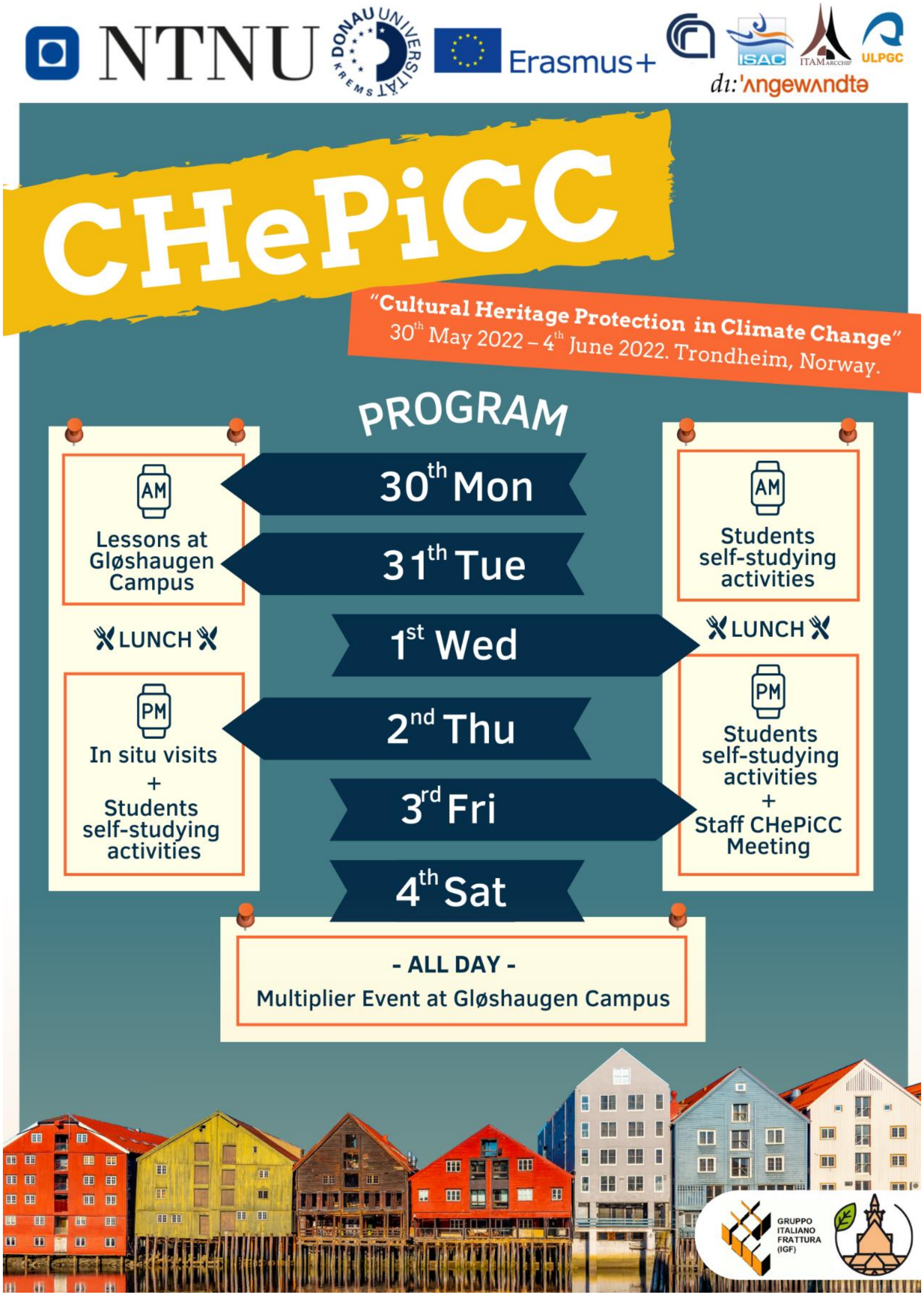
PROGRAM OVERVIEW



(Credits: Giulia Boccacci, "La Sapienza" University, Rome – Italy)

[DAY 1 – 30.05.2022]

Where:
- Gløshaugen Campus (morning)
- Bakklandet (afternoon)
- The Warehouses (afternoon)

What:
- Welcome, Presentation of School Program (morning)
- Lessons (morning)
- In situ visits (afternoon)

[DAY 2 – 31.05.2022]

Where:
- Gløshaugen Campus (morning)
- Nidaros Cathedral (afternoon)
- the Cathedral stone workshop (afternoon)
- the Fortress (afternoon)

What:
- Lessons (morning)
- In situ visits (afternoon)

[DAY 3 – 01.06.2022]

Where: Gløshaugen Campus (all day)
What: Students self-studying activities (all day)
What: Staff Internal CHePiCC Meeting (afternoon)

[DAY 4 – 02.06.2022]

Where:
- Gløshaugen Campus (morning)
- Nyhavna (afternoon)
- Dora and Dora archive (afternoon)

What:

- Lessons (morning)
- In situ visits (afternoon)

[DAY 5 – 03.06.2022]

Where: Gløshaugen Campus (all day)
What: Students self-studying activities (all day)
What: Staff Internal CHePiCC Meeting (afternoon)

[DAY 6 – 04.06.2022]

Where: Gløshaugen Campus (all day)
What: Multiplier event (all day)

DETAILED
DAY-BY-DAY
PROGRAM

DAY 1 - 30.05.2022

MEETING
Sentralbygg 1, Room S1
h 8:35

CHePiCC DAY 1

30th May 2022

START	END	DESCRIPTION	SPEAKER	TITLE	WHERE
8:45	8:55	School Opening	S. Hammer	Official NTNU Welcome	Gløshaugen
8:55	9:05	School Opening	C. Bertolin M. Schwai	Presentation of the Summer School and of its Scheme	Gløshaugen
9:05	9:30	Lesson	E. G. Johnsen	Bakklandet	Gløshaugen
9:30	10:00	Lesson	E. G. Johnsen	Warehouse in Kjøpmannsgata	Gløshaugen
10:00	10:30	Lesson	C. Bertolin	Monitoring campaign in the NTNU Warehouse in Kjøpmannsgata and its conservative issues	Gløshaugen
10:30	10:45	COFFEE BREAK			Gløshaugen
10:45	11:15	Lesson	M. Bye	PITCH Project	Gløshaugen
11:15	11:45	Lesson	T. Drdácký	Risk of Flood in Urban areas: Example of Prague	Gløshaugen
11:45	13:00	LUNCH BREAK			Gløshaugen
13:00	15:15	In situ visits	E. G. Johnsen M.Schwai C. Bertolin and all partners	Bakklandet, Warehouses	Trondheim City center
15:15	18:15	STUDENTS SELF-LEARNING ACTIVITIES			

Erasmus+

(Credits: Giulia Boccacci, "La Sapienza" University, Rome – Italy)

Day 1 – 30.05.2022

The Speakers are invited to upload their presentations before the beginning of their session. Please note that the presentations will be recorded. Zoom link: https://NTNU.zoom.us/j/99265434015?pwd=ZEZpNmlYMitBa2lJdW41bFhoQnloQT09

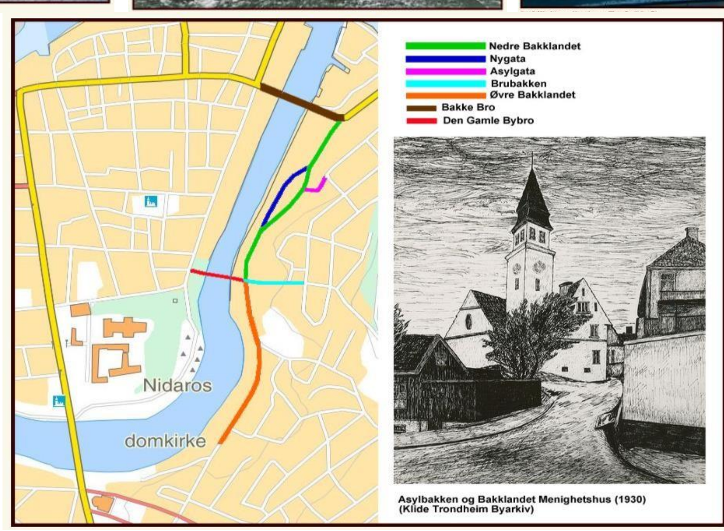
[IN SITU VISITS]

Meeting Point: Outside the main entrance of Sentralbygg 1, close to the Kantina
Meeting time: 13:00

Bakklandet

It is Trondheim’s best-known neighborhood. With original, colorful wood buildings and cobblestone streets, it has a “*koselig*” atmosphere and is a great place to spend an evening. You can sit outside one of the many street cafes or grab a beer at *Antikvariatet* while listening to live music at night.



Asylbakken og Bakklandet Menighetshus (1930)
(Kilde Trondheim Byarkiv)

The Warehouses

The historic harbour of Trondheim was the estuary of the river Nidelva. Along the western bank (city side) the merchants had their properties with dwellings and shops, and storage houses towards the river. The city consisting almost entirely of timber buildings was often ravaged by fires, and was in 1681 almost entirely destroyed. The measured for fire-safety taken after the former fire of 1851 proved inadequate, and an entirely new town plan with broad, straight streets was envisaged by the king. The storage buildings were separated from the rest of the built-up area by an avenue with an upper level serving the merchants' mansions, and a lower street serving the warehouses. This resulted in one of the most distinctive city-scape, not only in the city, but as a cultural and aesthetic heritage of national importance. The buildings stand along both sides of the Nidelven river; those on the east bank belonging to the un-regulated suburb Bakklandet after the more mediaeval pattern with dwelling, shop and warehouse combined on the same lots. Originally they were used as storage for such goods as grain, sugar, salt and fish.

The construction was the traditional technique of interlocking logs, with naked log-timber interior surfaces. When the shallow waters to the north of the city were dredged and protected by a sea wall in the early 19th century the insufficient harbour facilities were supplied with a necessary extension, and similar warehouses were built on the northern shore of the city, and later connected with the railway station on the artificial islands, forming another distinctive feature of the city-scape, the canal harbour. The original wharfs were not used as dwellings, but today, many have been converted into residential houses; this is however not permitted in the city side row along the river. Others are art galleries, coffee shops, restaurants, and boutiques. The cobbled walking paths make exploring the historic wharfs an easy and beautiful stroll. There are also several benches along the paths for those who want to relax. The Old Town Bridge over the Nidelven River is a great spot to get a picturesque view of the historic wharfs from a distance.

Source: https://www.gpsmycity.com/attractions/historic-wharves-29654.html

[RESEARCH QUESTIONS]

1. It is clear that the warehouses have an impact on the landscape of the city of Trondheim. Which warehouses' aspects have the most important identity among: color, form, location and use? In addition, what needs to be preserved the most?

2. How did the past decisions of the municipalities and of the people influence the actual landscape?

3. How does a NH, as a flood, put the CHB at risk? And how do extreme events modify the actual landscape?

4. What is the expected impact of climate change in term of intensity and frequency increase of flood events? What can be the impact in the Bakklandet district?

5. What are the preventive conservation challenges of Bakklandet district? What are the possible future steps? In your opinion, how could the preservation, the significance and the use of this district be improved, in a time of climate change?

DAY 2 – 31.05.2022

START	END	DESCRIPTION	SPEAKER	TITLE	WHERE
9:00	9:25	Lesson	M. Schwai	Urban layout of the center of Trondheim and the fortress	Gløshaugen
9:25	9:50	Lesson	D. Nilsen	The Cathedral of Nidaros, Building a Historic Monument	Gløshaugen
9:50	10:15	Lesson	M. L. Anker	Energy Smart Nidaros Cathedral	Gløshaugen
10:15	10:30	COFFEE BREAK			Gløshaugen
10:30	10:55	Lesson	A. Loli	The ZEB concept and the ZER tool at building scale and at district level	Gløshaugen
10:55	11:20	Lesson	S. Cavazzani C. Bertolin	Climate change impact on stone building: the Trondheim case study	Gløshaugen
11:20	11:45	Lesson	M. Haselberger	Problems today - challenges tomorrow! Decay of stone cultural heritage in Austria and expected changes related to climate change	Gløshaugen
11:45	12:45	LUNCH BREAK			Gløshaugen
12:45	15:15	In situ visits	M. L. Anker	Cathedral, The stone workshop, The fortress	Trondheim City center
15:15	18:15	STUDENTS SELF-LEARNING ACTIVITIES			

(Credits: Giulia Boccacci, "La Sapienza" University, Rome – Italy)

Day 2 – 31.05.2022

The speakers are invited to upload their presentations before the beginning of their session. Please note that the presentations will be recorded. Zoom link: https://NTNU.zoom.us/j/99265434015?pwd=ZEZpNmlYMitBa2lJdW41bFhoQnloQT09

[IN SITU VISITS]

Meeting Point: Outside the main entrance of Sentralbygg 1, close to the Kantina
Meeting time: 12:45

The Nidaros Cathedral

The Nidaros Cathedral, Scandinavia's largest medieval structure, is worth seeing even if just from the outside. Its history of construction is visible on the interior, with parts built in different styles. This is where St. Olav Ways, (a 643 km pilgrimage from Oslo built during the Middle Ages), ends, and where the royals of Norway are coronated.

The Cathedral in 1857

The Stone workshop

The Norwegian parliament has designated the restoration workshop (Bygghytta) belonging to Nidaros Cathedral Restoration Works (NDR) as a national competence center for the preservation and restoration of historic stone buildings. This means that in addition to restoring and maintaining Nidaros Cathedral and the Archbishop's Palace, NDR is tasked with preserving and further developing the traditional crafts represented at the Bygghytta craftsmen's lodge.

Source: https://www.nidarosdomen.no/en/ndr/om-ndr/nasjonalt-kompetansesenter-for-verneverdige-bygninger-i-stein

The Fortress

The fortress from 1695 can be visited for free. The surrounding park offers amazing views over the city and is popular for sunset picnics and sports. For a bird's-eye view of the entire city, go to the observation deck at Tyholttårnet. The tower hosts a restaurant with a pizza buffet (117 NOK, daily until 6 PM).

[RESEARCH QUESTIONS]

1. How has the Cathedral influenced the history and the development of the city of Trondheim? Is the Cathedral still influencing the city attraction? Is there any tangible and intangible value?

2. How has the landscape been preserved over the centuries? Why? Has the Cathedral influenced the landscape development?

3. How may the new project of an energy smart Nidaros Cathedral transform the significance of the Cathedral itself and of the surrounding environment?

4. Which strategy may be adopted to find a trade-off solution between the preservation of heritage/landscape significance and the adoption of mitigation actions to CC? Are you able to think about further possible mitigation actions applied to this case study?

DAY 3 - 01.06.2022

(Credits: Giulia Boccacci, "La Sapienza" University, Rome – Italy)

DAY 4 - 02.06.2022

MEETING
Sentralbygg 1, Room S1
h 8:20

CHePiCC DAY 4

2nd June 2022

START	END	DESCRIPTION	SPEAKER	TITLE	WHERE
8:35	9:00	Lesson	M. Haselberger	Problems today - challenges tomorrow! Decay of stone cultural heritage in Austria and expected changes related to climate change	Gløshaugen
9:00	9:25	Lesson	E. Verticchio	Archives and Libraries in Historic Buildings: natural climates and microclimate conditions for preservation	Gløshaugen
9:25	9:50	Lesson	C. Bertolin	The Dora archives: opportunities and conservation challenges	Gløshaugen
9:50	10:15	Lesson	A. Kaiser	Emergency preparations for libraries and archives	Gløshaugen
10:15	10:45	COFFEE BREAK			Gløshaugen
10:45	11:10	Lesson	M. Schwai	Nyhavna the district and the plans of development	Gløshaugen
11:10	11:35	Lesson	R. Narbona	Transfers: Landscape-Project	Gløshaugen
11:35	12:00	Lesson	G. Lobaccaro	Solar Energy in new district, the challenges of the Scandinavian Countries	Gløshaugen
12:00	12:55	LUNCH BREAK			Gløshaugen
12:55	15:15	In situ visits	C. Bertolin M. Schwai G. Lobaccaro	Nyhavna Dora Dora archives	Trondheim City Center
15:15	18:15	STUDENTS SELF-LEARNING ACTIVITIES			

Erasmus+

(Credits: Giulia Boccacci, "La Sapienza" University, Rome – Italy)

Day 4 – 02.06.2022

The Speakers are invited to upload their presentations before the beginning of their session. Please note that the presentations will be recorded. Zoom link: https://NTNU.zoom.us/j/99265434015?pwd=ZEZpNmlYMitBa2lJdW41bFhoQnloQT09

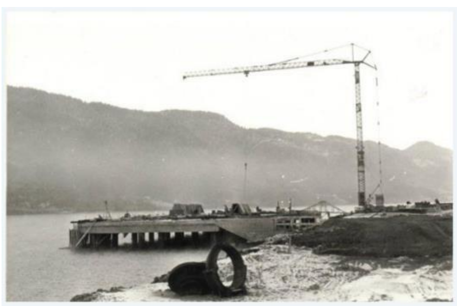
[IN SITU VISITS]

Meeting Point: Outside the main entrance of Sentralbygg 1, close to the Kantina
Meeting time: 12:55
Meeting Point and time near Nyhavna/Dora: Maskinistgata 1, 7042 Trondheim at 13:30.

