European Commission

Safeguarding Cultural Heritage from Natural and Man-Made Disasters

A comparative analysis of risk management in the EU

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Directorate-General for Education, Youth, Sport and Culture
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Abstract

Natural and man-made hazards, anthropogenic effects and extreme climate change events, are persistently putting the cultural heritage of Europe under pressure, with a daily incremental frequency. In addition, such disasters and catastrophes compound the conservation challenges and needs of the heritage assets. These events also menace the assets' social, cultural, historic and artistic values, the safety of citizens, and have an impact on local economies linked to tourism. Consequently, research on adaptation strategies, methodologies and other remedial tools is crucial, in order to safeguard Europe's cultural heritage from the continuous pressures it faces and the related decay-inducing consequences.

This Study presents a comprehensive overview of the existing knowledge, at European and international level, on safeguarding cultural heritage from the effects of natural disasters and threats caused by human action. Furthermore, it maps existing strategies and tools for disaster risk management in the 28 Member States, and provides evidence-based recommendations with the purpose of supporting European cooperation and improving the integration of cultural heritage in national platforms for Disaster Risk Reduction.

Résumé

Les catastrophes naturelles et anthropiques, les effets anthropogéniques et les phénomènes climatiques extrêmes exercent une pression systématique sur le patrimoine culturel de l'Europe, à des intervalles de moins en moins espacés. De plus, ces désastres et ces catastrophes aggravent les problèmes et les besoins relatifs à la conservation des ressources du patrimoine. Aussi, ces phénomènes sont-ils une menace pour la valeur sociale, culturelle, historique et artistique de ces ressources et pour la sécurité des citoyens. De plus, ils affectent les économies locales liées au tourisme. Il s'avère donc urgent de mener des recherches sur les stratégies d'adaptation, les méthodologies et d'autres outils permettant de protéger ce patrimoine des pressions auxquelles il est sans cesse confronté et des conséquences entraînant sa dégradation.

Cette étude offre un aperçu exhaustif des connaissances actuelles, à l'échelle européenne et internationale, sur la protection du patrimoine culturel des effets des catastrophes naturelles et des menaces causées par l'action de l'homme. Aussi, propose-t-elle une cartographie des stratégies et des outils disponibles, pour gérer les risques de catastrophe dans les 28 États membres. Enfin, elle fournit des recommandations pour aider à la coopération européenne et améliorer l'intégration du patrimoine culturel dans les plateformes nationales de réduction des risques de catastrophe.

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Executive Summary

Preface

The present Study responds to the request by the Council of the European Union to the European Commission to conduct a study on "Risk assessment and prevention for safeguarding cultural heritage from the effects of natural disasters and threats caused by human action", in the framework of the **Work Plan for Culture** (2015-2018)[1] - Priority area B cultural heritage.

Heritage assets and resources are of great value to society from a cultural, environmental, social and economic point of view, and their safeguarding from the continuous pressures of natural hazards, anthropogenic effects and extreme events due to global changes is of paramount importance.

Since 2007, cultural heritage has been a priority for European cultural cooperation, as highlighted by the **European Agenda for Culture**[2]. Furthermore it is considered a strategic resource for a sustainable Europe[3], as stated in the Council Conclusions of May 2014, and the European institutions have decided to celebrate it in 2018 with the European Year of Cultural Heritage.

At global level, the **Sendai Framework for Disaster Risk Reduction 2015-2030** (Sendai Framework)[4], the current global agreement on disaster risk management, adopted by the United Nations in 2015, includes among its priorities the protection of cultural heritage, and invites national authorities to cooperate in increasing an awareness of cultural heritage impacts in the context of exposure to hazards.

On 17 June 2016, the European Commission published an **Action Plan on the Sendai Framework**[5]**.** Covering a five-year period, the Plan provides for a more systematic disaster-risk-informed approach in EU policy making. One of the implementation priorities concerns the development of good practice regarding the essential integration of cultural heritage in national disaster risk reduction strategies to be developed by EU Member States.

Therefore, this Study can contribute to the integration of cultural heritage as a new focus area in the Sendai framework.

Objective and adopted methodology

The overall objective of this Study is to contribute to the development of good practices to integrate cultural heritage into national disaster and risk reduction strategies developed by EU Member States.

In order to support and achieve this aim, the following **specific Study objectives** were accomplished by:

[1] Conclusions of the Council and of the Representatives of the Governments of the Member States, meeting within the Council, on a Work Plan for Culture (2015-2018) (2014/C 463/02)
[2] Resolution of the Council of 16 November 2007 on a European Agenda for Culture (2007/C 287/01).
[3] Council conclusions of 21 May 2014 on cultural heritage as a strategic resource for a sustainable Europe (2014/C 183/08).
[4] Adopted on 15 March 2015 at the third United Nations World Conference on Disaster Risk Reduction and adopted by the UN General Assembly on 3 June 2015
A/RES/69/283; http://www.unisdr.org/we/coordinate/sendai-framework
[5] COMMISSION STAFF WORKING DOCUMENT Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030 A disaster risk-informed approach for all EU policies SWD(2016)205 final/2, http://ec.europa.eu/echo/sites/echo-site/files/1_en_document_travail_service_part1_v2.pdf

1) **Providing an overview** of the information available at EU and international level on risk assessment and prevention to safeguard cultural heritage from the effects of natural disasters and threats caused by human action (Chapter 2);

2) **Mapping the existing strategies** in all 28 Member States for disaster risk management of cultural heritage, with a focus on existing competence centres and tools, by survey and interviews to key experts (Chapter 3);

3) **Putting forward recommendations** on possible measures to improve the risk management of cultural heritage at European level (Chapter 1).

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

- **Task 1** draws an overview of the information available at EU and international level on risk assessment and prevention for safeguarding cultural heritage from the effects of natural disasters and threats caused by human action, using a State–of-the-Art approach (Chapter 2).
- **Task 2** maps the existing strategies and practices in all 28 MS on disaster risk management of cultural heritage, with a focus on existing competence centres and tools. This task was conducted through surveys and interviews with key actors in public and private research entities, policy-oriented international and national organisations (including UNESCO, ICCROM, ICOMOS, Council of Europe, Europa Nostra, National Ministry of Culture, etc.) and stakeholders operating on cultural heritage protection (e.g. Blue Helmets, Blue Shield, National, Regional and Local Authorities, Civil Protection, Private Associations) (Chapter 3).
- **Task 3** identified strengths and weaknesses through information exchanges and consultations amongst team members with the final aim of formulating conclusions and recommendations for Europe (Chapter 1 and 4).

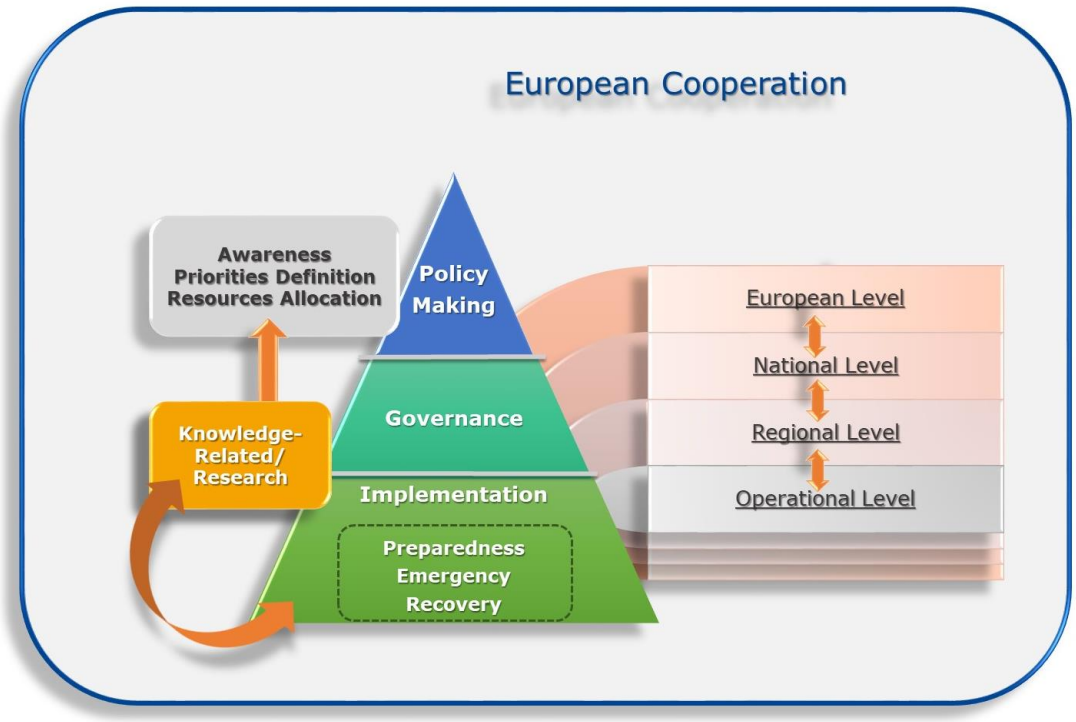
Diverse risk factors are taken into consideration. Acting individually and in combination, these are linked to threats caused by natural and man-made disasters (e.g., climate change, air pollution, flood, landslide, earthquake, volcanic eruptions, fire, armed conflicts and illicit trafficking). Special attention is also given to the impact of climate change as a consequence of human activity modifying the intensity and frequency of the occurrence of slow and extreme events damaging cultural heritage (e.g. surface recession and erosion by precipitation, bio-deterioration, de-cohesion and fracturing due to salt crystallization, sea level rise and thermal stress amongst other factors).

Key Lessons learnt during the Study

The integration of cultural heritage into national disaster and risk reduction strategies developed by EU Member States still suffers from:

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

To maximise synergies between the political, governmental and operational levels in the field of disaster awareness an integrated approach is required, as illustrated in the diagram below:



General recommendations

The Study findings and recommendations aim at addressing and overcoming existing gaps in policy making, administration and managerial implementation, practical application and knowledge/research levels of interest and activity.

The Recommendations are framed in line with the Sendai Four Priorities:

Priority 1 - Understanding disaster risk

Raise awareness

Promote dissemination activities, targeting all responsible stakeholders (public authorities, at European, national and regional and local level, public officers and owners) allowing them to acquire an in-depth understanding of the importance of cultural heritage, and the need for protecting it against all potential risks.

Support targeted projects

Support at EU and national level research and innovation programmes addressing all categories of risks, and undertake pilot testing and reporting at local level.

Priority 2 - Strengthening disaster risk governance to manage disaster risk

Promote collaboration of competent authorities

Foster collaboration by each country's competent authority (e.g. Ministry of Culture, Civil Protection, Police, Fire Dept.) for planning preparedness, emergency reaction and recovery and encourage coordinated actions among EU member states.

Support structural documentation

Support the documentation of structural aspects of built heritage through the use of IT tools, including the digitalisation of archival records and on-site laser scanning. This will facilitate operational procedures and ensure more easy and timely access to the required

information. Preferably, such activities should be carried out in advance of any disaster incident occurring.

Priority 3 Investing in disaster risk reduction for resilience

Establishment of priorities for protecting cultural heritage asset

Define priorities of cultural heritage assets to be rescued and make this information ready available to the relevant authorities.

Enhance education

The education of all those potentially affected by the consequences of disasters is a primary prerequisite for all categories of risk. Competent authorities should deliver:

- *Actions to educate specialists.*
- *In-post training for employees.*
- *Education programmes targeting the wider public and school children.*

Priority 4 Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction

Draft European Standards

European Standards for safeguarding specific categories of cultural heritage assets against the effects of different types of disaster should be drafted, building upon the results of previous and new research.

Foster the application of satellite services

Explore and pursue the potential of the Copernicus Programme for monitoring and assessing the impact of natural and anthropogenic disasters, humanitarian crisis and conflicts that can affect the cultural heritage sector and, consequently, enhance prevention and management, and facilitate early warning and recovery operations.

Support and enhance research

In order to address appropriate and relevant practices on the integration of cultural heritage in the national disaster risk reduction strategies, it is necessary to support and enhance research in the following issues:

- Prioritise environmental monitoring parameters in relation to the impact on heritage.
- Gather relevant historic data on assets under threat.
- Develop early warning and damage modelling systems to help safeguard the assets.
- Develop locational maps of European cultural heritage at risk that link with and relate to existing maps of natural and man-made hazards, and the potential risks.
- Create measure-oriented database information on the criticalities of cultural heritage and intervention priorities to strengthen resilience.
- Design, standardise and adopt recording systems for disaster-damaged heritage with existing systems.
- Address enhanced efforts on creating recovery measure preparedness in advance of an incident taking place.
- Develop assessments methodologies to consider and incorporate the financial impact of disasters, taking into account intangible and tangible heritage values.

Identified Gaps and Required Activities

Specifically, the Study found key gaps where issues concerning natural and man-made disasters affecting cultural heritage are not taken into consideration. Many such gaps were consistently and repeatedly identified in each of the studied risks.

In support of the above diagram and divided into policy making, administration and managerial implementation, practical application and knowledge/research these are collectively illustrated below:

Policy Making

In political and managerial terms there is a need for:

- General advancements in a trans-national understanding that cultural heritage requires protection from a wide range of potentially damaging multi-risks scenarios.
- Greater universal integration of cultural heritage requirements into existing and future funded research, information and mapping development programmes.
- Developing and promoting long-term cultural heritage measures and strategies to address the impact of both natural and man-made consequences.
- Improvements in collaboratively unifying the accessibility of National and Regional/Local strategic, guideline, and regulatory documentation that also overcomes the "linguistic obstacle" where texts are only available in local languages, not in English.
- The implementation of amendments to Eurocodes and other relevant standards to take into account the physical features, and the cultural and socio-economic value of traditional and historic assets, when addressing disaster scenarios.
- The recognition that the lack of maintenance and remedial work leading to negligence and/or abandonment, can be overcome through innovative financial incentives, including tax relief.
- An evaluation of the potential economic loss caused by all forms of physical damage.
- Supporting Long-Life pan-professional disaster training for experts in the built heritage and landscape field, covering the full range of relevant risks.