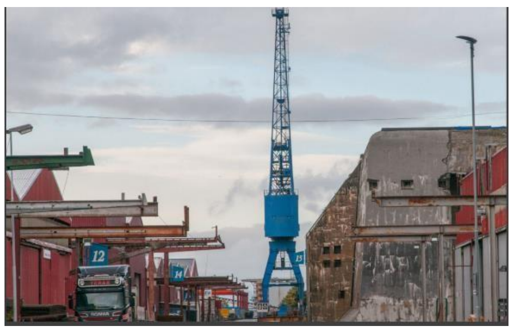
Nyhavna

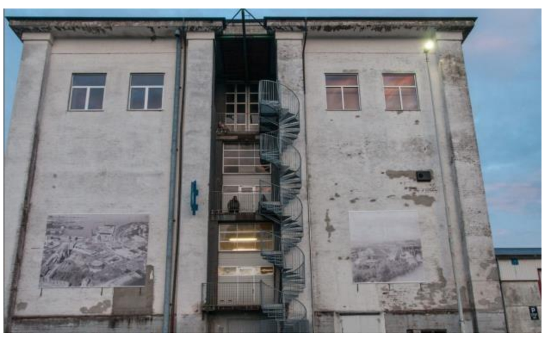
> Nyhavna is a port area in Trondheim, between Nidelva in the west, Lademoen in the east, Ladehammeren in the north and Nedre Elvehavn in the south. The harbor area at Brattøra is located on the other side of the River Nidelva, which passes between Nyhavna and Brattøra. In 1912, a new port plan was drawn up for Trondheim. This new area, between Nidelva and Ladehammeren, was named Nyhavna. Here is where the two German submarine bunkers, Dora 1 and Dora 2, from World War II were built.

Source: https://no.wikipedia.org/wiki/Nyhavna



Development of quay facilities at Orkanger in the 1920s. Photo: Orkangerinfo.no





Dora

The two German submarine bunkers, Dora 1 and Dora 2, from World War II were built at Nyhavna. Dora 1 was completed in the summer of 1943, while Dora 2 was never completed. Dora 1 was later converted into a warehouse and office building, and after the war Dora 2 was left to The Port of Trondheim. In 1943, Dora was bombed by the American Army. It was not damaged completely, while the buildings in the rest of the area around Nyhavna were badly damaged during the attack.

Construction of the bunker

Dora I, a former submarine bunker

Source: https://no.wikipedia.org/wiki/Nyhavna

Dora archive

The Dora archive consists of four archive institutions, one library and one museum. The mission is to preserve state, municipal and private archives from the Middle and North Norway and make these available to the general public. People are welcome to the communal reading room where they can study protocols, letters, photographs, maps and drawings, and carry on scientific research,and investigations.

Source: https://www.arkivsenteret.no/om-oss/

Archive Shelves

Archive records...an old book from the Middle Ages

[RESEARCH QUESTIONS]

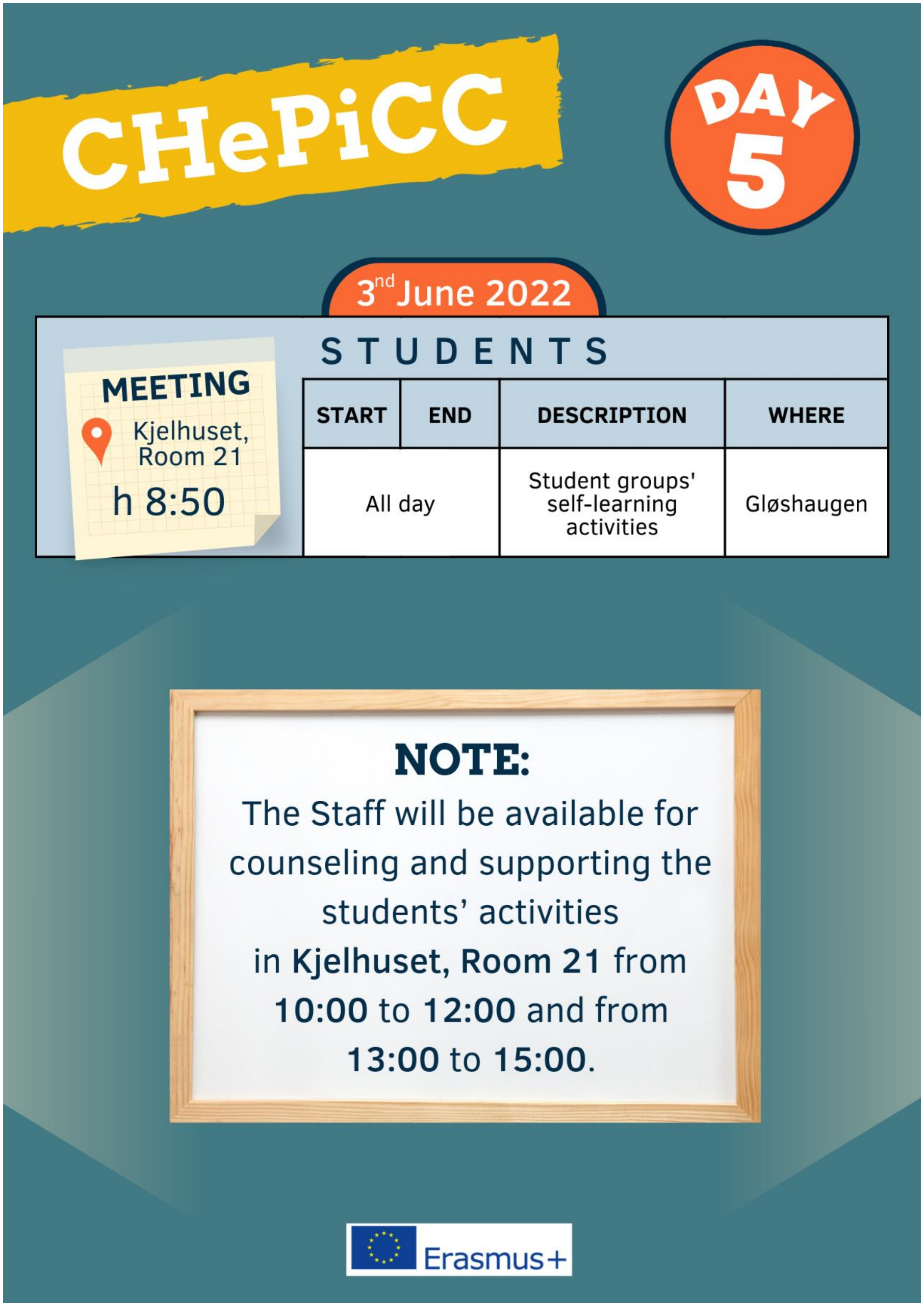
1. How do IIWW CHBs impact a landscape? What is your idea about keeping/demolish/reuse them? How is it possible to preserve the tangible and intangible value of these structures in a landscape that is always evolving/changing?

2. What can the request of maintenance and refurbishment of these structure be in the next future, due to the climate change forecasts? If you decide to keep the structures, what are the possible other suggested uses behind archives?

3. What is next? What are your ideas about attracting people to this district? What is your idea about better protecting/reusing the structures in time of climate change?

4. Comment the fact that they started building with stones to decrease the risk of fire.

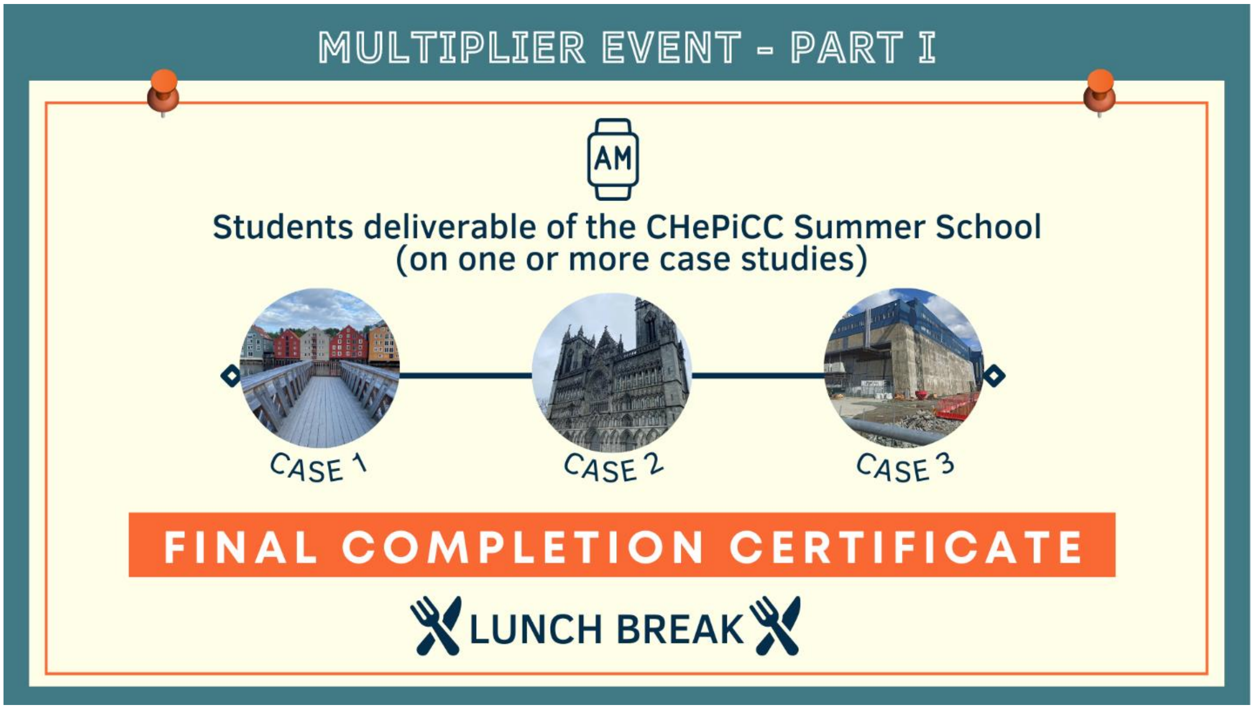
DAY 5 - 03.06.2022

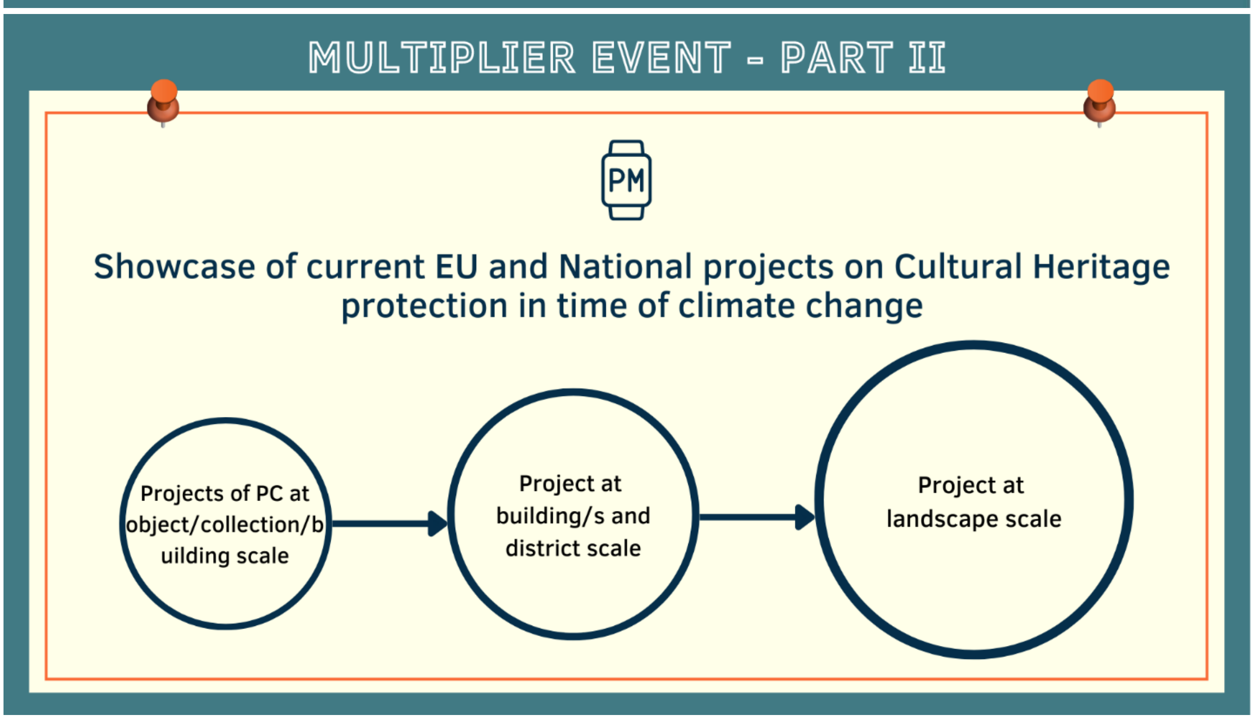


(Credits: Giulia Boccacci, "LaSapienza" University, Rome – Italy)

DAY 6 – 04.06.2022

The Multiplier Event has been organized by NTNU within the framework of CHePiCC and aims to cluster the research and networking projects in which NTNU is involved to optimize the dissemination of research results and activities. It is structured as follows:





(Credits: Giulia Boccacci, "LaSapienza" University, Rome – Italy)

MEETING
Realfabygget, Room R9
h 8:50

CHePiCC DAY 6

4th June 2022

START	END	DESCRIPTION	SPEAKER	TITLE	WHERE
9:00	9:15	Welcome	A. Kaiser	The CHePiCC - Online Erasmus Project	Gløshaugen
9:15	9:30	Into the work of the groups	S. Hammer C. Bertolin M. Schwai	The University Summer School	Gløshaugen
9:30	10:00	Students' Presentation	Group 1	Deliverable of the Summer School	Gløshaugen
10:00	10:15	COFFEE BREAK			Gløshaugen
10:15	10:45	Students' Presentation	Group 2	Deliverable of the Summer School	Gløshaugen
10:45	11:15	Students' Presentation	Group 3	Deliverable of the Summer School	Gløshaugen
11:15	11:45	Students' Presentation	Group 4	Deliverable of the Summer School	Gløshaugen
11:45	12:45	LUNCH BREAK			Gløshaugen
12:45	13:05	Projects of PC at object/collection /building scale	C. Bertolin	The Symbol Project	Gløshaugen
13:05	13:25	Projects of PC at object/collection /building scale	A. Califano	Spara och Bevara & Symbol Project	Gløshaugen
13:25	13:45	Projects of PC at object/collection /building scale	P. Foti F. Berto	GREIG	Gløshaugen
13:45	14:05	Projects of PC at object/collection /building scale	F. Frasca	Collection Care	Gløshaugen

(Credits: Giulia Boccacci, "LaSapienza" University, Rome – Italy)

START	END	DESCRIPTION	SPEAKER	TITLE	WHERE
14:05	14:25	Projects of PC at object/collection /building scale	B. Rankl	Conservation scientific research at the University of Applied Arts Vienna	Gløshaugen
14:25	14:40	COFFEE BREAK			Gløshaugen
14:40	15:00	Project at building/s and district scale	I. Flores-Colen M. P. Mendes	Efficacy Project	Gløshaugen
15:00	15:20	Project at building/s and district scale	R. Cacciotti	Small-scale wind tunnel for the investigation of the performance of building materials	Gløshaugen
15:20	15:40	Project at building/s and district scale	E. Poletti	PROTIND	Gløshaugen
15:40	16:00	Project at building/s and district scale	G. Lobaccaro	Helios	Gløshaugen
16:00	16:15	COFFEE BREAK			Gløshaugen
16:15	16:35	Project at landscape scale	A. Bonazza	The Interreg Central Europe Project STRENCH - STRENgthening resilience of Cultural Heritage at risk in a changing environment through proactive transnational cooperation	Gløshaugen
16:35	16:55	Project at landscape scale	A. Sardella	The Risk Mapping Tool Cultural Heritage Protection	Gløshaugen
17:15	17:35	Project at landscape scale	R. Narbona	Research group: Architecture, Heritage and Landscape from ULPGC. Integral project: Terraced Landscapes.	Gløshaugen

Erasmus+

(Credits: Giulia Boccacci, "LaSapienza" University, Rome – Italy)

PART III

Students' deliverables

GROUP 1

The challenges of preventive conservation and discussion of future use regarding the historic warehouses along the Kjøpmannsgata in Trondheim (Norway): consideration of special risks due to ongoing climate change

J. E. Afonso Santana, C. Calapiña Arriaga, M. Klinkert, P. Higgins, L. Vergelli

[HISTORY]

The early Trondheim

In Trondheim, the first recorded human activities can be tracked back ca. around 700 AD.

In the Year 997, when Olav Trggvason ordered the building of a residence and the church of Klemenskiren, which became later the foundation for Trondheim, there were already docks with warehouses towards the water. Since Norways Geography contains mostly of mountans and fjords Trondheim is, together with Oslo, the only place with a continuous form of lowlands.[1]

After the battle of Stiklestad in 1030, Christianity was implemented. Paganism was outlawed and new forms of cities which included churches were able to emerge. The first churches and monasteries in Trondheim were also built during that time.[2]

Figure 1 - Hypothetical Map of early Trondheim[3]

The rise of trading

At the end of the 12th century, more and more different types of buildings were erected; some were used as warehouses others also as homes. Between 1200 and 1400 the population of the city grew steadily. The warehouses played a vital role in the development of the city. Between 1274 and 1276 the King of Norway

Magnus Hakonson Lagabotes issued laws like the “landslov”, one of most important laws of medieval Europe. Among other rules and laws there was also a city law specifically for places like Trondheim. This law specifically ordered all merchants that they had to lay down on the piers where they rented a warehouse. It was forbidden to sell goods directly from the boat.[4] This was one of the reasons why the piers with warehouses became the lifeblood of the city.

The piers belonged to the shipowners and wholesalers. Their properties were divided into plots across the river.

The warehouses were not only used for the purpose of fishing and storage, but also some of them had entire farm facilities with residential and private houses, barns, and storage cages. Behind the warehouses there were residential houses constructed in a very cramped way. The Streets were usually build in a tight way, most buildings were made of wood. Only churches and a few other buildings consisted of stone.[5]

During the construction activity in the city, a lot of material was simply dumped into the river and created little islands. Because of that the piers were therefore built further out into the river and thick pawls were lowered to the bottom of the river, so merchants were still able to load and unload their ships. The use of flat jetties made it possible to walk across the river without a boat.[6]

The reconstruction of Trondheim

In 1625 there was also a landslide on the east side of the river. On the new terrain the foundation was laid for what is now Bakklandet.

Figure 2 - Map from 1658 depicting Bakklandet[7]

At that time the piers started to develop their characteristic appearance.

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[1] Thomas Hall- Planning and Urban Growth in the Nordic Countries 1. edition.

[2] Imsen Steinar- The Norwegian Domination and the Norse World, C.1100-c.1400 - Tapir Academic Press.

[3] Troøyen, M. / Johnsen, E.G.: Kjøpmannsgata 27, unpublished Master Thesis, Department of Architecture, NTNU Norwegian University of Science and Technology, Trondheim 2022.

[4] Pål A. Bertnes- Legal information in Norway - electronic and printed sources 5th edition.

[5] Thomas Hall- Planning and Urban Growth in Nordic Countries 1. Edition.

[6] Troøyen, M. / Johnsen, E.G.: Kjøpmannsgata 27, unpublished Master Thesis, Department of Architecture, NTNU Norwegian University of Science and Technology, Trondheim 2022.

[7] Troøyen, M. / Johnsen, E.G.: Kjøpmannsgata 27, unpublished Master Thesis, Department of

From the 15th century on the city's growth stagnated. The powerful Hanseatic League (Hansa Teutonica) decided to choose Bergen instead of Trondheim as their main hotspot for trading.[8] There was also the constant problem of fire outbreaks and the war with Sweden. While this was a problem for many cities in Europe, Trondheim burned down overall 15 times. Usually, the inhabitants just rebuild the damaged and destroyed part of the city again until Major General Johan Caspar von Cicignon ordered the rebuilding of the town. He was deprecatory towards the old medieval style of the city.

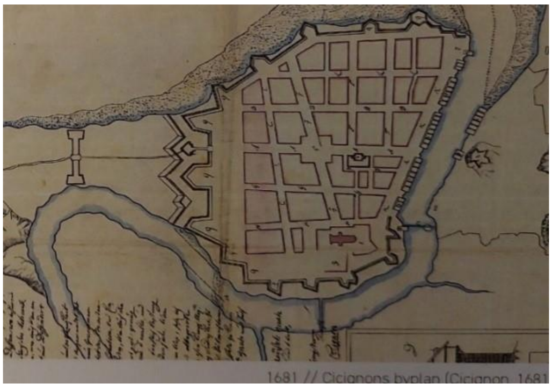

Figure 3 - Plan for reconstruction of Trondheim (1681)[9]

The new Trondheim should be modelled after a more baroque style like Versailles, so it could fit all the military and safety needs. Alongside the river there were streets with trees on both sides so there was an easy access to the warehouses.

Cicignon was also commited to further fortifier Trondheim. However, his plan was only followed partially.[10]

The industrial revolution

Trondheim was able to flourish and Bakklandet was still an important part of the city, until the industrial revolution reached Norway around 1850.

One important factor of the industrial revolution was the population growth. Along with other Norwegian Cities Trondheim underwent changes in infrastructure and urban development. Another way to boost the economic growth was the abolition of former trade restrictions. Together with the industrial revolution bigger ships with a much higher carrying capacity were established. With the consequences that the warehouses were seen as an obstacle to the town's development.

Architecture, NTNU Norwegian University of Science and Technology, Trondheim 2022.

[8] Elisabeth Gee Nash - The Hansa 1995 - Barns and Nobles.

In addition, the new Bakka bridge was also built, which made it difficult for larger ships to sail up to the piers. Trondheim maritime infrastructure needed to be modernized.

After Carl Adolf Dahl´s plan for the modernization of Trondheim was accepted in 1876 and the building of a new harbour, which was in the direction of the fjord meant that the centre urban development shifted away from places like Bakklandet.

After almost 1000 years of being the centre of Trondheim the piers lost its original function, and that also included Bakklandet.[11]

The abandonment and the decay

During the 20th century the warehouses of Bakklandet were still in some form of intermittent use for fishers but they were no longer the central place of the city.

Since they were not used that often anymore the forecourt increased.

They were seen as a problem and in the context of modernism some proposals were made to tear them down. They withstand the second world war without any serious damages and some of them showed signs of decay.

However, with the Midtbyen Plan from 1975 wooden houses were seen as a historic image of the city and it was therefore decided that buildings, like the warehouses of Bakklandet, should be preserved.[12]

[9] Troøyen, M. / Johnsen, E.G.: Kjøpmannsgata 27, unpublished Master Thesis, Department of Architecture, NTNU

[10] Thomas Hall- Planning and Urban Growth in Nordic Countries 1. Edition.

[11] Thomas Hall- Planning and Urban Growth in Nordic Countries 1. Edition.

[12] Troøyen, M. / Johnsen, E.G.: Kjøpmannsgata 27, unpublished Master Thesis, Department of Architecture, NTNU

[STATE OF THE ART (CONSERVATION STATE - RELATION BETWEEN BUILDING AND ENVIRONMENT - ACTUAL USE)]

In today's Trondheim the influence of the warehouses facing the Nidelva River is profoundly central at the urban level. They are in an enclave influenced by the forced connection between two densely populated districts, the city centre and the Bakklandet district, naturally separated by the river.

In the space between the two main bridges that guarantee this connection and, at the same time, on the west bank of the river, is where the warehouses of greatest historical importance are located, and they are the ones which are the subject of this study.

This front of buildings of Kjøpmannsgata, beyond being a historical landmark in the drawing of the city, is a central point in itself, and it is the image that the city wants to project towards its visitors.

It is important to highlight the relevance of the sector as a whole, beyond the interest of any individual warehouse. That what is presented in this section of the Nidelva river acts like an exposure of a particular constructive and architectural system of continuous application. In addition, it speaks directly of the idiosyncrasy of the city and its deepest conditions and traditions.

Although the sector continues to be an absolutely central point in the city and surely its most visible face; there is a deep conservation problem linked to the disappearance of its original use, that of goods and food storage, and the consequent lack of maintenance and repair tasks directly linked to this commercial activity.

Since the sudden disappearance of the original use of the warehouses caused by the construction of the new wharf, better prepared for larger ships, there has been a prolonged dichotomy between the abandonment of some of the warehouses and the architectural adaptation of the rest to a changing variety of uses. Today this dichotomy still holds, and even does so in a more complex way.

With the development of urban and architectural regulations, the level of intervention and reconstruction with respect to the original state of the buildings has become deeply invasive for most of the proposed and existing uses.

On the other hand, there are initiatives under development for the intensive conservation of the original state of some of the buildings which, however, have great difficulties searching for possible owners who might be interested in a building with a high level of historical responsibility, maintenance and ongoing continuous costs and whose future use and potential long-term profitability from a particular investment point of view are virtually unknown.

With this situation, the establishment of an intermediate situation is of critical importance, where the buildings can be used and have a certain level of economic profitability, but without this implying the loss of the character and original construction system. For this, it would be important to explore new uses, whose adaptation needs were not so far from those of the original use of the building.

The objective of this brief investigation, given this alarming situation (which is also aggravated by the conservation problems linked to climate change), focuses on the study of a series of proposed criteria to study the possible consequences and the level adaptation of possible future uses for these buildings.

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[OVERVIEW OF CLIMATIC PARAMETERS AND COMFORT ISSUES]

__Trondheim "historical" climate and climate change

In Trondheim (coordinates: 63,430-degree latitude & 10,395-degree longitude)the summers are cool, wet, and mostly cloudy and the winters are long, freezing, snowy, and overcast. Trondheim is located near a large body of water (e.g., ocean, sea, or fiord).

Temperature

Over the course of the year, the temperature typically varies from -5°C to 18°C and is rarely below -13°C or above 25°C (Table 1).

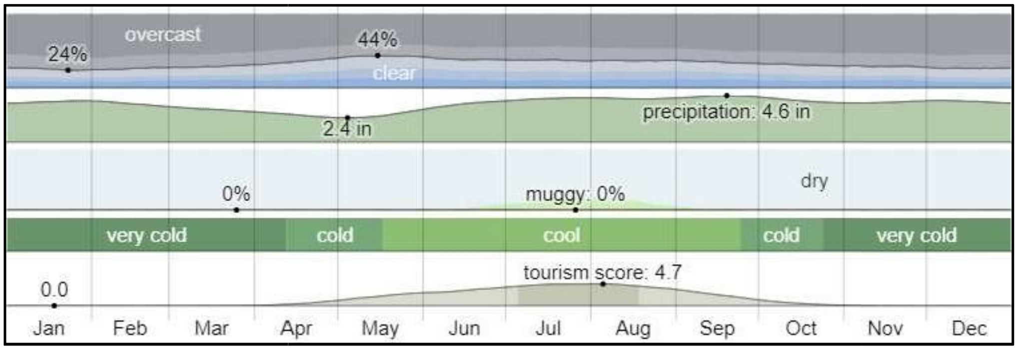
season	average temperature
warm (from June to September)	15°C July (hottest month): high average = 18°C VS low average = 11°C
cold (from November to March)	4°C January (coldest month): high average = 1°C S low average = -4°C

Table 1 – average temperature in warm and cold seasons

Average water temperature experiences some seasonal variations over the course of the year (Table 2).

season	average temperature
warmer water (from July to September)	above 12°C(high average of 14°C in August)
cooler water (from Dece ber to May)	below 7°C (low average of 5°C in March)

Table 2 – average water temperature in warm and cold seasons



Trondheim weather by month. Click on each chart for more information.

© WeatherSpark.com[33]

Precipitation

The wetter season lasts from June to March (the wettest month is September). The drier season lasts from March to June (the months with the fewest wet days in Trondheim are April and May). Among wet days, precipitation may be rain, snow (specifically from October to April), or a mixture of two.

Sun

The length of the day in Trondheim varies extremely over the course of the year (the shortest day in December has got around 4 hours and 30 minutes of daylight; the longest day in June 21 has got around 20 hours and 30 minutes of daylight).

The total daily incident solar radiation (UV and VIS waves) reaching the surface of the ground is a number which considers:

- seasonal variations in the length of the day
- elevation of the Sun above the horizon
- radiation absorption by clouds and other atmospheric constituents.

[13] https://weatherspark.com/y/68746/Average-Weather-in-Trondheim-Norway-Year-Round.

The average daily incident solar radiation experiences extreme seasonal variation over the year.

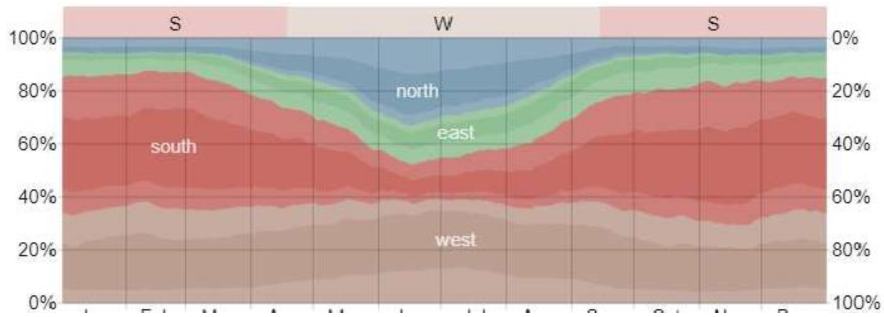
period	average daily incident solar energy per square meter
brighter period (from May to August)	above 4,2 kWh (June, the brightest month, average = 5,2 kWh)
darker period (from October to February)	below 1,1 kWh (December, the darkest month, average = 0,1 kWh)

Table 3 – average daily incident solar radiation in warm and cold seasons

Wind

period	average hourly wind speeds	direction of wind
windier period (from October to April)	more than 10 km/h (January, the windiest month, is 14 km/h)	more often from the south
calmer period (from April to October)	less than 10 km/h (July, the calmest month, is 7 km/h)	more often from the west

Table 4 – average hourly wind speeds in warm and cold seasons



The percentage of hours in which the mean wind direction is from each of the four cardinal wind directions. The lightly tinted areas at the boundaries are the percentage of hours spent the implied intermediate directions (northeast, southeast, southwest, and northwest).

WeatherSpark.com[14]

[14] https://weatherspark.com/y/68746/Average-Weather-in-Trondheim-Norway-Year-Round.

Climate change

In Trondheim the average temperature has not had a sharp increase in the 30 years from 1961 to 1990: only temperature-value dispersion has increased. This datum, confirmed also for the 30 years from 1991 to 2020, means an increase in extreme phenomena (hotter summers VS shorter and colder winters), with the consequent variation in the length of the different seasons. The increase in temperature fluctuations in the first and last months of the year causes freeze and thaw cycles, which usually occur precisely in winter. The cycles are harmful to the materials, e.g., the hygroscopic wood (damage functions).

__Object comfort versus human comfort - challenges and approaches

Built heritage and heritage collections require conservation approaches, which can cause conflict with the demands of human comfort.

Passive environmental control strategies historically focused on the wellbeing of the people who inhabited the buildings. This was at a time, where no electricity and advanced heating methods were available. As a side effect, many of these building constructions were also very conducive to the preservation of the building fabric. Unfortunately, not all of these approaches can be applied to the conservation of cultural heritage. In addition, the official regulations for the use and air conditioning of buildings in terms of health regulations and well-being have become more stringent, which limits the possibilities for using the buildings.

According to ISO 7730:2005[15]the level of comfort for a sedentary activity should be inside the margin between 19°C and 29°C on the floor surface, with the most ideal temperature being around 26°C. One of the main issues in developing suitable conservation concepts is balancing the essential conservation requirements of the objects with the needs of the people who live or work in these buildings. In terms of the challenging Norwegian climate, this makes things even more complicated.

KING and PEARSON discussed this problem in relation to buildings in Australia, but important key messages are applicable to this topic [Pearson *et al.*, 2000[16]].

➔ Objects and buildings are static and cannot move away from an adverse environment. In contrast,humans can adapt to unfavourable climate conditions by changing their location, seeking shelter, or dressing appropriately.