Administration and Managerial Implementation

There is a need for:

- Promoting, creating and piloting an effective co-ordinating methodology for all potential disaster related incidents, including those that transcend operational boundaries.
- Significant improvements in public awareness of disaster risk management issues through informed educational programmes.
- Training responsible employees on emergency disaster planning and how to respond accordingly.
- Digitising documentation related to cultural heritage by creating and making available electronic archival reference material.
- Setting up informed criteria and techniques for prioritising and securing valuable items and assets in the event of an emergency.

- Monitoring vulnerabilities to support preparedness and to assist in recovery procedures in emergency situations.

Practical Application and Knowledge/Research

Regarding practical requirements and knowledge related research there is a need for:

- The creation of a comprehensive inventory of cultural heritage assets that have been pre-assessed to be disaster endangered.
- The development of an effective risk management of cultural assets strategy that fully takes into account the true cost of loss and damage, along with an assessment of the non-market nature of related cultural heritage values.
- Collating and improving inspection and diagnostic observational data to establish an integrated methodology for the comprehensive modelling of the impact of disasters.
- Prioritising an understanding of multi-risk complex-system scenarios in urban historic centres, archaeological sites, and cultural landscapes regarding climate change impacts and other jeopardising factors.
- Creating and developing an effective early warning system to specifically address safeguarding Cultural Heritage from multi-risk and disaster situations.
- Developing appropriate quantitative design data, codes and procedures to ameliorate induced damage and establish funding action priorities.
- Overcoming the absence and promotion of pre-planned analysis and preventative measures required for the development of efficient plans to protect cultural heritage against disasters.
- Developing and promoting pre- and post-event informative documentation, based on soundly research findings, to enhance awareness raising in all levels of interested parties.

Résumé exécutif

Introduction

Cette étude répond à une demande que le Conseil de l'Union européenne a adressée à la Commission visant la conduite d'une étude sur « l'évaluation et la prévention pour protéger le patrimoine culturel des effets des catastrophes naturelles et des menaces causées par l'action humaine », dans le cadre du **Programme de travail (2015-2018**)[6] - Priorité domaine B patrimoine culturel.

Les ressources du patrimoine sont d'une grande valeur pour la société, d'un point de vue culturel, environnemental, social et économique. Il est donc de la plus grande importance de les protéger contre les pressions qu'exercent les aléas naturels, les effets anthropogéniques et les phénomènes extrêmes dus aux changements climatiques de la planète.

Depuis 2007, le patrimoine culturel a été une priorité pour la coopération culturelle européenne, comme il ressort de l'**Agenda européen de la culture**[7]. De plus, on le considère comme une ressource stratégique pour une Europe durable[8], ainsi que le Conseil l'a dit dans ses conclusions de mai 2014. Les institutions européennes ont donc décidé de le mettre à l'honneur en 2018, avec l'Année européenne du patrimoine culturel.

Au niveau mondial, le **Cadre d'action pour la réduction des risques de catastrophe 2015-2030** (Cadre d'action de Sendai)[9], l'accord mondial sur la gestion des risques de catastrophe qu'ont adopté les États membres des Nations unies en mars 2015, envisage, parmi ses priorités, de protéger le patrimoine culturel. Aussi, fait-il appel à la coopération des autorités nationales, pour favoriser une meilleure connaissance des impacts résultant de l'exposition du patrimoine culturel aux aléas.

Le 17 juin 2016, la Commission européenne a publié le **Plan d'action sur le cadre de Sendai**[10], couvrant une période de cinq ans. Ce plan offre une démarche plus systématique, fondée sur la connaissance des risques de catastrophe pour l'élaboration des politiques de l'UE. Parmi ses priorités, ce plan envisage le développement de bonnes pratiques, pour intégrer le patrimoine culturel dans les stratégies nationales de réduction des risques de catastrophe, que les États membres de l'UE devront mettre au point.

Aussi, cette étude pourra-t-elle aider à l'intégration du patrimoine culturel, en tant que nouveau domaine d'intervention du cadre d'action de Sendai.

Objectif et méthodologie de l'étude

L'**objectif général de cette étude est de contribuer au développement de bonnes pratiques, pour intégrer le patrimoine culturel dans les stratégies nationales**

[6] Conclusions du Conseil et des représentants des gouvernements des États membres, réunis au sein du Conseil, sur un programme de travail en faveur de la culture (2015-2018) (2014/C 463/02)
[7] Résolution du Conseil du 16 novembre 2007 relative à un agenda européen de la culture (2007/C 287/01).
[8] Conclusions du Conseil du 21 mai 2014 sur la dimension stratégique du patrimoine culturel pour une Europe durable (2014/C 183/08).
[9] Adopté le 15 mars 2015, lors de la troisième Conférence Mondiale des Nations-Unies sur la Réduction des Risques de Catastrophe et adopté par l'Assemblée Générale des Nations-Unies le 3 juin 2015 A/RES/69/283; http://www.unisdr.org/we/coordinate/sendai-framework
[10] DOCUMENT DE TRAVAIL DES SERVICES DE LA COMMISSION *Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030 A disaster risk-informed approach for all EU policies* (Plan d'action sur le cadre de Sendai pour la réduction des risques de catastrophe pour toutes les politiques de l'UE) SWD(2016)205final/2, http://ec.europa.eu/echo/sites/echo-site/files/1_en_document_travail_service_part1_v2.pdf

de réduction des risques et des catastrophes, qu'ont développées les États membres de l'UE.

Pour aider à la réalisation de ce but, on a atteint **les objectifs spécifiques de cette étude** par ce qui suit.

1) **Une vue d'ensemble** des informations disponibles, au niveau communautaire et international, sur la prévention et l'évaluation des risques, pour protéger le patrimoine culturel contre les effets des désastres naturels et les menaces venant de l'action de l'homme (Chapitre 2);

2) **Une cartographie des stratégies existantes**, au sein des 28 États membres, pour la gestion des risques de catastrophes pouvant affecter le patrimoine culturel, en mettant l'accent sur les centres de compétences et les outils déjà disponibles, par des enquêtes et des interviews aux principaux experts (Chapitre 3);

3) **Des recommandations sur l'adoption des mesures permettant d'améliore la gestion des risques relatifs au patrimoine culturel, au niveau européen** (Chapitre 1).

Pour atteindre ces objectifs, cette étude de 12 mois a été structurée en 3 tâches principales.

- **Tâche 1:** dresser un aperçu général des informations disponibles au sein de l'UE et au niveau international, sur l'évaluation et la prévention des risques, pour protéger le patrimoine culturel des effets des catastrophes naturelles et des menaces causées par l'action humaine, en faisant appel à des méthodes de pointe (Chapitre 2).
- **Tâche 2:** cartographier les stratégies et les pratiques existantes, au sein des 28 États membres, en matière de gestion des risques de catastrophe pouvant affecter le patrimoine culturel, en mettant l'accent sur les centres de compétences et les outils déjà disponibles. Pour remplir cette tâche, nous avons effectué des enquêtes et des interviews aux principaux acteurs d'organismes de recherche publics et privés, d'organisations nationales et internationales orientées vers l'action (y compris l'UNESCO, l'ICCROM, l'ICOMOS, le Conseil de l'Europe, Europa Nostra, le ministère national de la Culture, etc.), ainsi qu'aux parties prenantes agissant dans le domaine de la protection du patrimoine culturel (par ex.: les Casques bleus, le Bouclier bleu, les autorités locales, régionales et nationales, la Protection civile, les Associations privées) (Chapitre 3).
- **Tâche 3:** identifier les points forts et les points faibles, par l'échange d'information et la consultation entre les membres des équipes, afin de parvenir à formuler des conclusions et des recommandations pour l'Europe (Chapitres 1 et 4).

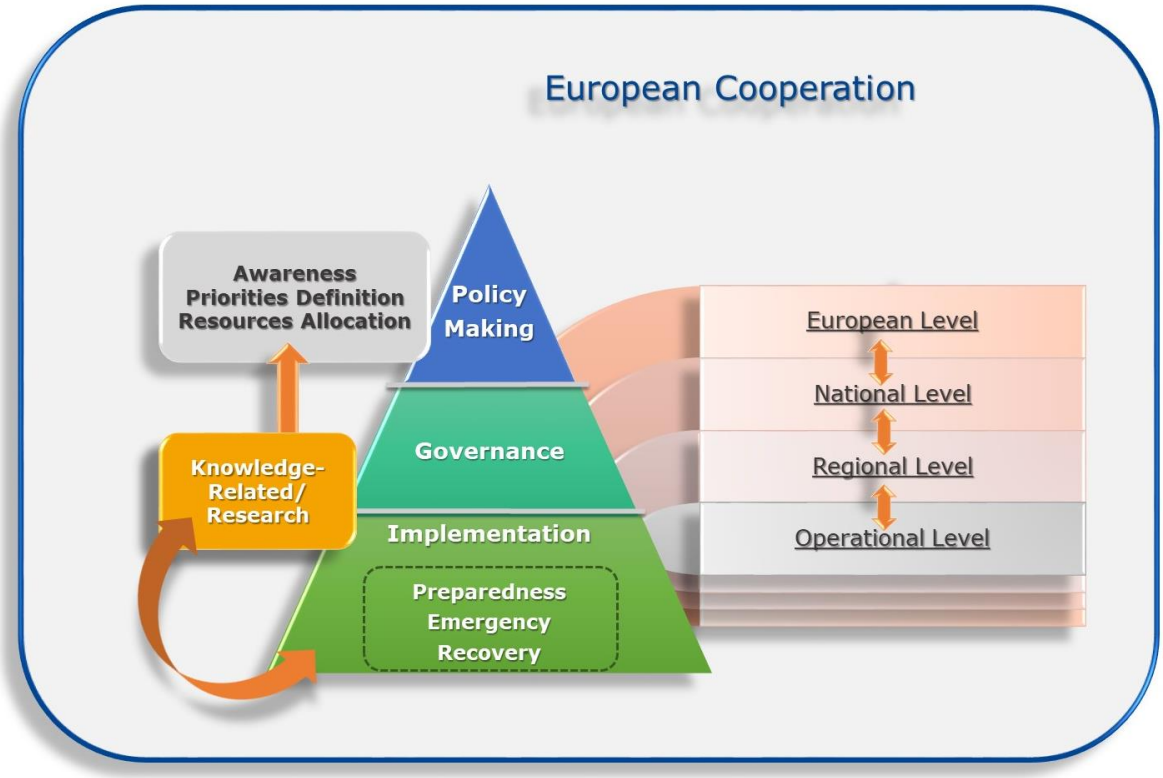
Cette étude a pris en considération plusieurs facteurs de risque agissant séparément ou en association entre eux. Ils sont liés aux menaces venant des catastrophes naturelles ou anthropiques (par ex.: les changements climatiques, la pollution de l'air, les inondations, les éboulements, les séismes, les éruptions volcaniques, les incendies, les conflits armés et les trafics illicites). Une attention spéciale a été accordée à l'impact des changements climatiques résultant de l'activité de l'homme. On a analysé l'intensité et la fréquence par lesquelles se produisent des phénomènes extrêmes et à évolution lente, entraînant la détérioration du patrimoine culturel (par ex.: la diminution et l'érosion de la surface à cause des précipitations atmosphériques, la bio-détérioration, la décohésion et la fracture à cause de la cristallisation de sels, l'élévation du niveau de la mer, la contrainte thermique, etc.).

Les principales leçons de cette étude

L'intégration du patrimoine culturel au sein des stratégies nationales visant la réduction des risques et des catastrophes, qu'ont développées les États membres de l'UE, est encore pénalisée par ce qui suit:

- **Le manque de coordination entre les diverses stratégies (européennes, nationales et régionales) des politiques de gestion des risques, dans la plupart des pays.**
- **Le décalage entre l'élaboration des politiques et leur application pratique.**
- **La faible priorité accordée au patrimoine culturel dans la planification de la gestion des risques.**
- **L'intégration non exhaustive des mesures relatives à la protection du patrimoine culturel, dans les stratégies de gestion des risques.**

Pour optimiser les synergies entre les niveaux politique, gouvernemental et opérationnel, en ce qui concerne la sensibilisation aux risques de catastrophe, il faut faire appel à une approche intégrée, comme l'illustre le diagramme ci-dessous:



Recommandations générales

Les résultats et les recommandations de l'étude visent à combler les lacunes qui affectent à présent l'élaboration des politiques et la direction gouvernance, l'application pratique et les niveaux d'intérêt et d'activité en termes de savoir et de recherche.

Leur présentation se fera conformément aux quatre priorités d'action de Sendai:

Priorité 1 — Comprendre les risques de catastrophe

Susciter une prise de conscience

Promouvoir des activités de dissémination visant toutes les parties prenantes (autorités publiques, au niveau européen, national et régional, les fonctionnaires et les propriétaires), pour leur permettre d'acquérir une connaissance approfondie de l'importance du patrimoine culturel et de l'exigence de le protéger contre tous les risques potentiels.

Soutenir les projets ciblés

Soutenir des programmes d'innovation et de recherche, au niveau communautaire et national, qui concernent toutes les catégories de risques et des essais pilotes au niveau local.

Priorité 2 — Renforcer la gouvernance des risques de catastrophe pour mieux les gérer

Promouvoir la coopération des autorités compétentes

Favoriser la coopération des autorités compétentes de chaque pays (par ex.: le ministère de la Culture, la Protection civile, les Sapeurs-pompiers, la Police), en ce qui concerne la planification, la préparation, la réaction lors de l'urgence et le sauvetage; et encourager la mise en place d'actions coordonnées entre les États membres de l'UE.

Soutenir la documentation structurelle

Aider à la mise en place de la documentation relative aux éléments structurels du patrimoine bâti, moyennant les outils informatiques, y compris la numérisation des archives et le balayage au laser sur le site. Ce qui va faciliter les procédures opérationnelles et garantir un accès aisé et rapide aux informations demandées. Il serait souhaitable d'effectuer ces activités avant que tout incident catastrophique ne se produise.

Priorité 3 — Investir dans la réduction de risques de catastrophe pour renforcer la résilience

Définir les priorités pour protéger les ressources du patrimoine culturel

Définir les priorités, en ce qui concerne les ressources du patrimoine culturel à sauver et faire en sorte que ces informations soient immédiatement disponibles.

Renforcer la formation

La formation de tous ceux qui seraient concernés par les conséquences potentielles de catastrophes est une condition préalable à appliquer à toutes les catégories de risques. Les autorités compétentes devraient mettre en place:

- *Des actions pour former des spécialistes.*
- *Des formations sur place pour les employées.*
- *Des programmes pour former le public et les enfants scolarisés.*

Priorité 4 — Renforcer l'état de préparation aux catastrophes pour intervenir de manière efficace et pour « mieux reconstruire » durant la phase de relèvement, de remise en état et de reconstruction

Élaborer des standards européens

Il faudrait élaborer des standards européens visant la protection de catégories spécifiques des ressources du patrimoine culturel contre les effets de types différents de catastrophes, à partir des recherches qu'on a déjà réalisées.

Favoriser l'application de services par satellite

Examiner et rechercher les grandes possibilités qu'offre le programme Copernicus, pour évaluer l'impact de catastrophes naturelles et anthropiques, des crises humanitaires et des conflicts pouvant affecter le secteur du patrimoine culturel. Ce qui se traduirait par une prévention et une géstion plus efficace et una facilitation des première alertes et des operations de récupération.

Supporter et encourager la recherche

Afin d'envisager des pratiques pertinentes et appropriées, en ce qui concerne l'intégration du patrimoine culturel dans les stratégies nationales pour réduire les risques de catastrophes, il sera nécessaire de supporter et d'encourager la recherche par rapport aux questions suivantes:

- Accorder la priorité aux paramètres de monitorage environnemental relatifs à l'impact sur le patrimoine.
- Collecter des données historiques pertinentes sur les ressources menacées
- Développer des systèmes d'alerte précoce et de modélisation de dommages, pour aider à la protection des ressources.
- Élaborer des cartes de localisation du patrimoine culturel européen exposé aux risques, faisant la liaison avec les cartes existantes des aléas naturels et anthropiques, ainsi que des risques potentiels.
- Créer des bases de données d'informations orientées mesure, sur les criticités du patrimoine culturel et les priorités d'intervention pour renforcer la résilience.
- Concevoir, standardiser et adopter des systèmes d'enregistrement du patrimoine endommagé par des catastrophes, à l'aide des systèmes existants.
- Déployer des efforts accrus pour programmer et mettre au point des mesures de relèvement, avant qu'un accident se produise.

Développer des méthodologies d'évaluation permettant de prendre en compte et d'intégrer l'impact financier des catastrophes, en considérant les valeurs matérielles et immatérielles du patrimoine.

Lacunes relevées et activités demandées

Cette étude a relevé les principales lacunes, alors qu'on ne prend pas en compte les questions relatives aux catastrophes naturelles et anthropiques pouvant affecter le patrimoine culturel. Beaucoup de ces lacunes ont été systématiquement repérées à plusieurs reprises, pour chacun des risques considérés.

Pour illustrer le diagramme ci-dessus, ces éléments sont tous envisagés ci-après par volets séparés et divisés dans les volets suivants: Élaboration des politiques, Gestion et mise en œuvre managériale, Politique/Management, Administration, Recherche/Savoir.

Élaboration des politiques

En termes de politique et de management, il est nécessaire de:

- Faire progresser la prise de conscience transnationale, quant au fait que le patrimoine culturel demande à être protégé contre une large gamme de risques multiples et potentiellement préjudiciables.
- Intégrer et généraliser davantage les exigences du patrimoine culturel dans les recherches financées, les programmes d'information et de cartographie déjà en cours.

- Développer et promouvoir des mesures et des stratégies à long terme concernant le patrimoine culturel, pour faire face aux suites des catastrophes naturelles et anthropiques.
- Améliorer la coopération pour harmoniser l'accessibilité aux lignes directrices stratégiques locales/régionales et nationales, ainsi qu'à la documentation réglementaire par delà la « barrière de la langue », lorsque les textes ne sont disponibles que dans la langue locale et non pas en anglais.
- Mettre en œuvre les amendements aux Eurocodes et aux autres standards pertinents permettant de prendre en compte les éléments physiques, ainsi que les valeurs culturelles et socio-économiques des ressources traditionnelles et historiques, quand on envisage des scénarios de catastrophes.
- Reconnaître que le défaut d'entretien et de travaux de réparation, entraînant comme conséquence la négligence et/ou l'abandon, pourrait résulter de l'absence de mesures d'incitation financière, y compris d'allègements fiscaux.
- Évaluer les pertes économiques que pourraient entraîner toutes les formes de dommage matériel.
- Financer des cours de formation continue pour les experts de toutes professions agissant dans le domaine du patrimoine bâti, couvrant toute la gamme des risques pertinents.

Gestion et mise en œuvre managériale

Il est nécessaire de:

- Promouvoir, créer et piloter une méthodologie de coordination efficace, pour tous les accidents potentiels liés aux catastrophes, y compris les accidents qui dépassent les frontières nationales.
- Améliorer considérablement la sensibilisation du public, quant aux questions liées à la gestion des risques de catastrophe, à travers des programmes de formation avisés.
- Axer la formation des fonctionnaires responsables sur les plans d'urgence et comment sur agir en conséquence.
- Numériser la documentation relative au patrimoine culturel et créer des documents de référence et d'archives électroniques immédiatement disponibles.
- Créer des critères et des techniques avisés pour définir les priorités et garantir la sécurité des ressources et des objets de valeur, dans une situation d'urgence.
- Assurer le monitorage des vulnérabilités, pour soutenir la planification préalable et aider aux procédures de secours, dans les situations d'urgence.

Applications pratiques et recherche/savoir

En ce qui concerne les exigences pratiques et la recherche liée au savoir, il est nécessaire de:

- Créer un inventaire exhaustif des ressources du patrimoine culturel, qu'une évaluation préalable a classés comme étant au risque de catastrophe.
- Développer une gestion des risques efficace de la stratégie des ressources culturelles, prenant réellement en compte le coût véritable des pertes et des dommages, tout comme l'évaluation de la nature non commerciale des valeurs liées au patrimoine culturel.

- Collecter et améliorer les données d'inspection et de diagnostic basées sur l'observation, pour définir une méthodologie intégrée permettant la modélisation complète de l'impact des catastrophes.
- Privilégier la compréhension des scénarios que caractérise un système complexe de risques multiples, dans les centres historiques urbains, les sites archéologiques et les paysages culturels, quant aux les conséquences des changements climatiques et d'autres éléments de risque.
- Créer et mettre au point un système efficace d'alerte précoce, tout spécialement conçu pour protéger le patrimoine culturel contre des situations de risques multiples et de catastrophes.
- Développer des données de conception quantitatives, des codes et des procédures appropriés, pour réduire les dommages indirects et fixer les priorités relatives aux actions de financement.
- Promouvoir, pour remédier à son absence, l'analyse préprogrammée et les mesures de prévention que demande le développement de plans efficaces, pour protéger le patrimoine culturel contre les catastrophes.
- Développer et promouvoir l'élaboration de documents d'information avant et après l'événement, se basant sur des résultats de recherches solides, pour améliorer la sensibilisation, à tous les niveaux, des parties concernées.

Introduction

In last years, considerable European resources have been committed to research and policy development, aiming at strengthening cultural heritage protection against the impact of natural and man-made disasters. The EU report "*Getting cultural heritage to work for Europe*"[11] clearly indicates that it is time to build on these achievements, making further steps in order to ensure the sustainable management and effective conservation of cultural heritage sites, structures and artefacts.
Disasters and catastrophes in consequence of natural hazards, anthropogenic effects and extreme climate change events pose risks to the physical conservation requirements of cultural heritage assets, their social, cultural, historic and artistic values, the safety of occupants and users, and to local employees whose economies are linked to tourism. In addition, urban expansion into coastal areas and flood plains, coupled with inappropriate building practices and overburdened infrastructure, increase the risks of putting enormous additional pressures on heritage sites, especially those in vulnerable urban locations. Climate change is also contributing to the increased intensity and frequency of hydro-meteorological events, resulting in damaging heavy rainfall, windstorms, heat waves and droughts.
The physical well being of cultural heritage, endangered by such impending disasters, can also be affected by inappropriate emergency and post-disaster actions, ill-conceived restoration and recovery phases. Significantly, this can result from a fundamental lack of adequate preparedness, before an emergency situation happens. The reasons are varied, but include the lack of understanding and funding, as well as bureaucratic barriers.
Research into adaptation strategies, methodologies and other remedial tools is urgently required to safeguard Europe's heritage from the continuous pressures it faces and their related decay-inducing consequences. Further concerted action, based on sound scientific study, analysis and promotion of results, is required to protect, strengthen, adapt and maximise on Europe's unique cultural patrimony.
Highlighted by the **European Agenda for Culture**[12], since 2007 **cultural heritage has been a priority for European cooperation on culture policy**, and is considered a **strategic resource for a sustainable Europe**[13], as stated in the **Council Conclusions of May 2014**. Being of value to society from a cultural, environmental, social and economic point of view, its sustainable management emerges as a strategic 21st century need.

Considering the unique, non-replaceable and non-interchangeable value of cultural heritage resources, the Council of the European Union requested the European Commission to conduct a study on "*Risk assessment and prevention for safeguarding cultural heritage from the effects of natural disasters and threats caused by human action*". Laying the foundation for the presented Study and its findings, this was occasioned in the framework of the **Work Plan for Culture (2015-2018)[14] - Priority area B cultural heritage.** The globally agreed **Sendai Framework for Disaster Risk Reduction 2015-2030** (Sendai Framework)[15], adopted by United Nations in 2015, has

[11] Getting cultural heritage to work for Europe. Report of the Horizon 2020 expert group on cultural heritage, 2015 ISBN: 978-92-79-46046-3. DOI: 10.2777/745666.
[12] Resolution of the Council of 16 November 2007 on a European Agenda for Culture (2007/C 287/01).
[13] Council conclusions of 21 May 2014 on cultural heritage as a strategic resource for a sustainable Europe (2014/C 183/08).
[14] Conclusions of the Council and of the Representatives of the Governments of the Member States, meeting within the Council, on a Work Plan for Culture (2015-2018) (2014/C 463/02)
[15] Adopted on 15 March 2015 at the third UN world conference on disaster risk reduction and adopted by the UN General Assembly on 3 June 2015 A/RES/69/283; http://www.unisdr.org/we/coordinate/sendai-framework

amongst its key priorities the need *'To protect or support the protection of cultural and collecting institutions and other sites of historical, cultural heritage and religious interest'* at national and local level.

On 17 June 2016, the European Commission published an **Action Plan on the Sendai Framework**[16], covering the 2015-2030 period. This plan calls for a more systematic disaster-risk-informed approach in EU policy making. One of the implementation priorities (Key Area 4) is on **the development of good practices on the integration of cultural heritage in the national disaster risk reduction strategies to be developed by EU Member States.**

The **overall objective of this Study is to contribute to achieving that intention** in addition to underpinning the Sendai Framework Action Plan Priority 4 "Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction".

In order to support and achieve these joint aims, **specific Study objectives** were accomplished by:

1) **Providing an overview** of the information available at EU and international level on risk assessment and prevention to safeguard cultural heritage from the effects of natural disasters and threats caused by human action (Chapter 2);

2) **Mapping the existing strategies** in all 28 Member States for disaster risk management of cultural heritage, with a focus on existing competence centres and tools, by survey and interviews to key experts (Chapter 3);

3) **Putting forward recommendations** on possible measures to improve the risk management of cultural heritage at European level (Chapter 1).

The Study's recommendations also aim to support the implementation of **Sendai Framework Action Plan Priority 4.** Their formulation is based on:

i) The outputs of the literature review of relevant studies and initiatives on risk management of cultural heritage at European and international level (See Chapter 2);

ii) The results of a survey targeting key actors in public and private research entities, policy-makers, international organizations and stakeholders operating on cultural heritage protection from all 28 Member States of the European Union (See Chapter 3).

The Study's detailed findings and recommendations also refer to the specific risks related to climate change, air pollution, flood, landslide, wind, earthquake, volcanic eruption, fire and armed conflict.

These recommendations have been reviewed and further developed, in order to reveal key identifiable gaps that require more focused attention and follow-up action by the full range of involved and interested parties (See Chapter 4).