➔ Sensory compensations and comfort preferences by humans can be contrary to the conservation requirements of the historic materials, for example:

O Lowering of relative humidity increases human comfort but hastens the desiccation of wood and leads to mechanical stress in the form of shrinkage and cracking.

O People prefer higher temperatures and may seek out radiant heat sources, which promote intense differential temperature stresses, resulting in strong mechanical strains and increased rates of oxidation.

The recognition that humans are more adaptable to uncomfortable climatic conditions than static objects due to their mobility and flexibility should be taken into account in relation to significant and vulnerable cultural heritage. Therefore, strategies for passive and low energy environmental control can be preferred for providing stable environmental conditions, which might not always match optimal conditions for human comfort. The main tasks are to identify aspects of the building construction which are beneficial for the environmental stabilization and to reduce and modify harmful factors [Pearson *et al.*, 2000[17]].

Summary of conservation requirements, objectives, and possible strategies

General material parameters

The Bakklandet warehouses are mainly wooden timber constructions, built on natural stone foundations, located close at and partly above the river. The foundations (basement) consist of a ring wall made of natural stone masonry, the river fronts are supported by inner and outer rows of massive wooden pillars. The timber constructions are characterized by a high frequency of vertical pillars for stabilization and closely staggered wooden boards around the walls and floors. The ceiling height is low, daylight can only enter most buildings through windows at the riverside and roadside (except warehouses situated next to open places). The buildings contain windows and wooden doors of different sizes and periods. Towards the river side there are large openings and wharves, which were used for loading goods. The roofs are a combined rafter and ridge roof, covered with slate or corrugated iron. Most of the warehouses are painted in different colours; most likely linseed oil was used as a binding agent [Troøyen, M.*et al.*, 2022[18]] .

[15] EN ISO 7730:2005: *Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria* , German version EN ISO, https://www.din.de/de/mitwirken/normenausschuesse/naerg/veroeffentlichungen/wdc-beuth:din21:89417255, accessed on 26.05.2022.
[16] Pearson, C. / King, S.: Passive Environmental Control for Small Cultural Institutions in Australia, in: Australian Academic & Research Libraries, 31/2/2000, pp. 69-78, DOI: http://dx.doi.org/10.1080/00048623.2000.10755117, accessed on 26.05.2022, pp.73-74.
[17] PEARSON / KING 2000, p. 74.
[18] Troøyen, M. / Johnsen, E.G.: *Kjøpmannsgata 27*, unpublished Master Thesis, Department of Architecture, NTNU Norwegian University of Science and Technology, Trondheim 2022.

Risks and vulnerabilities

In order of priority, the risks/vulnerabilities affecting warehouses are:

1) **fire**: history teaches us that fire has always been the main enemy of wooden warehouses: in presence of wind, the fire can spread from one warehouse to another,affecting the entire structure, from foundations to roof, and damage of wood is irreversible.

2) **flood**: considering the position of the houses, by the river, with their foundations directly under the water resting on a "quick clay", the risk of flood occurs whenever the water level of the river rises (due to long periods of rain or due to the melting snow) and, for this reason, the static capacity of the structure is lost. Due to climate change, the risk of floods is now increasing, as it is increasingly frequent the occurrence of extreme weather events.

3) **biological infestation**: one of the main consequences of elevated moisture/liquid water content (in general high humidity values) is the biological contamination by microorganisms, insects, and other invasive species. Damp wood is vulnerable to attack by mould, bacteria, and pests, whose life cycle is as fast as the conditions are suitable for their growth. The result of climate change is a warmer and more humid climate with the consequent acceleration in biological growth and a higher risk for infestation of structural wood (organic material).

4) **exposure to weather**: the external surface of the warehouses -roof and facades- in addition to the foundations is obviously subject to the continuous action of external atmospheric agents. The rain, whose direction and force are due to the action of the wind, can be more or less intense. The most exposed portions of wood will be more humid with all the consequent problems related to the water/moisture content inside the structure of the organic material. Climate change (stronger wind and heavy rainfalls/snowstorms) can make the situation worse. In addition, sunlight exposure depends mainly on the season of the year (different inclination of the light rays with respect to the earth's surface) and on the presence or absence of clouds in the air which represent a screen that attenuates the energy carried by the light rays, therefore their intensity. The irradiation of a surface consists in a transfer of heat and therefore in a heating of the irradiated material, in the case of wood the consequences are physical-mechanical stressors (deformations, fractures, cracks, loss of stability). Climate change action consists of an increase in sunlight intensity, thus in the wood decay.

5a) **freeze-thaw cycles**: Trondheim climate shows severe variations in temperature throughout the year. The problem of freeze-thaw cycles occurs whenever the temperature falls below 0°C (or much below in the presence of salts dissolved in the water) and goes back above 0°C (or above the temperature of transition between liquid water and ice). The consequences of the cycles are minimal if the cycles occur with low frequency over time but become alarming if the freeze-thaw cycles are recurrent (as in the case of the strong fluctuations in temperatures recorded in recent years due to climate changes). The mechanical stress to which the wooden material constituting the structure of the warehouses is subjected is caused by the greater volume occupied by the ice compared to the one occupied by liquid water. The liquid water that infiltrates into the pores and the voids of the wood, becoming ice below 0°C and increasing in volume, causes an increase in the size of the pores and the voids with consequent fractures and cracks. Due to climate change, we observe frequent freeze-thaw cycles also during winter, these are caused by the rise of average temperature.

5b) salt (sub)efflorescence: although there it is river water, its proximity to the sea makes it "mixed" and the capillary rising of salts through liquid water is a natural phenomenon for wet wood. The problem of the cycles increases when the water passes from the liquid form to the vapor form (evaporation) and the salts (mostly chlorides and nitrates) become insoluble in a smaller quantity of water (supersaturation of the solution) and crystallize in the pores and voids of the wood. Repeated cycles over time cause an increasingly marked crystallization. If the evaporation is fast (high temperature and presence of wind) the crystals are small in size and form below the surface → sub-efflorescence, if the evaporation is slow (low temperature, absence of sunlight and wind) the crystals are large in size → efflorescence. The greater intensity of climate fluctuations in temperature and humidity due to recent climate changes results in a greater speed of occurrence of the degradation phenomenon caused by the cycles of saline crystallization and dissolution.

Requirements regarding preventive conservations methods, goals and possible solutions

"Sustainability is the idea of using cunning, looking at what people did in the past, adding that to modern physics, and generally designing things that you're proud of because you didn't drag in a whole lot of electricity and energy." - Tim Padfield[19]"

Considering the climatic risks, material vulnerabilities, heritage value and specific problems related to future uses, there are high requirements in terms of environmental control and preventive preservation. The main aim is to safeguard the warehouses as a cultural heritage while respecting its significance, integrity and authenticity. This includes its accessibility to present and future generations. In addition, in times of climate change and limited energy resources, the reduction of the carbon footprint should be a part of a holistic and sustainable approach. During the last decades, the idea of *Passive Environmental Control* [Pearson *et al.*, 2000[20]]

[19] https://www.getty.edu/conservation/publications_resources/newsletters/22_1/dialogue.html, accessed 29.05.2022.

[20] Pearson, C. / King, S.: Passive Environmental Control for Small Cultural Institutions in Australia, in: Australian Academic & Research Libraries, 31/2/2000, 69-78, DOI: 10.1080/00048623.2000.10755117,

gained more attention, meaning to adjust climate parameters without mechanical facilities and artificial climate control systems but through well thought building design and fabrics with abilities to buffer. The advantages lie in the cost effectiveness, a less complicated installation and maintenance and environmental sustainability, as much less energy is required[21].These passive, non-mechanical methods often include historic and traditional building techniques.

The main aim of passive environmental control strategies lies in the reduction of mechanical strategies and the resulting reliance on constant energy supply and high maintenance. These strategies may be combined, if non mechanical strategies might not be enough [Maekawa*et al.*, 2015[22]]. As a result, energy-consumption, installation, and operating costs can be significantly reduced. As there are no complex machineries to be maintained, the environmental conditions are generally more stable and reliable.

Preventive conservation and passive climate control through appropriate building design are the basis for all further measures. Table 5 summarizes the most important aspects.

Requirement	Specifies	Possible Actions
Fire prevention	- highest priority! - sources of fire need to be avoided at all costs - development of a well thought fire prevention and emergency plan	- no electrical installations and if required: constant maintenance, use of electrical equipment under constant supervision - use of fire-resistant building and interior materials - no kitchens → no restaurants - installation of warning systems - education and information of owners, employees, and fire department
Flood protection	The risk of flooding is almost unavoidable due to the direct proximity to the river but may be reducible through appropriate flood prevention measures and structural modifications to the surrounding river landscape.	- if possible: barriers and partitions along the river sections - water drains leading away from the warehouses flexible use of the ground floors, no storage of valuable objects in this area and acceptance of regular flooding

[21] PEARSON / KING 2000, p. 70.
[22]Maekawa / BELTRAN / HENRY 2015, p. 92.

Climate stability	- creation of a stable indoor environment - low fluctuation rate of temperature and humidity slow adaption of the inner climate to the outside climate and slow acclimatization of the building fabrics	- use of porous and hygroscopic building materials for hygrothermal buffering - controlled natural ventilation (balance between air tightness and defined ventilation openings) with caution to unwanted intake of cold or hot winds, pollutants, insects and driving rain [Maekawa *et al.*, 2015[23]]. no sealing of surfaces through paint layers and protective coatings
Protection against water and moisture intake	- protect buildings from water intake through rain, in-situ groundwater, and rainwater runoff	- replace the dense tar paving of the adjacent street with permeable paving with natural stones and permeable joints - perimeter foundation drains can limit groundwater intake from the roadside - closure of large openings that are susceptible to water ingress - installation and maintenance of water drainage systems (wall gutters, downspouts, wall projections and drip edges) maintenance of external walls, basement and roofs and closing of leaks
Prevention against biological infestation and pests	- complete exclusion of pests and biological infestation not possible, but: - reduce access possibilities - deny food sources - avoid conditions they prefer (warmth, water, and high humidity) - related to the protection against water and moisture intake and climate stability avoid building and interior fabrics that could be a food source	- keep temperatures below 20 °c - values less than 75% RH are recommended to avoid microbiological activities [Maekawa *et al.*, 2002[24]]. - allow natural ventilation and air circulation - avoid building and interior fabrics that could be a food source (textiles, carpets, organic paint materials) - no storage of food / no restaurants - keep the surfaces clean and remove dirt and dust regularly - Integrated Pest Management: → monitoring and control → appropriate education and support → Remedial action if damaging species are discovered low hazard or non-toxic methods of control[25].

[23] Maekawa / BELTRAN / HENRY 2015, p. 99-100.

Protect against extreme climate parameters and sudden fluctuations	- protection against heat and severe cold - avoid freeze-thaw events - avoid dew point temperatures and resulting condensation dimensional changes and the resulting mechanical stresses in objects, mainly caused by short term fluctuations should be avoided	- controlled conservation heating against condensation and freezing indoor temperatures - controlled air exchange - insulation with water vapor permeable, fire resistant ecological insulation materials (especially roof insulation, e.g., with natural fibres) condensation should be avoided by not letting warm and damp air into cooler rooms [Staniforth, S., 2007[26]].[9]
Ecological and financial sustainability	- use of electric devices on a low level - low maintenance reduction of the carbon footprint	- preference of passive, non-mechanical strategies of environmental control improvement of energy performance
Consideration of human comfort	For conservation approaches, it might be necessary to reduce the level of human comfort to improve the environmental conditions for the historic materials.	

Table 5 – most important aspects of preventive conservation

[FUTURE USE PROPOSALS AND CONCLUSION]

Use proposals

The past use is not applicable anymore, the following suggested uses are also not applicable to all warehouses but can be viewed as examples of multiple uses for a liveable district with consideration of the heritage value.

Proposals for new use considers the central location of the warehouses (in the city centre) and their recognized aesthetic value (also for tourists), but also the nature of the buildings which require periodic maintenance-interventions over time and their low ceiling heights associated with the lack of daylight indoors as limits to the possibilities of transforming warehouses to new use.

A) flea market where it's possible to buy handmade products and local craft-made objects and gadgets.

PRO	- exploitation of the site for daily / weekly / monthly events - bigger flux of tourists in the city

[24]Maekawa / Toledo 2002, p. 5.

[25]English Heritage Guideline for Integrated Pest management, in: https://www.english-heritage.org.uk/siteassets/home/learn/conservation/collections-advice--guidance/eh-guideline-for-insect-pest-management-ipm-in-eh-historic-properties---website-version.pdf, accessed on 03.06.2022.

[26]STANIFORTH 2007, p.7.

CON	- not suitable climate indoors during cold season (but climate is milder than outdoors) - impossibility to also sell food and edible gifts

b) temporary exposition (spoken workshop) where Trondheim university-students and national or international artists can show and discuss their final projects in this unique "exposition space".

PRO	- during warm season the location is similar to the one of the Venice Biennale - enlarged knowledge of Norwegian and foreign people about this built cultural heritage
CON	- not suitable climate indoors during cold season (but climate is milder than outdoors) - impossibility to expose every kind of artifacts (not heavy, not degradable, etc.)

c) offices and housing (residential private use) not a great solution, the identity of the place is lost.

PRO	- the human use (life inside the buildings) lasts all over the year - improvement of the aesthetic issue indoors and outdoors, maintenance for long time
CON	- modification to the original structure with loss of the original value - need of an optime thermal comfort inside the building (especially during cold season) - high risk of fire derived from domestic kitchen use

d) shops, restaurants (commercial / private use)not a great solution, the identity of the place is lost.

PRO	- the human use (life inside the buildings) lasts all over the year, although the paid access - improvement of the aesthetic issue indoors and outdoors, maintenance for long time
CON	- alteration of the original structure with loss of the original value - need of an optime thermal comfort inside the building (especially during cold season) - high risk of fire derived from professional kitchen use - high risk of biological colonization caused by the presence of raw food and ready meals

e) visitors' heritage site, the best solution for the preservation of the warehouses in their original state. They are presented as a museum site for architectural history, as a learning space that offers the possibility to get an idea of the authentic appearance of the city of Trondheim during its history. A walk through the building enriches the visitor thanks to the discovery of information about materials, craftsmanship and building techniques; traces of past; what was the use of the building elements; the results of deterioration due to the climate change (salt efflorescence) ... The visitor, in this way, becomes aware of the urgency of conservation interventions and sustainable lifestyle in any case.

PRO	- with public access, the human use (life inside the buildings) lasts all over the year - information given via audio guides and robust panels placed somewhere indoors - maximum authenticity and integrity, no changes of original substance and appearance - no heating and electricity necessary - authentic experience includes sense of "darkness"
CON	- not possible for all buildings, only one selected object could be treated like this - requirement of staff and maintenance (suggested public ownership for the public access)

The following Table summarizes all the previous aspects in relation to the choice criteria.

	flea market (local products)	temporary exposition (spoken workshop)	offices, housing	shops, pubs restaurants	visitors' heritage site
heritage interest management (preservation of authenticity, significance, historical value)	green	green	red	red	green
economic advantage (owner)	yellow	red	green	green	yellow
comfort of the visitors	yellow	yellow	green	green	yellow
accessibility for the public	green	green	red	yellow	green
similarity to the original use	yellow	red	red		yellow
improbability of fire	yellow	green	red		
occupation through the year (linked to the maintenance)	yellow	yellow	green	green	
applicability of the proposal (high = large scale DISTRICT low = small scale BUILDING)	yellow	yellow	yellow	yellow	yellow

Table 6: future use proposals in relation to the criteria of choice: high = green; medium = yellow; low = red.

[CONCLUSIONS]

Even if there are of course no warehouses from the founding time of Trondheim, a place like Bakklandet still can give people the opportunity to see how the city developed, what crises it went through and the foundational changes that affect it. In the past with the industrial revolution and in the present and unfortunately, the future with climate change.
The warehouses are obviously no longer used for their original purpose, because of the introduction of modern transportation and food refrigeration. But there could be a combination of offering groceries and other products.
It would serve the idea that even if you cannot use a Cultural Heritage Building in its old way, there is still a possibility of usage.

Beside the issue regarding conservation of the colour form location and bringing some utilization back, the conformity is also maybe important for the city.

At least one of them could also be used as a form of small exposition.

Since the warehouses were of big economic importance and they were also rebuilt, repaired, and renovated over and over again, they are of course in some way a window into the past.