[16] COMMISSION STAFF WORKING DOCUMENT Action Plan on the Sendai Framework for Disaster Risk Reduction 2015-2030 A disaster risk-informed approach for all EU policies SWD(2016)205 final/2, http://ec.europa.eu/echo/sites/echo-site/files/1_en_document_travail_service_part1_v2.pdf

1
Recommendations

1 Lessons learnt and overall recommendations

The new European Union Civil Protection Mechanism legislation[1], adopted in 2013, represents a breakthrough in disaster risk reduction in Europe. The legislation places a strong emphasis on building a culture of disaster prevention, with a particular focus on risk assessment and risk management planning[2]. In addition to that, the Sendai Framework for Disaster Risk Reduction 2015-2030[3] (Sendai Framework), has included the need to protect cultural heritage among its key priorities.

In spite of this significant step forward, the **data gathered and the suggestions of experts** clearly show that risk management policies in most of the EU countries have been adopted to a limited extent. Moreover, the Study provides evidence that the **explicit protection of cultural heritage is still inadequately addressed**, and the **strategies for its safeguard are not yet comprehensively integrated in National Plans**. Encouragingly, an improved political will to support and protect cultural heritage exists, even though the team encountered more unrealised proclamations than real and effective pragmatic measures.

One of the major identified problems lies in the fact that **knowledge of hazards and risks is not yet structurally integrated with cultural heritage protection measures.** Whilst non-structural measures are rather well developed, with a portfolio of prevention documents, emergency plans, and recommendations, the practical application of preventive structural measures is generally lacking.

The results clearly reveal that safeguarding cultural heritage from natural and man-made disasters **still suffers from the fact that cultural heritage is not fully considered, or integrated, as a risk management priority in emergency situations**.

Undoubtedly, the **resilience issue deserves greater attention and prominence in each of the seven targets and four priority action areas** of **the Sendai Framework.** Perversely, it is widely recognized that cultural heritage, being a substantial element of historic cities, towns and villages, plays an irreplaceable role in the resilience of historic settlements. Such settlements are also commonly understood as complex adaptive systems possessing a considerable capacity for resilience. But, the resilience phenomenon is still not effectively approached or even theoretically supported. Any progress in this direction must therefore be underpinned with serious and well-focused research that combines economic, social and physical resilience needs with reasonable conservation requirements and policies. Conservation and resilience need to be equally matched and balanced. Either a "resilience friendly conservation policy" or "conservation friendly resilience policy" needs to be established and promoted.

Due to socio-economic dimension of resilience, this requires dedicated research and the development of methodologies to better evaluate the financial and humanistic consequences of disasters impacting on the cultural heritage, taking into account its intangible values. In particular, co-operation with the insurance companies across Europe has not been sufficiently developed to help support resilience through private insurance contributions.

A further major concern **is the lack of a meaningful alignment in the various processes from policy making to practical application.** Undertaking effective risk

[1] Decision No 1313/2013/EU of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism (OJ L 347, 20.12.2013, p. 924–947)
[2] http://www.unisdr.org/files/37556_finalannualreporteurope2014web.pdf
[3] http://www.unisdr.org/we/coordinate/sendai-framework

management needs to be considered in a wider perspective, in accordance with the range and responsibilities of the various interested parties.

Such political, governmental and operational interests in the field of disaster awareness and risk aversion functions are summarised in the following diagrammatic structure (Figure 1.1):

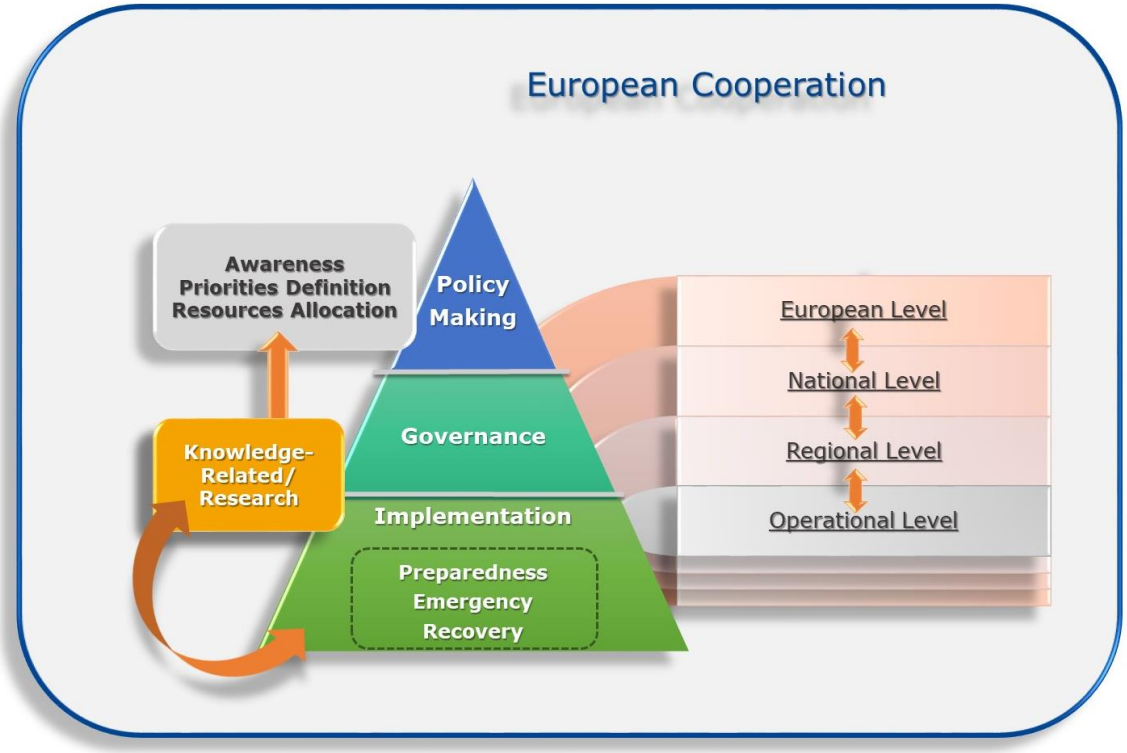


Figure 1.1 Diagrammatic flow of relevant data and information across political, governmental and operational interests to aid decision making in disaster awareness and risk aversion functions across all levels of involvement.

Where an episode occurs, a hierarchical structure and a strategy should already exist, so to pre-determine the actions that should be undertaken.

It is highly likely that the **majority of disasters affecting the built heritage will have immediate operational implications** involving safety considerations for the attending rescue services, operational crews, and owners. They should be operating on the basis of pre-planned practical programmes, based on adequate risk assessments, training and familiarisation techniques previously carried out. At this level, **feedback from the operational bodies is essential** in order to improve and refine the process. Appropriate information, data and experience will be required to deal more effectively with future incidents. In the normal course of events this material should be passed up through the operational line of command to be synthesised at regional level before being passed on to central government and further inform political direction, policy, legislation, standards and guidance. Such an information loop requires the creation and reporting of appropriate data, following an incident, on the circumstances and the effectiveness of actions taken preferably in a standardised format.

With adequate forethough, **appropriate measures** (preparedness, emergency, recovery) should also have been pre-considered and agreed between governmental departments and policy makers. Central government might pass the responsibility for

dealing with an incident down to regional and local authorities, depending on the repartition of competences in each Member State. Here adequate resources, both financial and human, need to be pre-determined and provided to deal with emerging circumstances.

At all levels, **European cooperation** is essential for strengthening response capacities to disasters of all actors involved and should be continuously boosted. The proposal for the creation of "rescEU"[4], a reserve of civil protection resources managed by the European Commission, represents a promising action in this direction.

The diagram also underlines **research as a key link in the chain** at all levels: increasing knowledge and awareness of the existing gaps, and the procedures to overcome them at European level and in the Member States, are fundamental prerequisites for the definition of priorities and the allocation of resources by decision makers.

Unfortunately, the Study confirms that **poor knowledge exists of the results of previous research in the field amongst state administrations and/or civil protection authorities and** points out that dissemination should be improved. Moreover, the **turning of research results into practice** and the **promotion of practical measures with direct applicability emerge as a priority**.

1.1 Objective of the Study and Methodology

The overall **objective of this Study is to contribute to the development of good practices to integrate cultural heritage into national disaster and risk reduction strategies developed by EU Member States.** Such an achievement is consistent with that indicated in the Sendai Framework Action Plan as key issue in the implementation of Priority 4 "Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction".

In order to achieve this goal, the following **specific Study objectives** were accomplished by:

1) **Providing an overview** of the information available at EU and international level on risk assessment and prevention to safeguard cultural heritage from the effects of natural disasters and threats caused by human action (Chapter 2);

2) **Mapping the existing strategies** in all 28 Member States for disaster risk management of cultural heritage, with a focus on existing competence centres and tools, by survey and interviews to key experts (Chapter 3);

3) **Putting forward recommendations** on possible measures to improve the risk management of cultural heritage at European level (this Chapter).

The Study recommendations primarily aim to undertake and support the implementation of the **Sendai Framework Action Plan Priority 4** as above, and their formulation is based on:

i) The outputs of the conducted literature review of relevant studies and initiatives on risk management of cultural heritage at European and international level (See Chapter 2);
ii) The results of the completed questionnaire directed to key actors in public and private research entities, policy-oriented international organizations,

[4] https://ec.europa.eu/commission/news/resceu-new-european-system-tackle-natural-disasters-2017-nov-23-0_en

and stakeholders operating on cultural heritage protection from all 28 Member States of the European Union (See Chapter 3).

The Study recommendations refer to different risks (climate change, air pollution, flood, landslide, wind, earthquake, volcanic eruption, fire and armed conflicts) and have been developed in order to address the identified gaps and are reported in Chapter 4 at different levels (political/managerial, governmental, knowledge-related/research).

General recommendations to safeguard the cultural heritage from natural and man-made disasters are aiming at overcoming existing gaps in the policy making and knowledge/research level. **Specific recommendations are suggested for each risk** and are directed to the different actors involved in the risk management process at European, National and Regional level, Operational Bodies and Owners. They are presented and structured in relation to the relevant stakeholders. Nevertheless, inevitably some repetitions do take place as, in a number of cases, the responsible stakeholders for each segment (research, education, projects, etc.) are interrelated.

1.2 General Recommendations

The following recommendations are framed in accordance with the Sendai Four Priorities for Action:

- Priority 1. Understanding disaster risk;
- Priority 2. Strengthening disaster risk governance to manage disaster risk;
- Priority 3. Investing in disaster risk reduction for resilience;
- Priority 4. Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction.

Policy Making

Developing and disseminating awareness

Regarding Priority 1, it is crucial that all decision makers (at European, national, regional and local level) and administrators in relevant authorities acquire an in-depth understanding of the importance of cultural heritage and the essential need for protecting it against all potential risks. Awareness should be raised, targeting all stakeholders (public authorities, at European, national and regional and local level, public officers and owners).

EU funding for specific projects

Supporting Priority 1, the continued EU support to relevant and related research/technical programmes is of great importance. It would be particularly relevant and informative to provide EU funding and scientific support to for the development of a pre-emergency pilot project at local level. Such projects should be initially of small-scale, for testing purpose, but an oversight programme should also drive a requirement to amalgamate and distil the individual results into meaningful guidance that could be disseminated to a wider audience of users, with follow-up assessment processes to determine and assess their applicability in operation.

Collaboration of competent authorities

Regarding Priority 2 the effective collaboration by each country's competent authority (e.g. Ministry of Culture, Civil Protection, Fire Dept., Police) for preparedness, emergency reaction and recovery is of great importance. For instance, in fostering the development of specific plans and coordinated action for the safe evacuation of culturally historic areas. Moreover, sharing information and knowledge between EU member

countries, in order to ensure the safe evacuation and transfer of equipment when dealing with different risks is a very significant issue.

Documentation

The documentation of structural aspects of built heritage is an effective measure in aiding their protection. In support of the Priority 2 the use of IT tools, such as the digitalization of archival records and on-site laser scanning, ensure easy access to required information, which is crucial for decision making during operational rescue procedures. Such activity should be carried out before any disaster incident occurring, providing core reference data against which damage can be fully assessed, should it take place. If an incident does take place first a post-disaster survey should provide a viable record to base any rehabilitation work. Interdisciplinary approaches should be developed, in order to interpret differences in resulting damage, in different areas of the same historical centre or asset, by pooling various specialists' interpretation, knowledge and understanding.

Stakeholder engagement

Regarding Priority 2, stakeholder/citizen involvement in all phases of disaster risk reduction process, accommodating their expectations and needs in the decision-making processes, is recommended.

Establishment of priorities for protecting cultural heritage asset

On Priority 3, in the event of a major emergency, rescuing all cultural heritage at risk (both movable and immovable) is likely to be impossible. For this reason, defining priorities before an event occurs is necessary to at least enable the rescue of the most important aspects/features. In order to prioritize such actions, monuments and heritage assets should be classified, based on their assessed vulnerability to potential risks and combined recognised value.

Enhancement of education

In support of Priority 3, the education of all parties interested in ameliorating the potential consequences of disasters affecting the cultural heritage is a primary prerequisite for all categories of risk. Various approaches are available:

Actions to educate specialists

The EU could encourage a greater understanding of the issues by supporting seminars and networks of collaborative postgraduate courses for specialists in different fields. The issue of Cultural Heritage Risk Assessment should not be solely conducted in theoretical terms; a connection between practical knowledge and its pragmatic implementation on the ground has to be achieved.

In-post training for employees

Supporting regular in-post staff training should be considered compulsory, with seminars and practical sessions providing information and understanding, and improving skills on how to deal with emergency situation occurring. These events should be pre-prepared to define the immediate actions that all employees should adopt in times of emergency. It is also beneficial to ensure that members of the action-taking task forces (e.g. Fire Department, Police, Red Cross etc.) regularly participate in readiness exercises and attend mandatory training seminars. Achieving familiarity of current operating conditions is essential to success.

Action taking programmes to educate the public

In addition, in further support of Priority 3, it is recommended that each country’s competent authorities introduce awareness raising seminars to educate the public about

the value of their historic heritage and its potential for economic development. It is also suggested that competent authorities (e.g. Civil Protection, Fire Dept., Police), organize preparedness seminars for citizen groups, assigning specific learning tasks to each participant. Related events should also inform school children, with the aim of developing an informed interest in the need to safeguard their cultural heritage.

Drafting European Standards

Pursuing Priority 4, the definition of European Standards for safeguarding specific categories of cultural heritage assets against the effects of different types of disaster should be promoted (covering buildings, sites, exhibits of museums, decorative elements, frescoes, mosaics, etc.). This should build upon research that has already taken place, capitalising on its findings.

Adoption of evacuation and recovery measures by cultural institutions

Concerning Priority 4, initiating and encouraging as many cultural institutions as possible to adopt evacuation and recovery measures for cultural heritage assets in emergency situations by looking at lessons learnt from previous historic incidents of good and bad practice is of great importance.

Foster the application of satellite services

In support of Priority 4, the use of the Copernicus Programme earth observation data and information for monitoring and assessing the potential impact of natural and anthropogenic disasters, humanitarian crises, and conflicts on cultural heritage and, consequently, enhancing prevention and management is reccomended.

EU funding for enhancement of research

Regarding Priority 4, there is a crucial need to assist research efforts to achieve a greater understanding of the:

- Assessment of structures;
- Intervention techniques (pre-emergency and post-emergency);
- Traditional materials, which are used extensively in historical structures, in addition to innovative materials (physico-chemically and mechanically compatible) and their application methods;
- Modelling of historical structures under several actions (seismic actions, wind actions, dynamic phenomena).

Combined, all of these aspects should be the subject of a comprehensive in-depth study that also incorporates the potential risks and impacts that could threaten the future viability of the cultural heritage.

Research level

In order to develop Sendai Priority 4, addressing appropriate and relevant practices on the integration of cultural heritage in the national disaster risk reduction strategies, it will be necessary to:

- Prioritise **monitoring** of **environmental** (climate and pollution) **parameters in relation to the heritage under threat** (building material, environmental context/exposure, tourism pressure, cultural and socio-economic value, general economic conditions vulnerability). Spatial and temporal solutions should be defined for each parameter, whether acting individually or in synergy.
- Gather **relevant historic data on the assets under threat** (e.g. construction phases, past interventions).

- Identify **critical and vulnerable elements of the assets** (chemical-physical, cultural, economic and social).
- Develop **early warning and damage modelling systems** to help safeguarding the assets.
- Develop **high spatial resolution maps of European cultural heritage at risk that link with and relate to existing maps of natural and man-made hazards and the potential risks.** Although this is a fundamental requirement for effective risk management, such integrated information is lacking over much of the European territory.
- Focus **research efforts on the creation of a comprehensive web-based GIS platform** aimed at providing relevant data for the hazard assessment and mapping of cultural heritage in its tangible and intangible manifestations. In the case of landslides such impacts should include for example geometrical characteristics (slope inclination, height, position, surface), geological and hydrological conditions, existing transport networks, and climatic data.
- Undertake the creation of **measure-oriented database information** on the criticalities of cultural heritage, on intervention priorities, and on how to strengthen resilience.
- Design and adopt **recording systems for disaster-damaged heritage** (indoor-outdoor), and standardise them with existing systems in order to avoid misunderstandings arising from incompatible approaches.
- Address enhanced **efforts on creating recovery measure preparedness.** Most of the current risk reduction plans are based on responses to emergency situations having already occurred and, generally, have not considered the benefits of preparing such plans **in advance** of an incident taking place.
- Direct **the research and development of assessments methodologies to consider and incorporate the financial impact of disasters**, taking into account intangible and tangible heritage values.
- Foster greater **pan-European cooperation between academia, research institutes, professional conservators, the rescue services, and all** levels of **public administration** (from Ministries to Local Authorities) that are involved in cultural heritage and civil protection matters.

1.3 Specific Recommendations

1.3.1 Climate Change

In spite of the widely recognized impact of climate change on monuments, archaeological sites and historic buildings, Cultural Heritage is only mentioned as one of the criteria for the definition of quality of life in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change on Impacts, Adaptation and Vulnerability (IPCC, 2014)[5].

Strategies for Safeguarding Archaeological Sites exposed to Climate Changes

The action taken to protect the Ħaġar Qim and Mnajdra Temples offers an example of how research can support the implementation of an appropriate strategy for safeguarding archaeological sites exposed to climate changes, especially those slowly occurring over time.

Dating to the period 3600 - 3200 BC both Temples are located on Malta's southern coast of high coastal cliffs. The complexes are registered on the UNESCO World Heritage List as being prehistoric monumental buildings representing unique architectural masterpieces.

Point of concern, the Temple's building material (globigerina limestone) was recognised as having continuously undergone chemical and physical deterioration due to the interaction with the environment. Over time, this created fracturing, surface disaggregation and severe structural damage.

With the aim of evaluating the impact of these environmental agents on the exposed monuments, and avoiding future deterioration scenarios by sheltering these assets from the elements, in 2005-2006 the "Environmental Monitoring at Hagar Qim and Mnajdra Temples" project (CT 2592/04) was carried out by Heritage Malta in collaboration with CNR-ISAC.

As a result, "temporary" shelters were proposed, purpose designed and installed to offer comprehensive protection against the impact of rain, solar radiation, wind erosion, marine aerosols, and temperature and relative humidity fluctuations, whilst also acknowledging the surrounding archaeological importance of the sites.

The shelters were constructed in 2008, under a EU co-funded project that provided almost two-thirds of the total cost. Since considered "temporary" they were designed to last for 25 to 30 years while research is on-going in order to identify more appropriate long-term alternative solutions.

Ħaġar Qim Park, photo taken in July 2016.

[5] IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment. Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

It is recommended that European Authorities be reminded about the:

- Value of the:
  - Development of a common legal framework for undertaking multi-hazard assessments and management in facing climate changes to be adopted in all Member States.
  - Adoption of focused inspection and diagnostics methodologies for supporting preparedness and recovery strategies standardised at European level, tailored for a sustainable management approach at National level in a changing environment.

It is recommended that National Authorities be reminded that:

- It is essential to integrate cultural heritage needs in the priority areas where risk from the consequences of climate change is recognised.
- The collection, analysis and synthesis of data associated with cultural heritage damage due to climate change is necessary to assist decision-makers in the implementation of effective strategies and procedures at national and regional level.
- Resources allocated to the development of methodologies for the efficient and effective early warning of climate change impacts (particularly extreme events) on the cultural heritage should be considered an investment rather than a cost. They contribute to safeguard cultural heritage, and consequently the related economy and safety of those involved (workers, operators, tourists, etc.),

It is recommended that Regional and local Authorities be reminded that:

- In order to promote the political, social, economic and cultural resilience of local communities facing the impact of climate:
  - Good practices and regional guidelines in Disaster Risk Reduction (DRR) and Management for Culture Heritage should be exchanged across all countries and regions (e.g. Historic Environment Scotland guides[6]).
  - Cultural institutions should be encouraged to adopt integrated climate monitoring with commonly agreed prioritised parameters.
- To enhance the social awareness on DRR:
  - Encourage municipalities, in collaboration with competent authorities (e.g. Civil Protection, Fire Dept., Police), to organize and deliver easily understood disaster preparedness seminars for citizens.
  - Improve civil education through specific programmes to inform school children.
  - Translate the results of academic research on climate change impact into pragmatic guidelines for stakeholders, including urban planners, conservation practitioners, cultural heritage owners and managers.
  - Enable the translation of academic research on climate change impact into pragmatic guidance for use by urban planners, the full range of conservation practitioners, cultural heritage owners and managers.

[6]https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=f24f7680-5d39-4c31-8e5c-a6a400a78b54

It is recommended that Operational Bodies and Owners be reminded that:

- Dealing with identified climate drivers causing deterioration is also dependant upon understanding the sensitivity of the materials under attack, and the environmental context in which the heritage asset is located.
- In the assessment process:
  - Establishing priorities in relation to the conservation needs of artefacts and assets should be considered in response to understanding the full effects of related climate change influences.
  - Any conservation actions also need to be considered in relation to prevalent climate conditions.
- Adopting continuous environmental monitoring of prioritised climatic parameters close to the historic asset, and/or planning specific checking of monthly or seasonal frequencies, can assist in defining risks in consequence of changing climatic effects.

1.3.2 Air Pollution changes

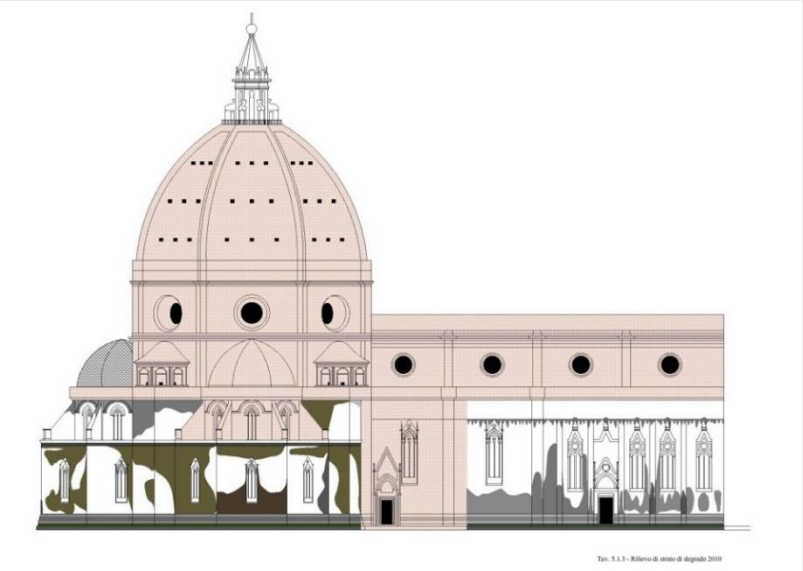
Building surfaces were often blackened by the effects of industrial processes of the past, but now different organic rich pollutants, emanating from vehicle exhausts, can cause buildings to visually take on "warmer tones" that are no less damaging. Additionally, the higher frequency of events of intense wind-driven rain can alter the distribution of damage on facades, and warmer climates can favour greater degrees of biological colonisation. The colour, distribution and effects of deposited materials on facades can have significant aesthetic and performance implications, requiring the adoption of new maintenance and conservation strategies to be pursued.

Blackening of Facades

The significant role of sulphur and anthropogenic carbon compounds has been previously widely demonstrated to the build-up of damaging surface soiling and black crust formation on historic buildings. The reaction of SO_2 with carbonate materials leads to the formation of gypsum (i.e. calcium sulphate dihydrate) through well-studied sulfation processes, whilst elemental carbon (EC) in aerosol form is recognised for its role in soiling, blackening, and creating aesthetic damage on external wall surfaces.

It should be noted that SO_2, while remaining a future damaging agent, has become a less significant issue over the last 20 years, due to the impact of beneficial EU environmental legislation. By contrast, understanding the effects of fine carbonaceous particles rich in organic compounds that are emitted by vehicular traffic is becoming an increasingly important factor in determining the future urban atmospheric quality. Such issues imply a change in building facade colour (particularly on those buildings constructed with a calcareous stone) that could appear more yellow-brownish in tone. These differences can arise from the oxidation processes in organic-rich facade deposits, and can be a result of the formation of compounds resembling organic humic substances linked to general biological action.

The colour change is currently particularly evident on the Santa Maria del Fiore Cathedral in Florence, where yellowing could well become of greater concern in the near future than blackening (Figure, see the areas designated in a military green colour on the left).



Soiling patterns estimated by photographs on the North side of Santa Maria del Fiore Cathedral, Florence (2010). The Military green and brown colours highlight areas covered by 1950. Pink areas not surveyed.

It is recommended that European Authorities be reminded about the:

- Need for the:
    - Adoption of strategies to reduce air pollution to achieve positive consequences for cultural heritage in urban areas (e.g. Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency as a tool of good practise).
    - Adoption of appropriate air quality thresholds relevant for the protection of cultural heritage, standardized at European level, and tailored for local level needs.

It is recommended that National Authorities be reminded that:

- It is essential to integrate cultural heritage in the priority sectors recognised to be affected by air pollution.
- To safeguard cultural heritage and, consequently, the related economy and safety of those involved (workers, operators, tourists, etc.), resources allocated to the following topics should be considered an investment:
    - The development of methodologies for the continuous monitoring of the deterioration of architectural surfaces due to the impact of pollution.
    - The implementation of modelling to quantify damage, and to assess vulnerability indicators.
- The collection of data on pollution impact on heritage to support the decision-making process at both national and regional level is necessary to efficiently address and prepare strategies for both legislative protection and conservation requirements.