A small exhibit, which would only use up one of those houses, could show people what the original purpose was. This small exhibit would be much smaller than an actual museum and maybe there would not even be the need for an entrance fee.
Old manufacturing tools and clothing, perhaps a model of an old fish boat, could be shown in combination with signs and audio guides.

Unlike many other small historical exhibits, it would also be an opportunity to display the direct and indirect impacts of climate change on these warehouses.

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GROUP 2

Trondheim Cityscape: Preservation of the City Identity

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[INTRODUCTION]

Norway has the world's second largest shoreline, and the sea has been the most important communication system all through Norwegian history. In fact, there is a strong interaction with the landscape, climate conditions, nature resources, and traditional communication systems in the development of the Norway built environment. The ship building technology was extensively developed by the Norwegians and fishery has been a major industry in Norway, i.e., stockfish and klippfish (dried and salted cod) industry has been paramount for the economy. Therefore, most of the Norwegian historic buildings are associated with the sea, which had an important role in the construction of the Norwegian built heritage.

Wood has been the most important construction material in Norway since Viking times. In the medieval time, wood building technology was developed to a very sophisticated level, enabling the best buildings to survive up to our time. The construction systems and technologies have later been developed in different regions considering the availability of materials and other local conditions (e.g., coastal buildings have had to adapt to harsh coastal climate such as strong winds, rain and high humidity). Timber buildings proved to be very suitable facing harsh climatic conditions and adapting to the functional needs of Norwegian society.

In this report we examine the importance of the preservation of the city identity, especially considering the most iconic Trondheim buildings (i.e., warehouses and Nidaros cathedral) and their relative importance on the preservation of the city landscape. We also present herein some solutions towards the maintenance and preservation of the buildings and the city identity.

[THE WAREHOUSES]

In Mid-Norway there is Trondheim, the largest city of the country and the most important trading port for the region. The river harbour has always offered a safe port where the first urban settlement was located. The city consists almost entirely of timber buildings, often ravaged by fires, like that of 1681.

Interventions can be done in the warehouses as long as their identity can be preserved. With identity we mean their colour, symmetry, cladding, form and different roof shapes, the pile foundation, the traditional log constructions, the flatbrygge along the water, the location and the use. From a visual and social point of view, the warehouses represent an identifiable "city-scape", with cultural and aesthetic heritage value of national importance.

By tradition, Norwegian houses used to be coloured either red, white, or yellow. The colours chosen by the owners of the house would signify their financial status. So, depending on the profession, social status, and location, houses would be painted the primary colours that symbolized their rank. This was not done to be malicious, but due to their resources. Since red was the cheapest, and easiest to produce, it was mostly reserved for fishers and farmers. Red house paint was used by mixing ochre with cod liver oil, and vegetable or animal oil, to get the bright shade that is popular in Norway nowadays. Therefore, the traditional Norway colour for lower-class houses was red, which stuck with and became a custom over the years, regardless of status. Since, yellow was slightly more expensive to produce, as it was made with ochre and cod liver oil, this was reserved for a higher status of people. Yellow typically symbolized the middle class concerning the Norwegian houses. Finally, white was reserved for the luxurious class, as minerals such as zinc were needed to get the tone. In the older days, white was the most expensive colour. Nowadays, the importance of the warehouses lies in the whole landscape and not in a single building. Therefore, the preservation of the warehouse's colour is a key aspect to preserve the identity of these historic buildings.

In Norway, it is common to have wooden architecture from the past but also in more recent buildings. In an ancient drawing, "Maschiusstikket" from 1674, it is depicted the structure alongside the river and much of the warehouses landscape is as it is today, even though almost everything burnt down in 1681. However, there are some distinct changes in size (e.g., some warehouses are built together, some of them are smaller, larger, or taller). Later, fires have led to many wharf buildings being replaced by newer, more modern types that use similar principles. In the more recent examples, like Kjøpmannsgata 27 (built between 1858 and 1876), the building structure is still clearly visible. Even though its height and size are increased with respect to the earlier warehouses, the way it is built is, of course, based on the traditional techniques: the ground floor consisted of two rows of notched log timber rooms, with a corridor in the middle. This was connected to the river via a gallery, where all the goods were brought on shore. An important aspect is that these buildings would sometimes have a space in front one of the long sides making a useful gap in the row of buildings, to minimise the risk of fire spreading.

The shape of the roof also says a lot about the history of the warehouses, as it was changed over time. Considering the shape of the roof it is possible to know when the warehouse was approximately built. The roof with the ridge in the east-west direction was predominant. From 1845 until about 1925 all the roofs that were built were half-hipped on both sides because of fire regulation. The same regulations also set the maximum height of the bryggen to less than 14 metres and most of the bryggen from 1850-1860 present those dimensions.

The warehouses were used as a food storage, to be able to market it. Therefore, the river is an important point where fishers can access the docks with their boat to put the fish inside the warehouses. Originally, the stairs, next to the doors that faced the river as the street, allowed one to quickly enter the warehouses to transport the merchandise, through a forklift. The building is a dark and cold place, where large air currents occur, allowing food to be better stored.

The original warehouses were not used as dwellings, but today many have been

converted into residential houses, however it is not allowed in the row next to the city along the river. Some are art galleries, cafes, restaurants and boutiques.
Trondheim's warehouses were generally made as a combination of wood frames and log structures allowing the creation of many different space distributions. Most of the buildings contain small and low rooms in the lower levels and very large and high spaces in the upper levels. New buildings are frequently built using concrete instead of wood because these buildings have improved fire performance. Sometimes, the concrete is covered with wood to simulate the old structures. However, the use of the original building material is neglected and can somehow affect the cultural and aesthetic values of the houses. For example, the facades are often retrofitted using aluminium windows, while the original were built using wood. The preservation and retrofitting of these traditional buildings should be always conducted using compatible and reversible materials and interventions. Furthermore, climate change (CC) can also affect the landscape and the structural integrity of the warehouses. In 1816 there was a sand slide upriver, which caused the Nidelva River to be shallow, causing the rise of the water to occur in a more important way. With CC the sea can rise up to 3.4 mm per year and this can strongly affect the warehouses.

[TRONDHEIM LANDSCAPE AND NIDAROS CATHEDRAL]

Trondheim is well known for its wooden built environment with traces back to the Middle Age. In more recent times much of the traditional wooden houses are being replaced by architecture structures made of brick, concrete and steel, creating a more heterogeneous typology with variations in scale, volume and heights. Moreover, the cultural and historical aspect of the landscape also includes the urban fabric with its green areas, gardens and parks and also how the tangible and intangible dimensions are perceived.
The natural landscape is integrated into the city centre of Trondheim in such a way that the urban and the natural landscape interact with each other for the development of the city. Moreover, the historic city is integrated by natural elements such as the Nidelva River, the Trondheim Fjord, the coastal area, the valley and the hills surrounding the city.
Trondheim developed in medieval times, from the bank to the mouth of the river Nidelva. However, in 1681, almost the entire city was destroyed by a strong fire, which allowed the creation of a new city plan, thus proposing larger streets and building two-storey homes. However, until the 19th century, it was still a village of low-rise wooden dwellings.
In 1841 and 1842 two fires left large parts of the city in ashes and the use of wood as main construction material was banned in 1845. However, before this legislation was implemented, the citizens managed to reconstruct the city using wood. With the implementation of the new legislation, a new architectural style based on brick was introduced. Later on, the use of concrete and steel gradually changed the performance of some parts of the city center into a more diverse and complex urban landscape (i.e. new materials were introduced, and the new typology opened up for buildings in several stories, creating a brand-new

architectural style).
World War II changed the organization of the landscape, giving it a more modern imprint. The biggest variation concerned the use of new materials, such as brick, concrete and steel, and for this reason the image of the city has changed a lot, passing from a landscape rich in wood to a heterogeneous landscape.
Also, there are new changes taking place nowadays. Think, for example, of the fact that people want to work in the city center (Kjøpmannsgata 37 is an example), and this generates pressure to construct new buildings on limited space. This situation can certainly represent a risk to the historical urban fabric of Trondheim, which must be preserved.
The monumental streets and squares replaced the narrow and curvy streets after the fire of 1681. Furthermore, the urban landscape of Trondheim is also characterized by the river Nidelva and the canals surrounding the historic core on the peninsula, establishing attractive urban spaces with its water surface, representing more a visual element than a functional one. Another important spatial element connected to the historic urban landscape of the city center, is the green parks. Marinen park, located on the south of Nidaros cathedral, is the most important green space in the city, especially in summer periods where it also hosts festivals. The river Nidelva and the canals form important prerequisites for the development of the urban landscape that also encompasses the built environment.
Nidaros Cathedral is the world's northernmost important Gothic cathedral and Norway's national sanctuary. It is situated in the middle of Trondheim city centre and was originally made of wood and built from 1031 onwards. During the Middle Ages, and after independence was restored in 1814, the Nidaros Cathedral was the coronation church of the Norwegian kings. In 1991, the present King Harald V and Queen Sonja were consecrated in this cathedral, demonstrating the importance of the monument for the Norwegians.

[A REFLECTION ON THE IDENTITY OF THE WAREHOUSES AND THE CATHEDRAL]

The identity of Trondheim is very much influenced by the Warehouses and the Nidaros Cathedral, and some of the aspects that are related to the colour, form, location and use of both buildings are of paramount importance for the preservation of the cityscape. It should be stressed again that intervention can be done in the Warehouses as long as their identity can be preserved because they represent an identifiable cityscape with cultural and aesthetic values of national importance. Those buildings vary in height, width and proportions, roof shape and angle, as well as in colour and detail. These aspects give the Warehouses their charming and characteristic rhythm and at the same time appear as clear individual parts in a whole. Therefore, the importance of the Warehouses lies in the whole landscape and not in the single building. Over a period of time, warehouses have not been used, so no significant structural changes have been made. An important aspect is that these buildings would sometimes have a space in front one of the long sides making a useful gap in the row of buildings, to minimise the risk of fire spreading. What increases its patrimonial value, but the lack of maintenance produces an unattractive visual aspect. The original

warehouses were not used as dwellings, but today many have been converted into residential houses. Therefore, the preservation of the warehouse's identity is a key aspect to preserve the landscape of Trondheim. Interestingly, the warehouses were repeatedly destroyed by fires and rebuilt always on the same sites and following the same construction rules established in the twentieth century.
Nidaros Cathedral is the world's northernmost important Gothic monument, and it is an important part of the city's identity: i.e., in the study of Kyttang and Bye (2019) the Cathedral was identified as the most significant historic building in Trondheim landscape. In this case, aspects like the colour, form, location and use are also of fundamental importance in the preservation of the city landscape. The interaction between nature and the urban fabric is evident. Monumental historical landmark buildings like the Cathedral dominate the urban landscape and thus shape the cityscape. Therefore, all new buildings should not break important landscape silhouettes. The case of Nidaros is representative of the fact that it is necessary to preserve the colour and above all the structure and shape because they are peculiar characteristics of the historical period in which it was built and part of the cityscape. Additionally, the air pollution situation in climate change has contributed to an accelerated deterioration of the monument. Therefore, it is necessary to think of some strategies to avoid irreversible damage and, at the same time, to keep the original materials and the identity of the Cathedral. These strategies, listed in the following subsections, concern architectural barriers, the use and maintenance of the historic building considered, and the proper maintenance of the green spaces.

- **Barriers**

The barriers in the city prevent free movement and make it difficult to use some spaces (Figure 1). It is important that the city has easy connections with the most emblematic sites and that there are spaces of utility and to further relationship between people. For this reason, certain obstacles such as different elevations, various vehicle and train crossings, etc. are complicating free movement. For example, the barriers between the warehouses were set up in order to prevent the spread of fire. And yet, in the cathedral, there is only one minor barrier, which is an outer fence with a gate, that allows people to get close to it (Figure 2).

Figure 1. Some of the barriers identified in the city of Trondheim.

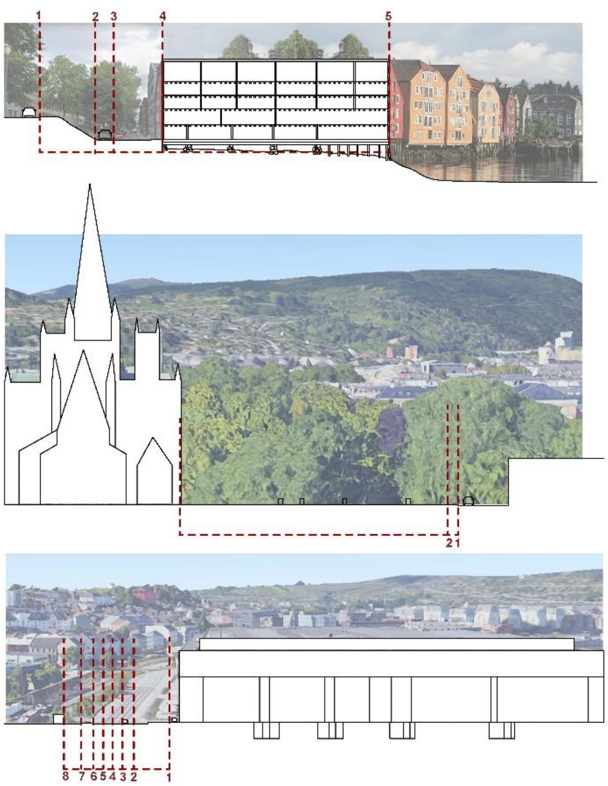

Figure 2. Comparison of the different barriers identified in the city.

- **Warehouses use**

Currently, most warehouses are not in use, so they are not maintained. It is important to reactivate the use of warehouses so that cultural events can take place and business offices can settle herewith encouraging the economy to support the revitalization of the neighbourhood. Therefore, important events such as concerts, social events, and cultural events will help to revive the area.

- **Maintenance**

It is important that maintenance is carried out on a regular basis to maintain the heritage and landscape of Trondheim. An example would be the cathedral of Nidaros, which can be kept in good condition by ongoing repair and restoration. However, the lack of maintenance in warehouses is due to the fact that they are not used and/or due to the lack of funds to keep them intact.

- **Green spaces**

Integrating green spaces means giving the city spaces to develop activities such as sports and provide a "green lung" (Figure 3). Nature provides spaces where you can interact with other people and integrating it can be an option to remove some barriers, such as heavy traffic. An example would be The Fortress and its environs, with large natural spaces where people can relax and relate to each other.

Figure 3. Green spaces that can be integrated in the landscape.

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GROUP 3

NO(r)WAY in TRONDHEIM?
Close-up to CH to find a way to preserve against flood risk

Dietrich F., Jokin I., Moreno Falcon M., Ogut O.

[ABSTRACT]

Climate change is one of the global problems that threatens the current conditions, even the future existence of Cultural Heritage (CH) values. Flood, as one the main natural hazards, have been affecting by water cycle changes in the planet towards the climate change. This study tried to investigate the flood hazard and the vulnerability of three significant cultural heritage areas (i.e., Warehouses, Nidaros Cathedral, and DORA facilities) in Trondheim (Norway) according to the framework of integral conservation and the methodological model Art-Risk. The results indicate that the significance and the use of Cultural Heritage are affected by many driving forces that have the potential to reduce -even dissolve- the consequences occur after an emergency. Some suggestions have been made both for decision making and the practical solutions in order to preserve these CH areas against the high flood risk.

[INTRODUCTION]

Floods are natural hazards that affect the city of Trondheim regularly. According to the last report of the Intergovernmental Panel on Climate Change (IPCC, 2022; IPCC, 2022b) the risk of extreme precipitation and modification in trend of the precipitation is increasing. For this reason, in the future the risk of flooding would increase if the levels of prevention, early warning and response are not improved.

When a flood happens, the impact not only depends on the frequency and the severity of the danger, but also depends on the vulnerability of buildings and social resilience (Bonazza et al. 2021). So, to estimate the impact of an emergency it is needed to know danger, vulnerability, and resilience.

To evaluate the vulnerability in a cultural urban area, it is necessary to use methods that consider the resistance of the materials and structures, as well as the resistance of the immaterial value of the heritage building. The material and immaterial values of the cultural areas indicate how these areas will be remembered and rethought around the identity of the city (Paoli et al., 2012). As long as it is possible, it is necessary to preserve all these values.

This document has five following chapters. In the next chapter, the case studies are briefly introduced by their functions and locations in the city. The used materials and methods of implementation of Art-Index in the case of Trondheim are described. In the section of Results and Discussion, the flood analysis and the vulnerability indexes of three CH areas are presented. Some multi-scale and multi-disciplinary strategies are suggested for each case specifically, as well as general ones to be valid for Trondheim.