It is recommended that Regional and local Authorities be reminded that:

- Initiate and encourage as many cultural institutions as possible to adopt an integrated approach to the environmental monitoring of recognised damaging pollutants as a tool for preventive conservation.
- Adopt mitigating actions through regulations at regional and local level that are aimed towards the significant reduction of harmful pollutants.
- Effect urban planning to encourage sustainable mobility that also considers the impact of air pollution on cultural heritage assets.
- Promote actions aimed at reducing the exposure of cultural heritage to anthropogenic pollutants (such as gases, and soluble and carbon fractions of particulate matter).
- Promote sustainable mobility initiatives for citizens and the tourism sector (e.g. by providing and facilitating the use of bicycles, electrical powered transport, improved public transport, and a greater realisation of pedestrianized zones and cycle lanes, etc.).
- Plan the creation and modification of public green spaces in urban areas to include an indigenous range of flora and species with low pollen production and Biogenic Volatile Organic Compound (BVOC) emissions.
- Develop management strategies to accommodate growth in tourism whilst controlling pressures on surrounding areas, and on access routes to cultural assets, that also have the aim of reducing atmospheric particle re-suspension.
- Enhance social awareness of the effects of air pollution on cultural heritage assets by:

- Improving civil education through specific programmes to inform school children.
- Fostering an accessible and free dissemination of relevant and easily understood information in order to reach a wider public.
- Enabling the translation of academic researched results on pollution into pragmatic guidance for use by urban planners, the full range of conservation practitioners, cultural heritage owners and managers.

It is recommended that Operational Bodies and Owners be reminded that:

- Dealing with identified pollutants causing deterioration is also fundamentally dependant upon understanding the sensitivity of the materials under attack, and the environmental context in which the heritage asset is located.
- Seasonal monitoring of aerosol (including bio-aerosol) compositions and concentrations in the proximity of monuments and heritage assets should be adopted as the appropriate methodological approach in any environmental assessment of the cultural heritage.
- In the assessment process:
  - Establishing priorities in relation to the conservation needs of artefacts and assets should be considered in response to understanding any related changes in polluting contaminants.
- Defining cultural heritage risks from the impact of pollutants allows managers to determine investment and funding priorities for relevant preservation actions to reduce the causes.

1.3.3 Flood and Landslide

Floods are of considerable concern to high level and local governing authorities worldwide, and there is extensive documentation supporting preventive, operational and resilience measures aimed at the reduction and mitigation of loss and damage caused as a result. Even though cultural heritage suffers significantly during flood events, and its loss and damage substantially influences resilience processes and characteristics, it is still largely considered a marginal issue.

Even though the EU Flood Directive and adoption of the Sendai Framework for Disaster Risk Reduction gives the strongest political support to the protection of cultural heritage against flood disasters, there is an undeniable need to develop maps of the European cultural heritage stock at risk that, critically, must be related to existing maps of natural and man-made hazards and potential risks. Such information is lacking over most of the European territory, though it is a fundamental requirement for establishing risk management strategies and activities.

Referencing the coordinates of cultural heritage assets is crucial for an effective application of the Emergency Management Service (EMS). Furthermore, a description of the type and condition of the cultural heritage asset must support any graphical representation. This requirement should be added to the EU Flood Directive. The European remote sensing and global positioning systems should also be exploited to monitor necessary data for modelling adverse situations and for evaluating the conditions that trigger the release of an early warning. Together with *in-situ* monitoring, this combination of supporting information will substantially improve the operability of preventive and operational measures in Europe.

Therefore, as additional work following this Study, it is recommended that future questionnaires on measures adopted in individual EU countries, include questions focused on implementation of the Flood Directive from a cultural heritage point of view. In doing so respondents should take into account trans-boundary river catchments that do not fit the boundaries of individual states, Figure 1.2. The questions should involve establishing the degree of the cultural heritage stock at risk, leading to the creation of hazard and risk maps with distinctly identified and marked locations of cultural heritage assets, and where the map legend content and accompanying information on the cultural heritage can be explicitly read together with the necessity of preventive and/or protective measures.

Landslides and similar phenomena (e.g. avalanches, mud flows, debris flows, rock falls) can also cause a major loss of historic assets, objects and the architectural heritage. Such events can affect large areas, and resulting damage is mostly irreparable. The object or building can be dislocated from its original position, severely distorted and, in many cases, partly if not totally demolished. Landslides frequently accompany floods, having the same triggering mechanism in consequence of heavy rainfall.

Earthquakes are the second major cause of landslides, with additional important triggering factors such as erosion (e.g., by river or sea), and human activity (excavations at the bottom or surcharge at the top of a slope).

Landslides occur with a very wide range of velocities. Unlike other natural disasters, such as flood that can occur rapidly and without warning, some landslide phenomena are slow and can happen over a period of many years. Such forms of landslides can be destructive although there is more available time for initiating emergency actions. From the territorial point of view, landslide hazards are widespread throughout Europe, although their consequential threats and impacts are local and generally occur in predictable areas.

Figure 1.2 There are 69 trans-boundary catchments in Europe, with significant differences between the MSs concerning the proportion of land area that is part of a trans-boundary catchment. This map is a product of the Transboundary Freshwater Dispute Database, Department of Geosciences, Oregon State University. Additional information about the TFDD can be found at: http://www.transboundarywaters.orst.edu. The map is reproduced from the STARFLOOD website.

It is recommended that European Authorities be reminded about the:

- Lack of detailed knowledge of cultural heritage in danger of loss due to the effect of flood and landslides.
- Lack of detailed knowledge and data regarding what is being lost due to the effects of flood and landslides.
- Measures focused on flood are developed by the majority of EU countries while those for landslide only by few.

It is recommended that National Authorities be reminded that:

- Recent major disasters show that early rectification of identified deficiencies on cultural heritage assets is the most effective measure reducing its damage or loss.
- Relevant information can be found in the analysis of flood and landslide incidents.
- Responsibility (administrative, financial, organisational, insurance) for the flood and landslide protection of cultural heritage assets should be clarified in regulations.
- Landslides are so devastating that preventive measures are either extremely expensive or ineffective, (usually both). Early warning – EMS supported – and evacuation or strengthening is recommended.
- In the case of flood, protection barriers (temporary or permanent or combined) are capable of protecting large territories with cultural heritage assets (historic settlements), however, there are some negative implications concerning the cultural heritage context, e.g. a settlement and its river.

It is recommended that Regional and local Authorities be reminded that:

- Securing flood and landslide protection measures requires all involved to also understand what constitutes cultural heritage historic value and significance.
- More attention should be paid to non-structural measures and incentives that may generate and support structural interventions, along with a mobilization of greater and distributed public resources. Such measures include a wide variety of instruments from guidelines, mobile applications, training and awareness raising, to insurance programmes.
- The structural measures require more concentrated and substantial financial resources. However, they have important economic and social impact, but an assessment of these impacts, and the relevant cultural heritage data and its inherent value, are not systematically collected.
- Centrally provided pools of post-disaster protective equipment for preserving residual values and for preventing further collapsing should be accumulated.
- Providing building owners with guidelines and remotely accessible tools supporting regular maintenance and early repair of deficiencies will help to substantially reduce the extent of damage.
- After the disaster, partial as well as total restoration or reconstruction work should preferably be carried out, with the same materials and construction technologies as the original as far as possible from the sustainability point of view.
- Risk analysis of historic buildings and cultural assets should analyse, describe and protect their special characteristics.

It is recommended that Operational Bodies and Owners be reminded that:

- Simple compliance with current legislation will not sufficiently protect buildings.
- More can be achieved in a pre-planned risk analysis and preventative approach to ameliorate the consequences of a flood or landslide incident from occurring, by involving the production of:
    - A Maintenance Handbook.
    - A Risk Management Plan.
    - Appropriate Insurance coverage.
    - Staff and occupancy training.
    - Additional achievable practical measures.

1.3.4 Wind Risk

The damaging effects from wind is now considered a serious threat and risk, leading to the loss of life, property, and infrastructure as a result of partial structural damage, collapse or flying debris. Although the risk of damage to historic buildings in Europe (and worldwide) due to wind and driven rain is well documented, the full scale of the consequences has not yet been fully assessed or analysed.

In addressing this issue it is necessary to coordinate various communities to serve as inter-agency coordinators. With a remit to establish links with NGO's and international organizations, including UN agencies, there is a need to empower them with the responsibility to serve as a bridge between policy makers and those responsible for carrying out risk reduction activities at the local community level.

It can also be considered that developed wind engineering technologies could be showcased in the disaster risk reduction marketplace. Such a link could promote specialised practical equipment to potential users and partners that could be re-tooled to meet the specialised needs of particular regions by incorporating local building and land-use practices.

Figure 1.3 World Heritage City of Telč (CZ), effect after a local tornado in July 2013

It is recommended that European Authorities be reminded about the:

- Lack of detailed analysis about the property damage related to historic structures caused by storms and wind.
- Measures focused on flood are developed in the majority of EU countries, but only few of them address the consequences of windstorm.

It is recommended that National Authorities be reminded that:

- Accessible detailed database of wind speed records should be maintained.
- Relevant wind codes should incorporate the effects on building loads and design within urban areas.
- A knowledge database of relevant specialist skills and examples of good and poor practise be created, maintained, and updated regularly.

- The need for sustainable design in response to climate change may shift the engineering focus from damaging winds only to the wider range of wind speeds, thus requiring new engineering concepts and guidelines.
- Protection against strong winds could require modification of building standards also with respect to the building details and protection concepts and shapes.

It is recommended that Regional and local Authorities be reminded that heavy *windstorm warning systems should be adopted to initiate relevant protection measures.*

It is recommended that Operational Bodies and Owners should be reminded that:

- More can be achieved in a pre-planned risk analysis and preventative approach to ameliorate the consequences of wind damage through the formation of a Damage Limitation Plan.
- The Appropriate Insurance coverage is required to assist in the preservation of the cultural value of historic buildings.

1.3.5 Earthquake and Volcanic eruption

Unfortunately, for various reasons (financial, gap of knowledge, negligence, etc.), it is a common occurrence that the reinforcement of heritage structures is only applied after an earthquake occurs. Immediately after an earthquake incident, emergency mechanisms are primarily mobilized to safeguard human lives -as they should be- and then to move on to preserve the remaining cultural heritage assets. Thus, pre-paredness and pre-event prevention devices are the main deficiencies in this area of risk. With regard to volcanic eruption, in spite of a high concentration of World Heritage sites in risk prone areas (Southern Europe), few studies have been conducted to date in relation to the protection of cultural heritage in such events.

Earthquake at the village of Vrissa (Greece), 2017

The village of Vrissa in southern Lesvos, Greece, has been a residential area since antiquity. Its architectural uniqueness, with features of neoclassicism and popular art, differentiates it from other historical centres on the island. Traditional stone masonry constructions (one or two-storeys with tile roofs) are the most common structures. The strong earthquake of M_w 6.3 that hit on 12 June 2017 was devastating, resulting in the loss of one life and extensive damage of the village structure.

Almost no preparatory measures were in place prior to the event. Unfortunately, the anti-seismic provision was only applied to a limited number of buildings, where some effective restoration works (e.g. connection of walls with steel tie rods) prevented serious damages. Lack of preparedness proved to be the most significant deficiency.

Regarding emergency actions, the competent authorities reacted fast and in a well-organized and coordinated manner. Specialized teams of engineers arrived immediately after the incident in order to inspect buildings and to evaluate damage caused by the recent incident. The historical centre of 800 inhabitants had to be evacuated.

Recovery is an ongoing and demanding process, and many factors are still pending:

- Decrepit buildings, which pose an immediate risk to public safety, need to be handled first, and demolitions have to be avoided, unless there is no alternative solution.
- Repairs on buildings need to be conducted on the basis of relevant technical specifications and not arbitrarily.
- Financial incentives need to be offered to private owners in order to help repair their properties. It is perceived that the Greek state may be willing to assist in the restoration efforts to avoid desertion.

The experience from observations of failures and their causes can be of considerable importance in guiding the future reinforcement of earthquake damaged buildings where the main failures are attributed to: structural defects; poor repairs following previous earthquakes (1845, 1867, 1981-1983); unsuccessful interventions, and the lack of maintenance as a result of abandonment.

It is recommended that European Authorities be reminded about the:

- Need for awareness of the importance of protecting cultural heritage from geological hazards.
- Need for improved dissemination of information on the risks due to earthquake and volcanic eruption that threaten the protection of Europe's cultural heritage.
- Need of EU funding for the enhancement of research and education in this field.

It is recommended that National Authorities be reminded that:

- EU funding for the enhancement of education on sismic and volcanic risk is fundamental, particularly in postgraduate courses for:
  - Civil engineers for an in-depth understanding of cultural heritage issues, the mechanical behaviour of traditional and innovative materials, and structural typologies.
  - Architects (and archaeologists to a degree) for:

i. Raising awareness about the value of "human settlements," through collating statistics of events in damaged historical centres from sismic and volcanic activity.

ii. Understanding simplified mechanics of what is "formally achievable" under the term "mechanically durable." Courses should be organized to strengthen an interdisciplinary approach.

- Pilot studies of large structural units (museums housed in monumental buildings, modern museums, historical towers, churches, bridges, etc.) should be promoted with the aim of performing works on them more effectively (from a structural and economic viewpoint).
- A hierarchical multiple-factor classification of monuments based on uniqueness, history/emblematic value, congregation areas, scarcity of structural materials, housing of heritage objects, etc. would help assist in determining priorities, intervention decision making, and the allocation of resources in EU programmes.
- Specific guidelines and standards for the restoration of privately owned buildings should be formulated by competent authorities.

It is recommended that Regional and local Authorities be reminded about the:

- Need for the enhancement of education, specifically:
  - Actions to educate engineers: Municipalities and technical associations could introduce local seminars to provide guidelines for handling specific works. As each region requires different technical needs, speakers with an understanding of the area's unique characteristics would be beneficial.
  - In-job training for employees in positions of responsibility: Compulsory training and practise drills to provide integrated emergency planning information, and guidance on the use of specialised equipment, should explicitly define employee duties in case of an earthquake. Members of the action-taking task forces should also be involved.
  - Action-taking programmes to educate the public: Collaborating Ministries and Municipalities should introduce mandatory readiness exercise seminars to educate the public, and especially children, about the value of cultural heritage and, in conjunction with competent authorities organize earthquake preparedness seminars for citizen groups.