[CASE STUDIES]

This study aims to investigate a part of the upcoming events that will be caused by climate change for three case studies in Trondheim, Norway. The first area is located on the western shore of the river Nidelva. It is the worldwide famous ensemble of the Warehouses (Kittang et al. 2019). The second case is the biggest cathedral in Northern Europe that is called Nidarosdomen (Mikaelsson, 2019). The third one is the DORA facilities -with a specific focus on DORA I (Grini, 2022) that is currently functioning as archive and library- in the north-eastern part of the city (fig. 1).

Figure 1: Location of three case studies. Data obtained from Google Earth.

[MATERIALS AND METHODS]

To study the hazard, flood zones has been identified according to the 10 years period return and the 100 years period return. A map with the projection of the expected changes for the near future (2100) was also included. The data used for flood zone mapping is from Norwegian Water Resources and Energy Directorate (NVE, 2022).

Based on the produced maps, the factors which puts the Cultural Heritage (CH) sites in danger, are evaluated. Knowing the challenges, the study is to come up with ideas which would support the risk reduction, and which should facilitate the protection of the CH in Trondheim.

To study the vulnerability, the model Art-Risk (Diaz et al. 2022; Moreno et al. 2022) has been adapted to Trondheim scenery. There are different models to evaluate the risk level in a heritage area (Julià & Ferreira, T., 2021). One of these models is Art-Risk, which proposes the use of vulnerability matrix and hazards to map the level of risk in a heritage landscape (Moreno et al. 2022; Diaz et al., 2022). One of the main advantages of Art-Risk is that it allows to include factors related to immaterial values to calculate the vulnerability and risk. By this reason, this model has been selected to discuss different possible scenarios after any possible emergency in cultural urban areas in Trondheim (Norway).

Art Risk uses a list of vulnerability factors and describes five different levels of vulnerability (very low, low, medium, high and very high; 1, 2, 3, 4 and 5 respectively to obtain the numerical values for index) according to different possible situations. From the relationship between the worst possible scenario and the data collected in each building, a vulnerability index is obtained and represented as a percentage. The index is calculated by using the following formula:

$$VI = \frac{SumVulnerabilty\ factors(\ SITE)}{Sum\ Vulnerability\ Factors\ (WORSTCASE)} * 100$$

Table 1 shows the new relations established between the level of vulnerability that is evaluated according to relevant factors i.e., the current occupation, heritage value, structural modifications, maintenance for the installation system, and degree of conservation. Due to the time limitations of this study, the vulnerability levels have been simplified into 3 levels (low, medium, high).

The vulnerability values have been adapted within the theoretical international framework of integral conservation (Obad, 2019). According to this theoretical framework, the interventions in heritage areas should facilitate positive impacts in the present, as well as in the future, in the territory. Besides, it should remark the necessity to include heritage management within the urban planning . This theoretical framework offers other ways to preserve the heritage than traditional approaches. This way to understand the heritage, has been defined by some scholars as something typical for Norwegian cities (Nyseth, T., & Sognnæs, J., 2013).

The abovementioned model implemented to the cases of Warehouses, Nidaros Cathedral, and Dora I Archive allows to identify the factors that decrease the vulnerability of these heritage places.

Besides, five possible scenarios in terms of usage of warehouses are hypothesized i.e., Museum, Offices, Community Center, Hotel, as well as without any function -vacant-. Each scenario is evaluated by the index and analyzed by considering all the defined factors.

Table 1: Vulnerability factors and level of vulnerability according to possible scenarios.

Vulnerability factors	Level of vulnerability		Linguistic descriptors
Current occupation and use	Low	1	Noticed and respected by people inside and outside
	Medium	2	Noticed and respected by people only outside
	High	3	Not noticed and/or respected by people
Heritage value	Low	1	Concerned and well-known at international level
	Medium	2	Concerned and well-known at national level
	High	3	Not concerned and/or well-known at all
Structural modifications	Low	1	Nearly no modification
	Medium	2	Modifications that made with professional guidance
	High	3	Modifications conflicting with the identity
Maintenance for Installation systems	Low	1	Regular condition monitoring
	Medium	2	No condition monitoring
	High	3	No condition monitoring and installation not used for long time
Degree of Conservation	Low	1	Optimal conservation
	Medium	2	Requires conservation
	High	3	Ruin

[RESULTS AND DISCUSSION]

Flood Areas

Figure 2 shows the flood zones in Trondheim. These are located on both sides of the riverbank and in the coastal area. Figures 3, 4 and 5 show the affected zones within the 3 study cultural urban areas and show an increase in the flooded zones in the near future (2100). While the cathedral is not affected by the floods, the

Warehouse, and the archive Dora I suffer periodic floods at least every 10 years. The high frequency of the events indicates that the floods in Trondheim are not caused by climatic extreme events. Floods usually occur in late winter, when heavy rainfall falls, and the ground and gutters are still frozen (Meiforth, 2017). For this reason, it is important to take preventive measures that prevent the deterioration of the affected heritage areas in the long term. Figure 6 also shows the square meters of the Dora 1 archive that have been affected by periodic flooding.

Figure 2: Flood zones in Trondheim (forecast in 2100). Flood data obtained from NVE, 2020

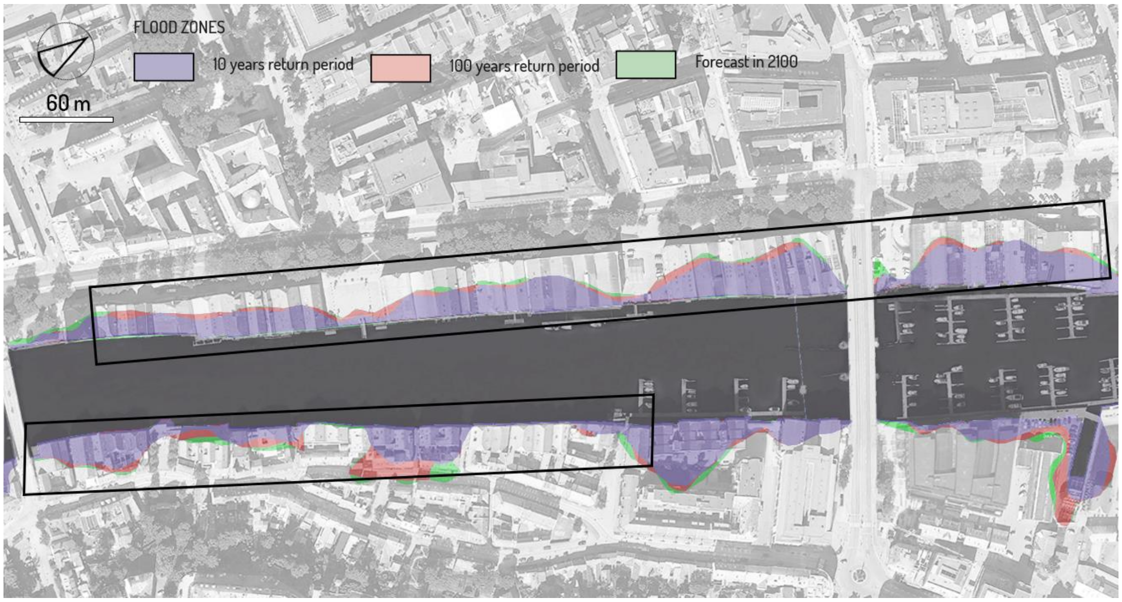

Figure 3: Flood zones near to warehouses. Warehouses are remarked with a black line. Flood data obtained from NVE, 2020

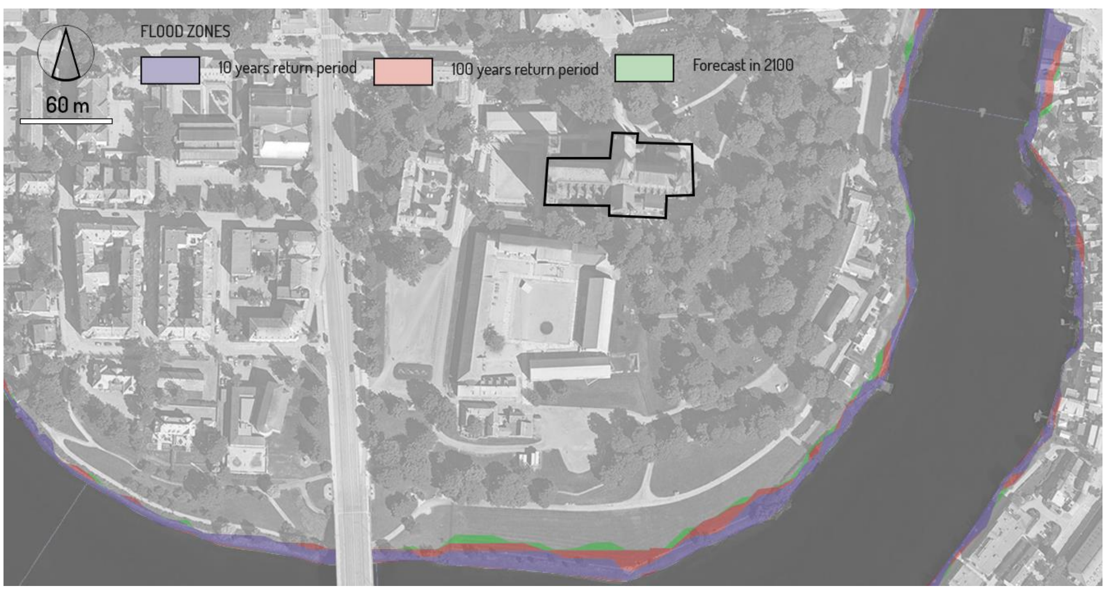

Figure 4: Flood zones near to Nidaros cathedral. Nidaros Cathedral is remarked with a black line. Flood data obtained from NVE, 2020

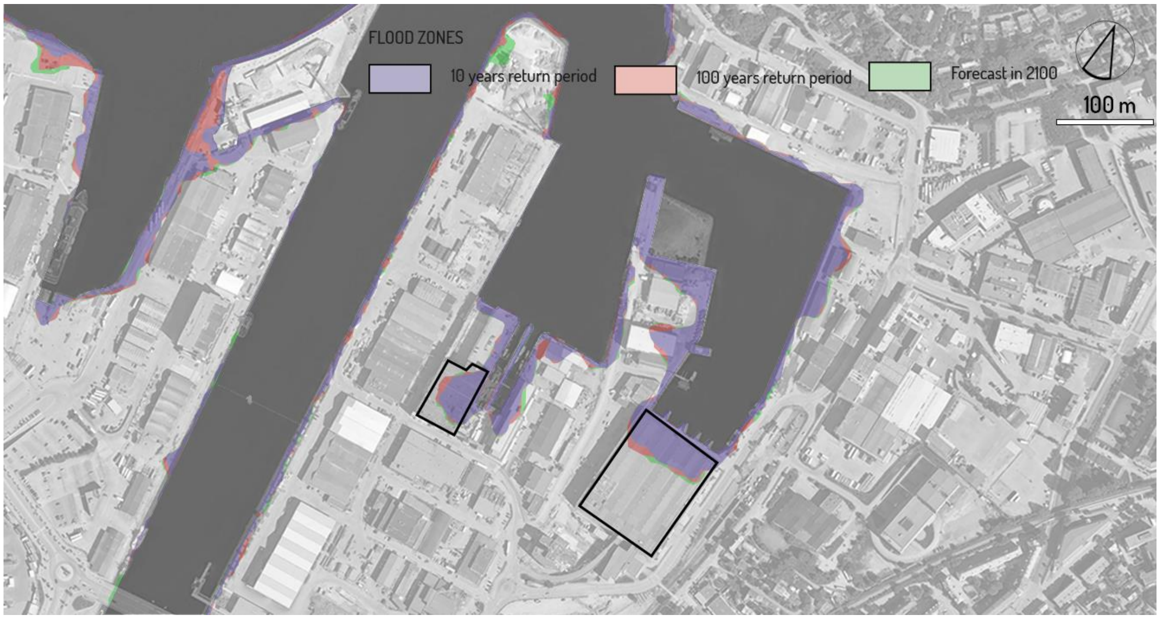

Figure 5. Flood zones near to Dora archives. Flood data obtained from NVE (2020).

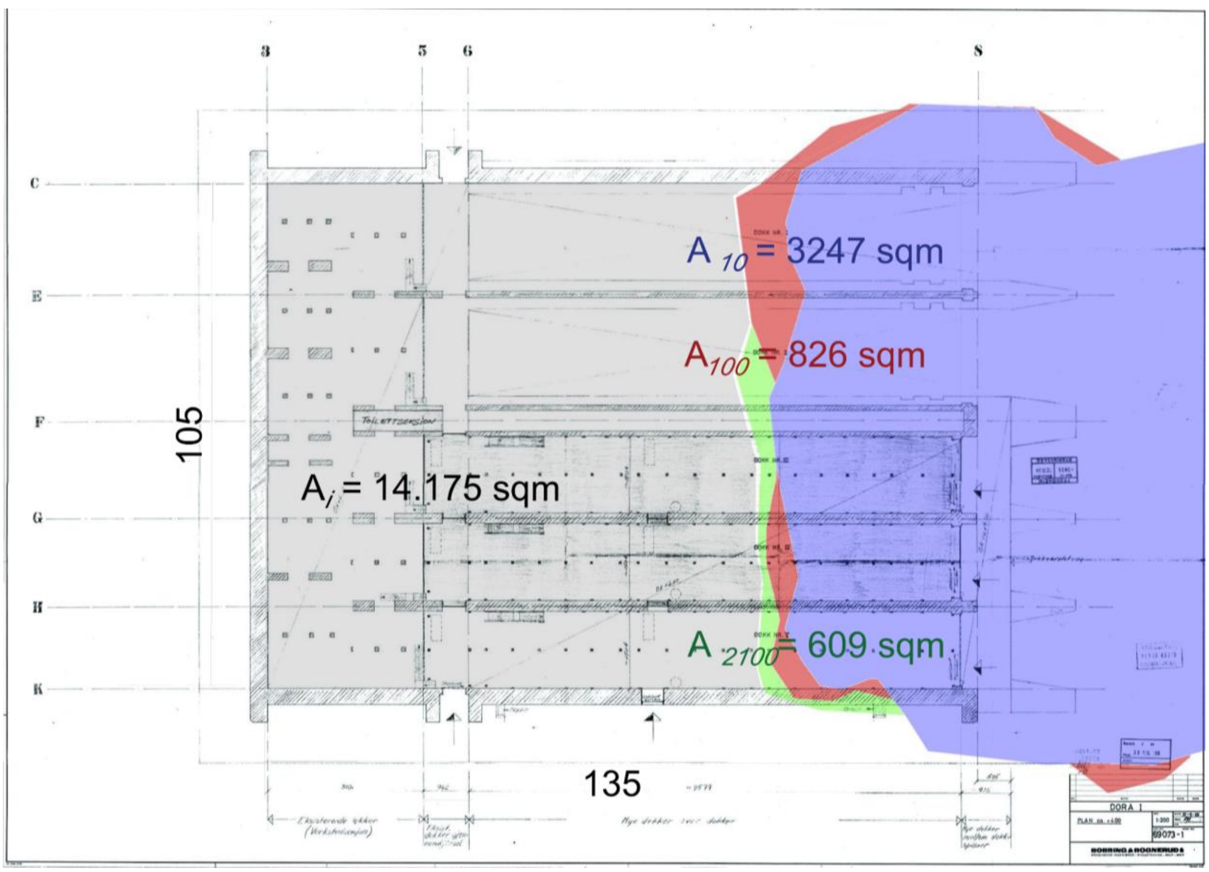

Figure 6. Flood Zone impact on DORA I. Flood data obtained from NVE (2020). Base map (1969) obtained from Municipal Archives of Trondheim (available online: https://www.flickr.com/photos/trondheim_byarkiv/4698749231)

The interior area of DORA I is calculated by excluding the exterior walls. By overlapping the plan with flood areas, it showed that 23%, 29%, and 33% of the total floor area are at the risk of flood by following the diachronic analysis of flood areas, as it is represented in figure 6.

Vulnerability

Table 2 shows the vulnerability index and the difference due to defined factors investigated in the three studied cases. The group of warehouses is the most vulnerable (VI= 66%) because nowadays not all of them have an occupation and use. The cathedral is the least vulnerable due to the fact that it is in currently under use every day and hour. Additionally, it is well conserved at national level without improper structural modifications, needs for the installation system. Regarding the degree of conservation, it has low vulnerability. The Cathedral is not in a flood-risk zone, so besides the least vulnerability there is no exposure to the flood hazard.

Table 2: Vulnerability matrix and Vulnerability Index (VI) of Warehouses, Cathedral and Dora I.

Vulnerability Factors	Warehouses	Cathedral	Dora
Current occupation and use	3	1	1
Heritage Value	1	1	2
Structural modifications	2	2	2
Maintenance for Installation system	2	1	1
Degree of conservation	2	1	1
Vulnerability Index	66,67%	40,00%	46,67%

Table 3 show the vulnerability indexes of the possible five scenarios of warehouses. The most vulnerable is vacant situation without any function (VI= 86,67%) and hotel comes after with the value of 60,00%. The vulnerability by structural modifications increases particularly in the hotel and museum scenarios because there are more needs to intervene within the original building in order to meet nowadays' legal requirements for these novel functions e.g., fire protection, emergency exits, and daylight. All the vulnerability factors, except structural modification, is highest in the scenario where the warehouses are not used. On the other hand, VI decreases in the scenarios where warehouses are re-functioned as offices, hotels. According to this matrix, the least vulnerable scenarios are the functions of museums, community center, and offices.

Table 3: Vulnerability Matrix and VI for the hypothetical scenarios

Vulnerability Factors	Museum	Offices	Community Center	Vacant	Hotel
Current occupation and use	1	1	1	3	1
Heritage value	1	3	2	3	3
Structural modifications	3	2	2	1	3
Maintenance for Installation system	1	1	2	3	1
Degree of conservation	1	1	1	3	1
Vulnerability Index	46,67%	53,33%	53,33%	86,67%	60,00%

[SUGGESTED STRATEGIES]

Following the analysis some strategies are proposed for different stakeholder both specific for each case and holistic for all CH sites in Trondheim.

Case-Specific Actions

As a re-action to the flood forecast (see figure 5 and 6), a waterproof wall that divides the internal structure is proposed as it is shown in figure 7 and 8 due to the fact that 23%, 29%, and 33% of the total floor area are endangered to be in flood zone in 10 years in return, 100 years in return, and 2100 in future forecast respectively.

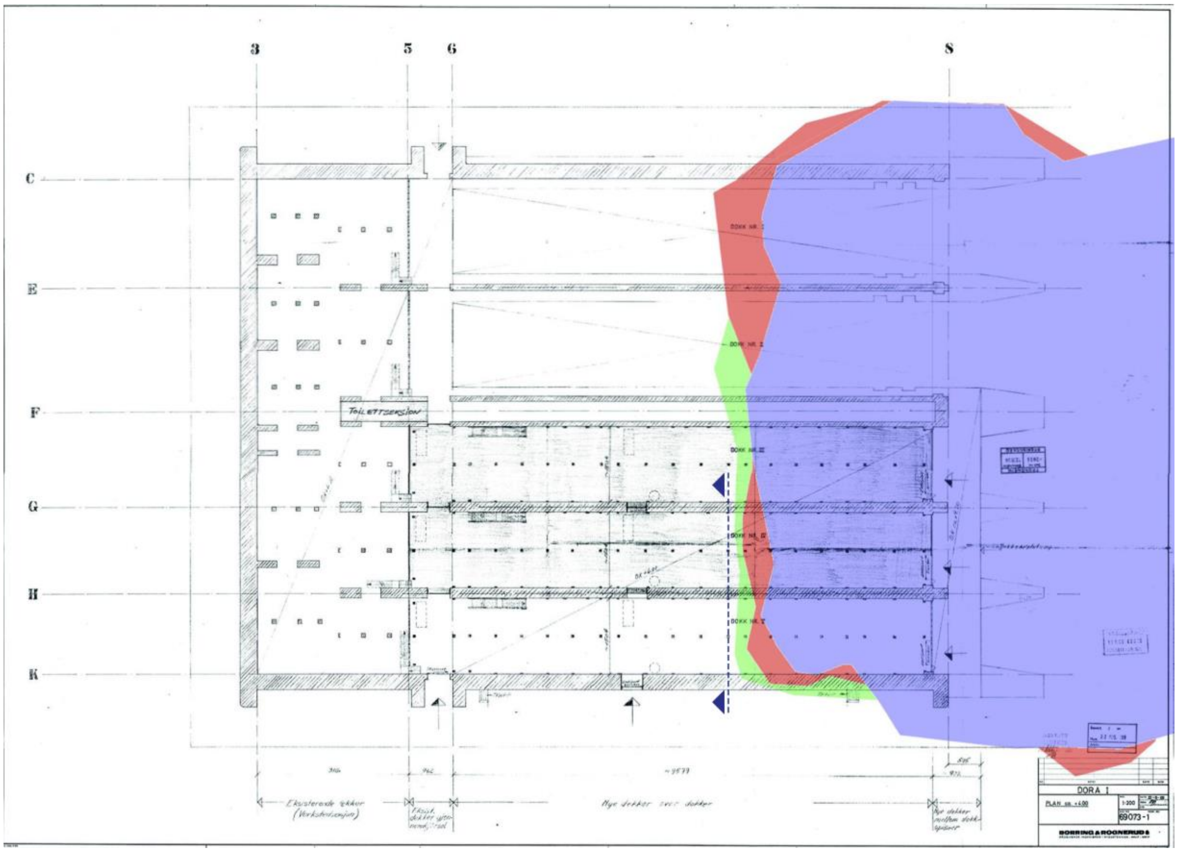

Figure 7. Overview plan for proposal wall. Flood data obtained from NVE, 2020.
Base map (1969) obtained from Municipal Archives of Trondheim (available online:
https://www.flickr.com/photos/trondheim_byarkiv/4698749231)

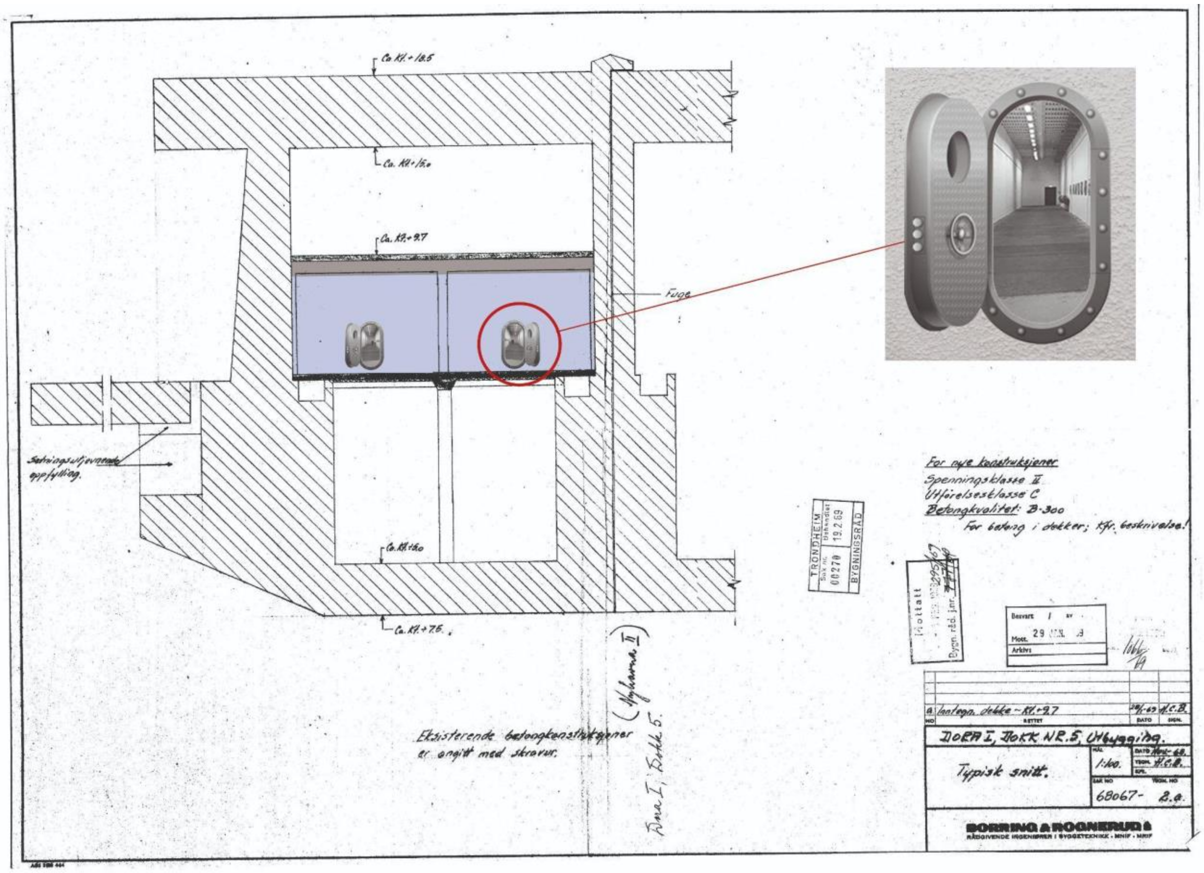

Figure 8. Section for proposal wall. Base section (1968) obtained from Municipal Archives of Trondheim (available online: https://www.flickr.com/photos/trondheim_byarkiv/4698737817/)

Case-wide Strategies

In-situ diagnosis and data gathering: Depending on the site, specific actions have to be taken. A general recommendation for all three sites is to do Laser Scans in order to have a 3D-Model of the current condition. It would be important to include characterization and aging studies of materials to study the functionality of buildings. Further it is recommended to make sure there are up-to-date architectural projects at hand, in order to have a consistent documentation.

Questionnaire: To explore the opinion of the community of Trondheim a questionnaire where both local residents and visitors will be the target audience. The main aim of this surveys is to study the attitudes of the local community regarding the preservation and preservation of cultural heritage and its use in a modern context. To process the results a forced Likert scale with 5 possible answers could be used.

Stakeholder Engagement: This topic requires a multidisciplinary and interdisciplinary collaboration with many fields such as conservatives, historicians, architects, mechanical and structural engineers, as well as users of these CH areas (i.e., tourists and residents) and public actors from multiscale governmental organizations. A preliminary stakeholder scheme is presented below, however, as holistic stakeholder mapping is a mandatory but considering all the interests, concerned, and need of all the related stakeholders. All the possible interactions among the individuals and the organizations need to be studied and considered in all the phases of CH conservation.

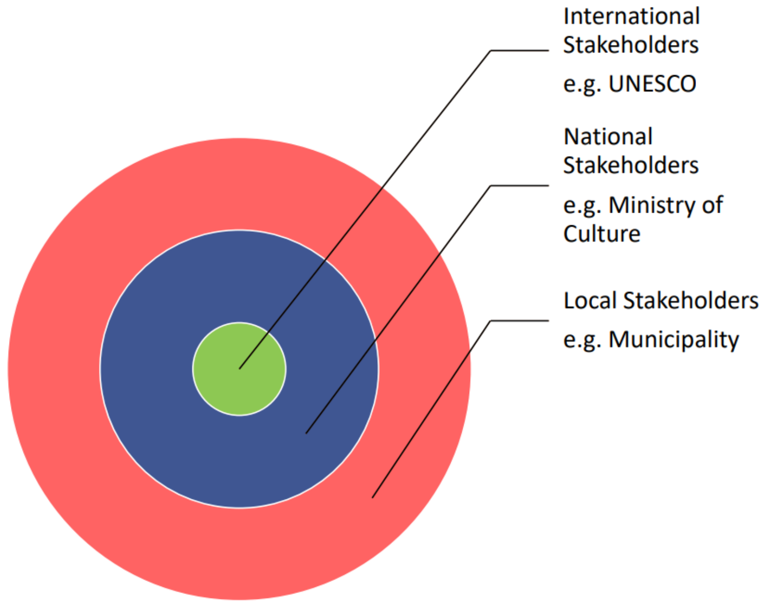

Figure 9. Stakeholder multiscale clustering

[CONCLUSION]

Built heritage management changes according to cultural, political, and economic contexts.
It has to be researched whether there is a specific way to understand the management of heritage in Norway. It appears that preservation plans, and urban regeneration are strongly linked in Trondheim. A huge interest in preserving the heritage areas is evident since local government promotes their use. When the building has more functions and therefore represents more values, it is more likely that people come up with a solution in case of emergency. Besides, the integral conservation allows more flexible solutions than traditional conservation methods. It is considered to be an advantage that does not make the residents feel a loss and/or change of the form, the colour, or any other feature related to the CH. Even though these changes may cause an irreversible impact on the structure, they can make the CH more resilient according to integral conservation approach.

The chosen method is used to provide an overview of how grave the impact in the three case studies. The results obtained indicate that Warehouses and Dora are affected by periodic floods every 10 years. It is worth to be mentioned that these maps are not 100% accurate as they are most likely based on a climate model.

Knowing that the weather system and world is far more complex it cannot be explained 100% precisely.

Regarding vulnerability, Warehouses were more vulnerable that Cathedral and Dora I due to occupation, maintainability and conservation degree. Besides, vacant Warehouses present a greater vulnerability in an emergency.

Adapted methodology helped to describe the vulnerability level of each scenario that hypothesized for Warehouse. This documentation of Warehouses should be part of the Recovery Plans for the worst-case scenario that may cause a severe loss of the Cultural Heritage due to flooding caused by heavy rain events as represented in figure 3.

It is assumed for the Cathedral the documentation is useful but not as much needed as the flood risk maps do not indicate a risk for flooding, as represented in figure 4.

Regarding Dora I**,** the documentation should be kept as a backup. And Expert Advisory Board is needed (Structural engineers, experts for conservation as the concrete shows some damages caused by deterioration, simulation specialists) in order to conserve the shared cultural heritage site.

The preliminary results obtained serve to reflect on the current risks that affect the cultural areas of Trondheim. Next step should include some strategies by keeping the heritage value of each case study in a professional stakeholder collaboration. Stakeholders have to be as holistic as needed i.e., from local, national, and international levels, as well as the users of the city e.g., citizens, employees, commuters.

Acknowledgments

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GROUP 4

Heritage Identity at Risk: Three case studies in Trondheim

C. Aguiar Botello, I. Barakat, G. Boccacci, M. Panahifar

[INTRODUCTION]

Nowadays, culture and Cultural Heritage represent the most important foundation for creating and maintaining identity, belonging and citizenship values. Heritage and culture, indeed, influence and are affected by the daily life of every community and its people. The value and potential of Cultural Heritage, if well managed, is a key aspect of community development and a factor of increased quality of life in societies that are in a constant state of evolution (Di Pietro, 2017: 1).

Warehouses, Nidarosdomen and Dora bunkers are the main cultural and industrial heritages in Trondheim which influence the character of the city.

In this overview we are trying to look at three heritages in Trondheim, to see why they are part of the character of the city, what risks are treating them and what are the possible solutions for reprograming these buildings.

This overview has been separated in three chapters below, where their identity and potential risks have been analyzed:

1. Identity
2. Risk Overview
3. Conclusion

We think it is important to distinguish between environment and landscape. The environment is what we observe, the purely physical elements, the biotope. The set of natural elements living and inert that make up the environment that surrounds us. This environment is observed by us and filtered by our own consciousness and experience, which generates a personal image of what we are observing.

Therefore, the landscape is a subjective image, a perception that varies depending on the person who is in front of this panorama. Gilles Clement, in his book “Gardens, Landscape and Natural Genius”, defines the landscape as what you keep in your mind when closing the eyes in front of a sight. In other words, it is a perception, almost an imagination of what really exists and that has been modified by our consciousness, our experiences and our culture.

The cultural landscape could be considered as an entropized landscape, that is, a landscape in which are present elements of the culture and society of a territory and therefore speak of human activity, of a way of inhabiting, to build, to live and etc. about a culture. In this sense, the historical complex of Bakklandet has a great value, which goes beyond its mere form or aesthetics. It is a cultural and anthropological heritage, and that is where much of its value lies. Thanks to the presence of this together, we can be aware of a way of living, of a constructive

tradition, an economic system etc.
Preserving a landscape is not preserving a picture or a panorama, is preserving history, preserving heritage, preserving culture (Figure 1). This can resume somehow this reflection, that these three concepts are in a constant dialogue shaping a system from where any of them can't be taken away.