- Need of municipal pre-earthquake inspection of cultural heritage assets: Technical departments should employ professional staff specialised in conservation and restoration techniques. Inspections and condition assessments should be conducted before earthquakes occur, whilst also pre-identifying safe public refuge areas for use during an event. In the case of abandoned or decrepit buildings, contact should be made with owners to explain the need for remedial works and to outline any available incentives.
- Need for regular maintenance of fire-extinguishing devices as earthquakes can commonly result in the occurrence of a fire. Consequently, all active and passive protection measures should be maintained in excellent condition.

It is recommended that Operational Bodies and Owners be reminded that:

- The installation of a network of accelerometers at specific points on major cultural assets is an important way of recording seismic action and in helping to determine a relevant response to an event.
- Seismic isolation might be proposed as a solution where reinforcement is impossible to comply with present-day building codes.
- A funded pre-event detailed digital/photographic survey record of cultural assets would allow for a greater degree of reconstruction after an earthquake.
- Additional funding will be required to ensure a sufficient number of skilled employees are available to create and complete digital database material.
- Earthquake resistance evaluation of cultural assets where a high number of occupants can exist and be at risk (e.g. churches, museums) should be systematic, mandatory and a prerequisite for approval in their operation.
- In such circumstances detailed layout information should be posted clearly indicating escape exits, the location of water flow valves and, electric power switches, ventilation, air conditioning etc.
- With due regard to security requirements, record sheets for earthquake-damaged cultural assets and collections should be prepared indicating the location of the most important and valuable items.

1.3.6 Fire Risk

In addition to the growing serious concerns over the loss life, the number, authenticity and quality of European historic buildings and their contents is now also recognised as being steadily eroded through the effects of fire. But the full extent of this, and the actual number of lives lost, across Europe remains unknown.

Library Fire: University of Lyon (France), 12 June 1999

Founded in 1866, the library possessed some 450,000 books and historically important publications. A large proportion of the collection, estimated at 350,000 items, were destroyed. This included all periodicals from the 19th and 20th centuries, in addition to the basic collections required for the Humanities and Law programmes. The incident caused significant disruption to the students and the university.

In addition to the books, the upper reaches of the building interior and the roof were totally destroyed, with associated water damage to the rest of the underlying structure due to fire fighting operations.
The investigation into the cause of the fire suspected arson, as traces of hydrocarbons and their spontaneous combustion were subsequently discovered.

It is recommended that European Authorities be reminded about the:

- Lack of detailed knowledge and data regarding how many cultural assets and lives are being lost to the effects of fire across Europe.
- Need for an integrated universal approach to address the issues.

It is recommended that National Authorities be reminded that:

- Relevant information can be found in the analysis of near-miss and actual fire incidents.
- Responsibility for the fire protection of historic buildings should be clarified in regulations.

It is recommended that Regional and local Authorities be reminded that:

- Securing full fire protection measures requires all involved to understand what constitutes historic value and significance.

- Centrally provided pools of post-disaster protective equipment for preserving residual values and for preventing further collapsing should be accumulated.
- Working with others could reduce the number of abandoned or vacant historic buildings, at specific risk from arson and to help ensure renovation or development work takes into account their historic nature.
- Affording greater powers to enforcing building owners to carry out renovation work could ensure empty buildings at risk from fire are returned to the market place.
- Partial, as well as total reconstruction work, should preferably be carried out with the same materials and construction technologies as the original.
- Fire Risk analysis of historic buildings should describe, analyse and promote their special characteristics, to specifically explore their potential weakness to fire-spread through lack of compartmentation, interlinked voids and spaces.

It is recommended that Operational Bodies and Owners be reminded that:

- Simple compliance with current legislation will not sufficiently protect their buildings.
- More can be achieved in a pre-planned risk analysis and preventative approach to ameliorate the consequences of a fire incident from occurring, involving the production of:
    - A Fire Safety Handbook incorporating a Fire Safety Log.
    - A Damage Limitation Plan.
    - Appropriate Insurance coverage.
    - Staff and occupancy training.
    - Additional achievable practical measures.

1.3.7 Armed Conflicts and Terrorism

Contrary to natural disasters such as flood and fire, the risk to cultural assets through man-made disasters like armed conflicts, terrorism or environmental accidents in Europe are regarded as lower; however, these man-made disasters cause considerable dangers too. On the one hand, the risk exposure is more dynamic and more often subject to rapid changes (depending on the political situation) and, on the other, the type of danger makes it difficult to implement risk-mitigating techniques, especially as these events are characterised by a target-oriented approach.

Figure 1.4 World Heritage Property "Ancient City of Aleppo" (Syrian Arab Republic)[7]

It is recommended that European Authorities be reminded about that:

- Although the risk is regarded as low, armed conflicts and terrorism cause real threats to cultural property and assets.
- Consequently, the development of long-term concepts and strategies is necessary.
- Despite different responsibilities and methodological approaches, synergy-effects in the field of risk-assessment and mitigation can be identified.
- At international level all efforts should be embraced to promote the acceptance of a legal framework for the protection of cultural heritage assets, especially where no assessment of clear responsibility is ascertainable by international courts, as it is the case for war activity contractors.

It is recommended that National Authorities be reminded that:

- Contrary to the assessment of risks and the implementation of protection-instruments in case of natural disasters, armed conflicts and terrorism are subject of other security, military and police-related authorities.
- There is need to establish or to develop civil-military cooperation.
- With reference to the framework of civil-military cooperation, a revision of the legal framework has to be considered.

[7] http://germancenter.net/wp-content/uploads/2016/04/aleppo-syria-destruction06.jpg

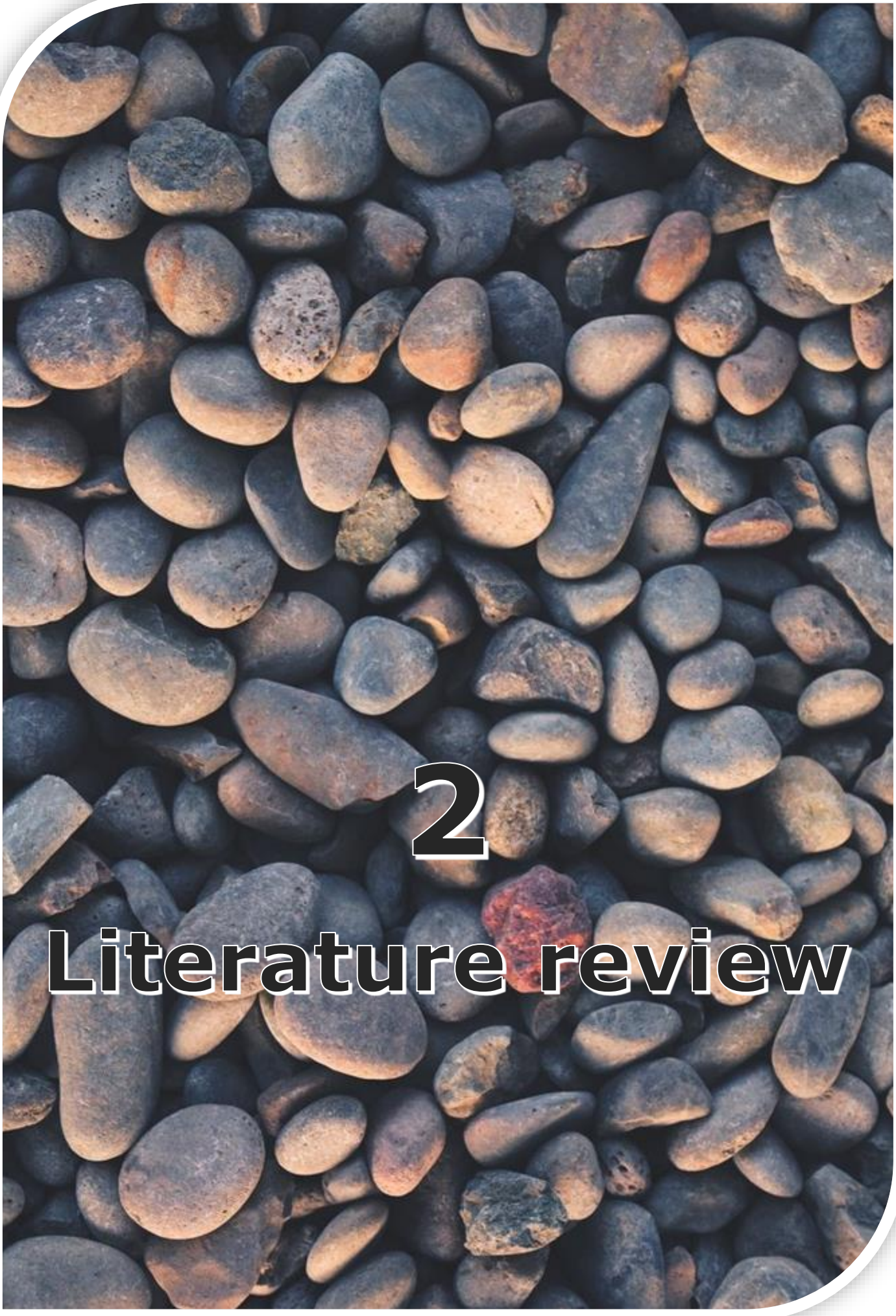
- The implementation of the stipulations regarding the Enhanced Protection, as laid down in the Second Protocol 1999, can serve as a best-practise example of civil-military cooperation.

It is recommended that Regional and local Authorities be reminded that:

- Preparatory measures in civil-military cooperation have to be undertaken on a local and regional level.
- The coordination between civil and military forces should be ensured through coordination centres.
- On-site knowledge and local experience are crucial for the implementation of protection-measures.
- The creation of local awareness constitutes one of the key-elements to increase the responsibility of indigenous stakeholders.
- The cooperation of civil and military forces has to be established or improved through joint training exercises at a local level.
- Information on the necessity of civil-military cooperation in the field of cultural property-protection has to be initiated at a local level in schools; consequently, the curricula should be amended to incorporate this.

It is recommended that Owners be reminded that:

- They should report irregularities concerning possible terrorism-activities to the relevant authorities.
- They should contribute to the efforts of the civil and military forces by providing much needed local information and knowledge.
- They should ensure adequate records of their ownership and of their assets preferably certified and digitalised.



2

Literature review

2 Literature review and existing initiatives at EU and international level

This chapter is based on the work conducted within Task 1 – Literature review and exiting initiatives at EU and international level. This Task, primarily based on a State-of-the-Art approach, reviewed current knowledge on the risk management of cultural heritage at European and international level including published and "grey" literature and reports, institutional guidelines and recommendations, European Union, international and national documents derived from relevant studies, research projects, initiatives and programmes, including EU-funded projects and coordination activities.

Specifically, the approach adopted aimed at the realization of a state of art concerning:

- Assessment of the impact of natural and man-made disasters on cultural heritage.
- Monitoring and early warning system of natural and man-made disasters.
- Resilience strengthening and risk management.
- Training and dissemination actions.

In addition, the following criteria drove the selection of relevant studies and initiatives to be reviewed:

- **Definition of cultural heritage** based on the broader aspect defined by the Council Conclusions of May 2014 (2014/C 183/08)[1]: *"consists of the resources inherited from the past in all forms and aspects - tangible, intangible and digital (born digital and digitized), including monuments, sites, landscapes, skills, practices, knowledge and expressions of human creativity, as well as collections conserved and managed by public and private bodies such as museums, libraries and archives. It originates from the interaction between people and places through time and it is constantly evolving."*
- **Cultural heritage categories**. Built environment (buildings, townscapes, archaeological remains), natural environment (rural landscapes, coasts and shorelines, agricultural heritage) and artefacts (books & documents, objects, pictures) were considered, with major focus on tangible heritage assets, such as monumental complexes, archaeological sites and cultural landscapes in remote/urban/coastal areas.
- **Risks factors.** Diverse risk factors were taken into consideration, acting individually and in combination, linked to threats caused by natural and man-made disasters (e.g., climate change, air pollution, flood, landslide, earthquake, volcanic eruptions, fire, armed conflicts and illicit trafficking). Special attention was also given to the impact of climate change as a consequence of human activity in changing the intensity and frequency of the occurrence of slow and extreme events damaging cultural heritage (e.g. surface recession and erosion by precipitation, biodeterioration, decohesion and fracturing due to salt crystallization, sea level rise, thermal stress, etc.).
- **Geographical dimension and spatial scale** of the addressed challenges (local, regional, national, transnational, European and international level).
- **Developed general and large impact**, namely cross-border risk management measures and supporting tools, e.g. insurance programmes, educational programmes, prepared structural and non-structural measures in heritage sites and territories.

[1] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014XG0614(08)&from=EN

- **Time scale of the event and of the related impact**, from the point of view of preparedness measures, actions during emergency and recovery measures for building resilience to disasters.