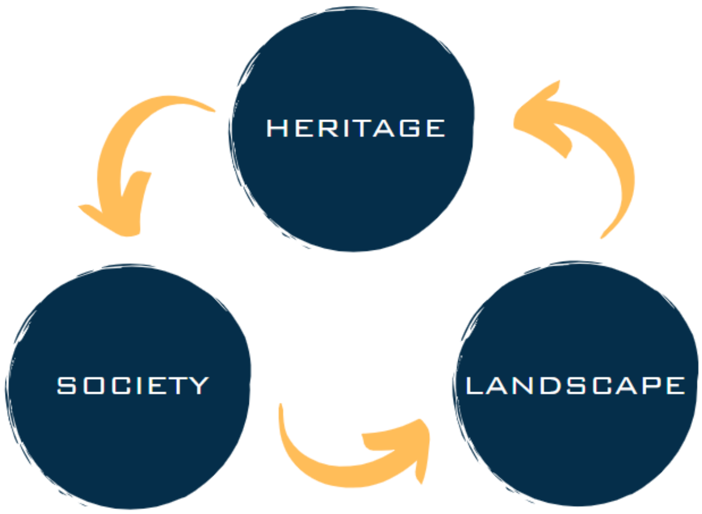


Figure 1. Heritage – Society – Landscape

[IDENTITY]

What gives a building its identity? People look places with different attitudes and their perceptions are not the same. Experts in Cultural Heritage field should think differently and consider whole parameters that make an identity for a heritage.
In this overview we thought about all items which contribute the definition of the case studies. In Figure 2 are reported many aspects which influence a heritage building. We tried to organize them in categories: aesthetic, environment, society. The lack of each one will change the identity of the heritage. This means that a combination of all factors makes the identity of these three cultural heritages.

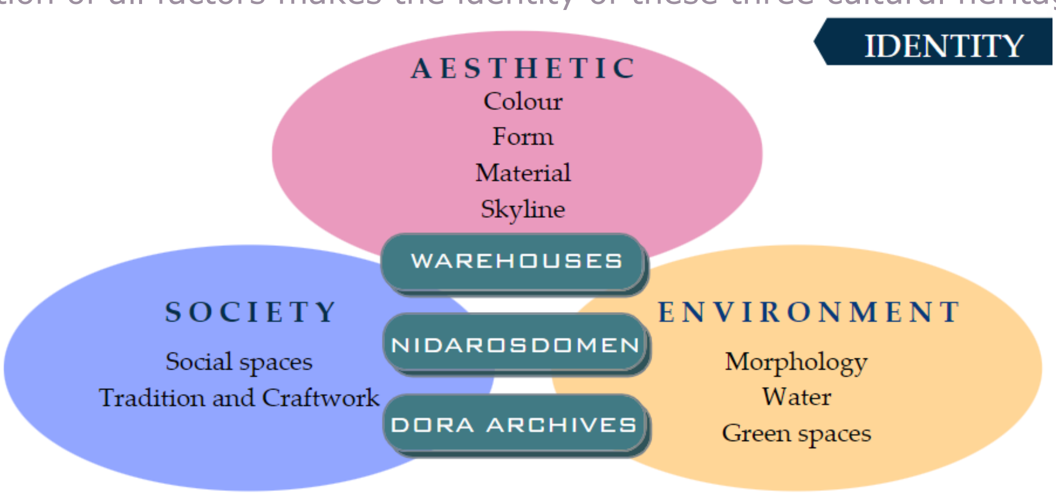
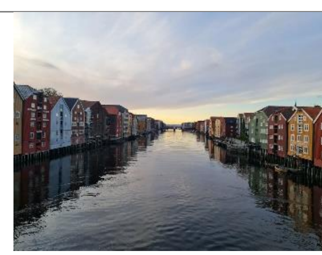


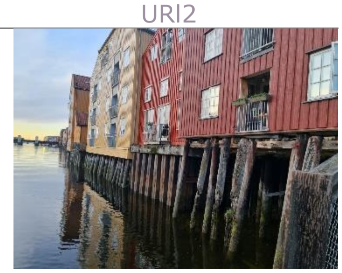
Figure 2. Organized categories of identification items.

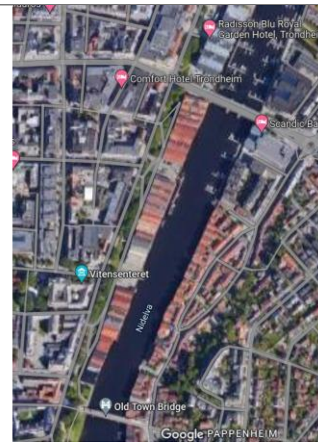
Nidelva River Warehouses

In table 1 are reported the identification items we found to be relevant for Nidelva river warehouses.

Table 1. Identification items overview of Nidelva river warehouses (Author).

Category	Identification	Details	Picture
Aesthetic	Color	Various warm colors create a specific visualization	
	Form	Rhythm in forms	
	Material	Traditional material and structure	
	Skyline	Create a unique up level view conceded with sky and sea	

Society	Social space	Beaches to relax	 URL1
		Places to work	
		Tourist attraction point	 URl2
	Traditions and craftworks	Traditional structure	
Environment	Morphology	Structured based on location	
		Located in different height from street level	

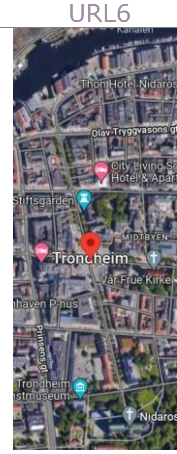
	Separated by green spaces with neighborhood	 Google maps
Water	Directly connection to the sea	
	unique accessibility (boats, bridges)	 URL1
	Reflection	

Nidaros Cathedral
During the history cathedrals were the respectful places which people tried to build them skillfully because they consider them as a symbol for cities. Nidaros cathedral was not an exception of this fact and during many years while it was destroyed by fire, many times people were eager to rebuild it again and safe it. Obviously, the reason is that this building is a part of citizens' identity which is going to be discussed in detail in Table 2.

Table 2. Identification items overview of Nidaros Cathedral.

Group 4

Category	Identification	Details	Picture
Aesthetic	Material	Traditional material (soap stone)	
	Form	High sharp cone structure	 URL3
	Skyline	Recognized by people from all over the city	 Google Earth (3D view)
Society	Social space	Surrounded by green space to stay and rest	 URL4
	Traditions and craftworks	Attractor space	 URL4

		Event center	 URL5
		Material arts	 URL4
Environment	Morphology	Landmark of the city	 URL6
		Locating at the beginning of the way to centrum and sea	 Google map

	Green space	Separated by green spaces with neighborhood	 Google map
		Acoustic	

Dora Bunker

World war II brought a German heritage to Norway beside the dreadful results. Dora I was used as a bunker and Dora II supposed to be added to that, but it was not finished successfully. Now these huge buildings are squired Trondheim archive and Dora II is an ocean water analysis site. Based on the unique identity of Dora this heritage is kept and even it is reused as Trondheim archive. In table 3 we will discuss about the identification items regarding Dora.

Table 3. Identification items overview of Dora Archive.

Category	Identification	Details	Picture
Aesthetic	Color	Workers community	 Google Earth (3D view)
	Material	Different color to separate the new part from the old one	
		Imported German reinforce concreate	

	Form	Huge cubic form with high density	
Environment	Morphology	effective transportation infrastructure	 Google Map
		Causing a huge industrial zone	
		Accessibility to sea	 Google Earth (3D view)
Society	Social space	Workers community	 Google Earth (3D view)

Just imagine that the case studies were in different forms and colors than the real one (Figure 3). The tables are representing how each factor set a specific feature for the warehouses. Figure 4 reports an example of different locations for Nidelva's warehouses with a road in place of the river. In Figure 5 we have tried to remove the river from the satellite view of Trondheim, especially close to the cathedral zone. In Figure 6 we removed the green space surrounding the cathedral and put a huge square in place of it. In figure 7 the Dora bunker was thought as a structure far away from the sea. In Figure 8 the materials constituting the building were replaced by other different materials to show how it would change.

Figure 3. Warehouses in different form and color.

Figure 4. Warehouses in different location.

Figure 5. Trondheim without its river (Google map).

Figure 6. Big square in place of the green area in front of Nidarosdomen (Google map).

Figure 7. Dora bunker far away from the sea (Google Earth 3D view).

Figure 8. Dora bunker with different materials.

[RISK OVERVIEW ON CASE STUDIES]

In the following tables (4-5) we tried to relate the real Climate Changes risks and the identity items we have identified to try to make connections between them and try to figure out what item would be affected by what risk. The aim was to establish strategies about what is in a more vulnerable situation, and what are the priorities, to start an active procedure to preserve the heritage, the landscape and the culture.

For this purpose, the identity items were grouped in three categories and the potential risks derived from climate changes were reported as well. A sort of icon code was used to establish the different damages that may have affected each of these items: full symbols meaning "Permanent Damage" and empty ones meaning "Temporary Damage". The different damages were also divided in three grades of severity depending on the size of the symbols (bigger ones, higher risk, medium ones for medium risk and smaller one for smaller risk) – *Table 4*. This same process was made for all the three case-

studies individually. Unfortunately, while doing this operation we faced some issues related to the lack of quantitative data to produce reliable conclusions. For this reason, we prefer to leave the table empty in order to show to the readers only the method of a possible risk analysis considering aesthetic, society and environment aspects and we really hope to have further occasions to collect data and fill out the table accurately.
Future research can consider the idea of creating one table for each of the different case studies and compare them by overlapping.
In this way, it would be possible to see analyze them as a set. This could have been the most interesting aspect of the tables because it would have allowed us to establish priorities and strategies on a preservation plan.

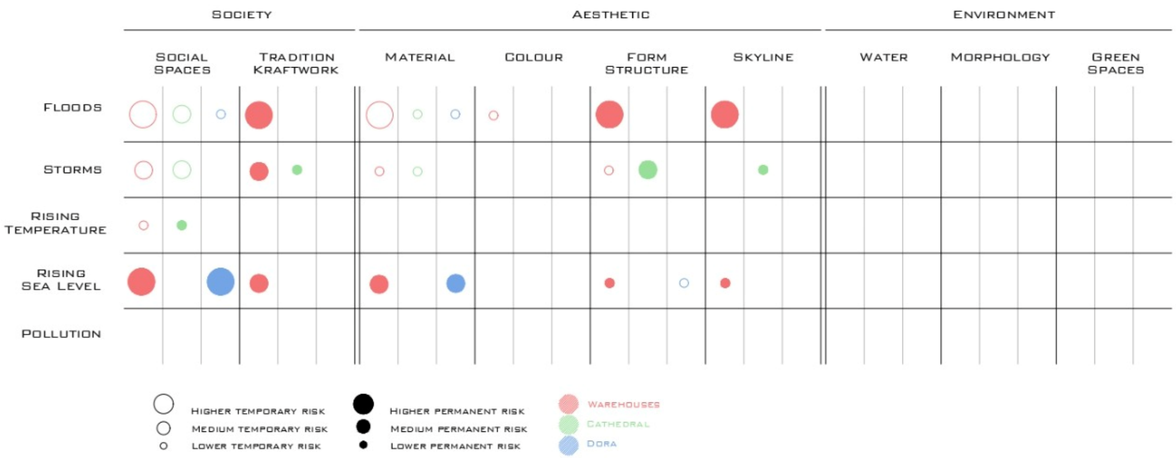
Table 4. Climate Changes risks affecting identity items (society, aesthetic, environment) in a case study.

	Society		Aesthetic				Environment		
	Social Spaces	Tradition Kraftwork	Material	Colour	Form Structure	Skyline	Water	Morphology	Green Spaces
Floods									
Storms									
Rising Temperature									
Rising Sea Level									
Pollution									

○ Higher temporary risk ● Higher permanent risk
○ Medium temporary risk ● Medium permanent risk
○ Lower temporary risk ● Lower permanent risk

Although it was not possible to complete the table with reliable data, the authors nevertheless tried and obtained a preliminary result (shown in Table 5). Even if not all fields are filled in, and the information contained can only be considered qualitative, it can already be noted that among the three cases taken into consideration (Warehouses, Nidarosdomen and Dora bunker), warehouses are in a more dangerous situation when we consider the possible risks associated with climate change.

Table 5. Preliminary results.



[CONCLUSION]

We believe that the elements we have listed and described, categorized within the macro-areas of "aesthetic", "environment" and "society", are those that confirm and constitute the identity of these historical sites that we had the pleasure of studying and visiting during the Summer School. The identifying elements define the landscape and heritage of Trondheim and must be preserved in the final aim of preserving the landscape, society and heritage.

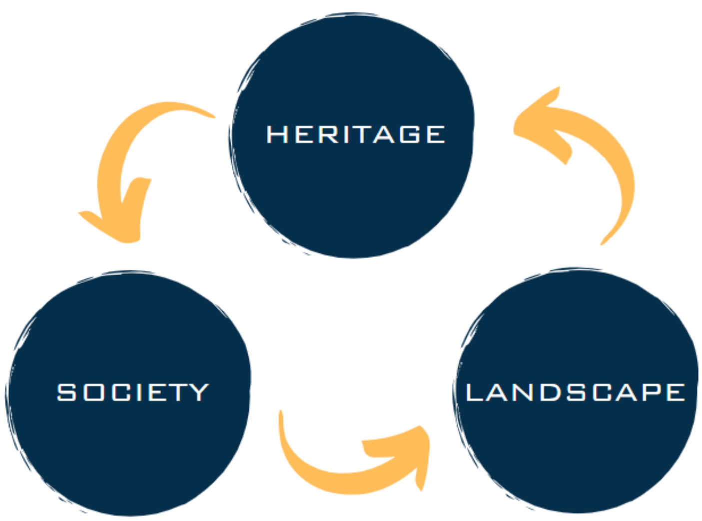


Figure 9. Relationship between Heritage – Society – Landscape.

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PART IV

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CONCLUSIONS

The concept of the CHePiCC Summer School and its Outputs focuses on built cultural heritage as integral part of cultural landscapes and vice versa, both seriously affected by climate change and related natural catastrophes.
Climate change itself is the connecting element and affects both cultural landscapes and cultural heritage. The concept for the summer university is applicable to any cultural landscape and its built heritage in Europe. It functions as important medium to gather practical experiences and get to know the respective built heritage and cultural landscapes on-site. HE students were given the chance to learn about applicable maintenance, preparedness and preservation measures by developing tailored measures for a given site and by implementing and actually testing their ideas.
The concept focuses on the effects of climate change in a certain climate zone, and develops possibilities to teach sustainable, eco-friendly and cost-efficient preparedness measures for built cultural heritage and maintenance measures for cultural landscapes. The whole concept is hybrid, student-centred, following a strict hands-on approach and is research based.

The project has brought significant contribution in terms of INNOVATION as it transferred the transdisciplinary approach to cultural heritage protection in climate change that is already well-established in research projects (purely academic basic research to applied and practical research in combination with different stakeholders) to the higher education level. In addition, it brought formats contemplated in research projects on cultural heritage protection and climate change into higher education, and it was developed as hybrid version of a summer school, tackling the challenges of bringing highly interactive and hands-on approaches to remote participants.
Moreover, the CHePiCC school has given HE learners the possibility to join not only lessons but even on-the-field visits and self-learning moments that stimulated the discussion on the topics of concern.

The project has brought significant contribution in terms of IMPACT has the CHePiCC School has been attended by people (both learners and teachers) from all over the world. In addition, stakeholders on local, regional and national levels were included in order to underline the complementarity of this project to high-level research projects on cultural heritage, climate change, cultural landscapes and cultural heritage protection carried out by the partners in the project consortium.

The target groups learned a transdisciplinary approach which is essential when dealing with aspects the subject in question. They can take this approach with them, establish it at their (future) working place or in their (future) research groups and therefore contribute to a professional behavioral change and further development within their own field.
An additional value for the project participants is that peer-learning possibilities were enhanced. The participants were enabled to build a high capacity in climate

change effects on different climate zones, landscapes and different types of cultural heritage.

The project has brought significant contribution in terms of TRANSFERABILITY has the CHePiCC School
set up allowed the transfer of either the entire topics or parts of them into almost any curriculum in higher education. HE learners can extract their specific needs from the and include them into already existing curricula or into near future ones. Moreover, the setup of the School allowed different levels of participation for the HE learners, thus facilitating equity and inclusion: listening to lessons and actively participating in the discussions brought up by the teachers; being tutored during self-learning activities and on-the-field visits; writing of final reports and preparation of presentations about the School topics.
In addition, the entire concept of the School can easily be transferred to other frameworks. As a matter of fact, the idea of the School was born from choosing a city (Trondheim, in this case), selecting the points of interest according to the School's topics, and finally engaging the local and international experts in the field (academics, stakeholders etc.) to deliver high-level lessons and activities. For this reason, the School main concept has a high potential and can be easily adapted to other conditions, cities and situations that may be interesting to study in the framework of the Cultural Heritage Protection.

CHePiCC Summer School

"Cultural Heritage Protection in Climate Change"

30th May 2022 –4th June 2022

Trondheim, Norway

Supported by