Initiatives, research and innovation projects performed at European level were the primary scientific reference of the Study with a focus on projects dealing with the safeguarding of cultural heritage, but also many other projects related to effects of natural disasters and of threats caused by human action, summarized in Figure 2.1

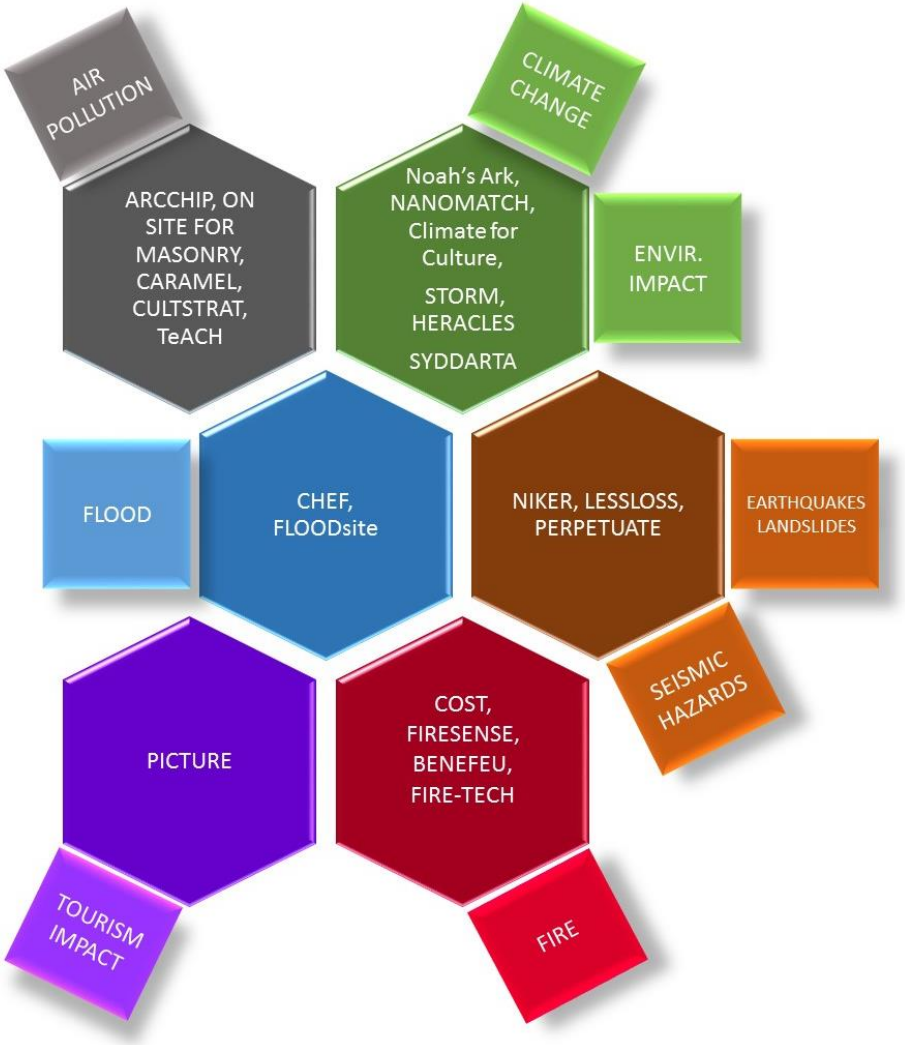


Figure 2.1 Selection of funded projects on natural and man-made disasters relevant to the Study in object.

In the ensuing sub-chapters funded projects at European, National and Regional level have been mentioned for the different risks. In ANNEX A, these and other projects, which can be capitalized upon for cultural heritage interests, are listed.

Finally, it has to be mentioned that the websites cited in the following text were accessed during the Study period, and verified in December 2017.

2.1 Climate Change

Introduction to climate changes threats and protection

The Intergovernmental Panel on Climate Change (**IPCC**) defined in the Fourth Assessment Report (IPCC, 2007) the climate change, as follows:

> "Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. See also Climate variability; Detection and Attribution."

Therefore, natural and man-made disasters can be due or influenced by climate change, which can affect several sectors including cultural heritage. For that reason, the IPCC in the Fifth Assessment Report mentioned for the first time the "Cultural Heritage" issue, specifically in WG3's, Section 3.4.3 *Wellbeing*: "Most policy concerned with climate change ultimately aims at making the world better for people to live in. That is to say, it aims to promote people's wellbeing. A person's wellbeing, as the term is used here, considers everything that is good or bad for the person — all aspects that contribute to making their life go well or badly. [...] In the context of climate change, many different metrics of value are intended to measure specific components of wellbeing: amongst them are the numbers of individuals at risk from hunger, infectious diseases, coastal flooding, or water scarcity. These metrics may be combined to create a more general measure. Schneider et al. (2000) advocates the use of a suite of five metrics: (1) monetary loss, (2) loss of life, (3) quality of life (taking account of forced migration, conflict over resources, cultural diversity, and **loss of cultural heritage sites**), (4) species or biodiversity loss, and (5) distribution and equity" (IPCC, 2014).

In order to analyse what the possible consequences are, the importance of understanding how climate change can impact on our historical, cultural and natural heritage including landscape, is a cutting-edge issue. Here, the European Commission, and other international and national institutions are increasingly undertaking related research and several communities and platforms have been recently developed on the topic (Climate Adapt and Disaster Risk Management Knowledge Centre - DRMKC, Partnership for Environment and Disaster Risk Reduction – PEDRR). Indeed, several regulations, laws and strategies have been released over recent decades, that consider the effects of climate change on cultural heritage.

In relation to the EU research programmes, it should be mentionated that FP7 research focused on climate impacts assessment on heritage sites, new orientations in H2020 Societal Challenge focus on how to implement tools for mitigating climate change impacts. H2020 projects are therefore solution-oriented.

Assessment of the impact, monitoring and early warning system related to climate effects on cultural heritage

Illustrated below the first two **EU funded Projects** concerned with the assessment of past and future climate change impacts (i.e. both risk and damage assessment) of on cultural heritage sites, cultural landscapes, built heritage and indoor collections of objects, should be considered as pioneer milestones in this field.

Specifically, FP6 Noah's Ark Project (2004-2007), produced a **Vulnerability Atlas and Guidelines** for Cultural Heritage protection towards climate change for the first time (Sabbioni et al., 2010; Bonazza et al., 2009a, b). Noah's Ark coupled climatology with conservation science expertise, and acquired a unique know-how in delivering future forecast of Cultural Heritage vulnerabilities induced by outdoor climate changes, including extreme weather related events. The scientific approach developed within Noah's Ark was the base for further research carried out by the FP7 Climate for Culture Project (2009-2014). In this project, hazard and damage projections were forecasted to assess the impact of the slow ongoing climate change rather than extreme events effects on outdoor and indoor Cultural Heritage sites (Leissner et al. 2014, 2015; Hujibregts et al., 2012; Kramer et al., 2013; Antretter et al., 2013; Martens, 2012). This developed research methodology coupling climatology, building engineering and conservation science expertise, allowed the creatation of more than **55,000 assessment of vulnerability maps** of historic building envelopes and preserved internal artworks. In addition, predictions for sea level increase as a potential threat to many coastal regions and their Cultural Heritage until the year 2100 was calculated using scenario simulation with a global climate model (Jungclaus et al., 2006) and data from the regionally coupled atmosphere-ocean model (Sein et al., 2015).

Another project can be mentioned concerning this thematic, the FP7 European Cultural Heritage Identity Card - EU CHIC (2009-2012). The primary objective of the EU-CHIC project was to propose a **strategy and systems**, for the most efficient methods and tools of harmonising criteria and indicators to track changes, caused by human interventions and environmental impacts, on the tangible cultural heritage across Europe and its neighbouring countries. This project worked on the efficient compilation and storage of data for each asset and structure required to support maintenance, conservation and rehabilitation activities. A data management concept called the *Chiceberg protocol* was developed. In addition, the project team produced accurate criteria and indicators for resilience assessment[2,3].

Recently, the H2020 program funded two more project aimed at enhancing the resilience in facing the climate changes effects and natural hazards. In particular, the H2020 Heritage Resilience Against CLimate Events on Site - HERACLES (2016-2019) project has as a main objective "to design, validate and promote responsive **systems/solutions for effective resilience** of cultural heritage against climate change effects, considering as a mandatory premise a holistic, multidisciplinary approach through the involvement of different expertise. This will be operationally pursued with the development of a system exploiting an **ICT platform** able to collect and integrate multisource information in order to effectively provide complete and updated situational awareness and support decision for innovative measurements improving cultural heritage resilience, including new solutions for maintenance and conservation."[4,5]

[2] http://www.eu-chic.eu/
[3] http://cordis.europa.eu/project/rcn/92042_en.html
[4] http://www.heracles-project.eu
[5] http://cordis.europa.eu/project/rcn/203438_en.html

Whilest the H2020 Safeguarding cultural heritage through Technical and Organisational Resources Management - STORM project (2016-2019), with the collaboration of ICCROM, will propose "a set of novel predictive models and improved non-invasive and non-destructive methods of **surveying and diagnosis**, respectively for effective prediction of environmental changes and for revealing threats and conditions that could damage materials and structures of cultural heritage. […] Moreover, the STORM project will determine how different vulnerable materials, structures and buildings are if affected by different extreme weather events together with risks associated to climatic conditions or natural hazards, offering improved, effective adaptation and mitigation strategies, systems and technologies to different materials and structures."

An important result of STORM will be a **cooperation platform** for collaboratively collecting and enhancing knowledge, processes and methodologies on the sustainable and effective safeguarding and management of European cultural heritage[6,7].

Furthermore, an INTERREG Central Europe project, Risk assessment and sustainable protection of Cultural Heritage in changing environment – ProteCHt2save (2017-2020) has been funded in order to mitigate the impacts of climate change and natural hazards on cultural heritage sites, structures and artefacts. It will focuse primarily on the development of feasible and tailored solutions for building resilience of cultural heritage to floods and events of heavy rain. Outputs of ProteCHt2save project will strengthen the risk management and protection of cultural heritage across central Europe, delivering **ICT solutions and tools** in order to support regional and local authorities to prepare measures and evacuation plans in case of emergencies[8].

Safeguarding cultural heritage against the effects of natural disasters, the EU funded Project Protecting Mediterranean Cultural Heritage During Disasters – PROMEDHE[9] (2016-2018) aims to reinforce national resource capacities and procedures to optimize their response to natural disaster, paying particular attention to the landscape, and archaeological and cultural sites whithin the region. The project's objective is to create a **cross border regional network of experts** to cooperate and share experiences in the field of cultural heritage protection during disaster management. To do so, PROMEDHE looks to create fertile ground by promoting a **common approach and methodology** for use by the involved Civil Protection Authorities.

In the past, another INTERREG IIIC Sud (2007-2013), the Patrimoine et prévention des risques naturels - NOE Project involved four countries (Italy, Greece, Portugal and France) with 5 state partners. This project was aimed at **preventing in facing natural risks** (floods, earthquakes, fires) for the cultural heritage, considering cross-cutting actions amongst cultural heritage experts, intervention specialists and local authorities; enhancing the transfer of knowledge amongst the Mediterranean Regions, through utilizing innovative pilot sites. The approach was designed to promote strategies based on the local experimentation of new applications at European level[10].

Finally, other EU funded projects that also consider the impact of climate change on cultural heritage, can be mentioned, including FP7 Building Capacity for a Centre of Excellence for EO-based monitoring of Natural Disasters – BEYOND (2013-2016)[11],[12] aimed at developing a **Centre of Excellence**, within the National Observatory of Athens, for Earth Observation-based monitoring of Natural Disasters in south-eastern Europe, and the Balkans. This approach covered earthquakes, volcanoes, extreme

[6] http://www.storm-project.eu/
[7] http://cordis.europa.eu/project/rcn/202681_en.html
[8] http://www.interreg-central.eu/Content.Node/ProteCHt2save.html
[9] http://www.promedhe.eu/
[10] http://www.interreg4c.eu/uploads/media/pdf/NOE_2S0066R.pdf
[11] http://www.beyond-eocenter.eu/
[12] http://cordis.europa.eu/project/rcn/108747_en.html

weather events, fires, fire smoke and toxic gasses, emission concentrations, dust storms, air quality and impacts to human health, that were grouped into three research domains: RD1 - Meteorological and human induced hazards, RD2 - Geophysical hazards, and RD3 - Atmospheric pollution and air quality, with direct and indirect effects on public health and ecosystems.

Specifically considering cultural heritage, the BEYOND **Floods Observatory** and the **FloodHub** service contribute to the implementation of the EU Floods Directive (2007/60/EC), and support the integrated flood risk management. Indeed, the EU Floods Directive on the assessment and management of flood risks aims **to reduce and manage the risks that floods pose to human health, the environment, cultural heritage and economic activity** (see section on Flood risk of this Chapter).

Within the IRSES - Marie Curie Action "International Research Staff Exchange Scheme", the FP7 Cultural and Natural Heritage in Arctic and Sub-Antarctic Regions for a Cross-Cultural and Sustainable Valorisation Process and Tourism Development: Siberia, Lapland and Patagonia – POLARIS (2013-2017) was also funded. This project intended to undertake a comparative study of three different regions: Siberia (Russia), Lapland (Sweden) and Patagonia (Argentina) that have a series of common features as regards their **natural and cultural heritage**, and are destined to experience similar changes due to the global warming and globalisation processes. is a concern for these regions, especially in the Arctic and Sub-Antarctic, as their cultures and territories are deeply affected by the impacts of climate change. Therefore, on studying these extreme regions, the project aims to enhance **training professionals working in public administrations** in order to improve their educational background, and support students with postgraduate curricula linked to tourism, geography, natural heritage, politics and social economics.[13]

Considering the 7th Framework programme, another project mentioning climate change effects, including Cultural Heritage, has been developed, the FP7 Economics of climate change adaptation in Europe – ECONADAPT. This project, within the "WP6. Case Study: Economic Project Appraisal", aimed at assessing adaptation costs and their uncertainties. In particular, it uses a Real Option Analysis to appraise the potential investment in flood reduction, utilizing detailed climate model projections and hydrological modelling, assessing the full **economic costs of climate change** (including on **cultural heritage**, human health and indirect second order effects) [14].

In the LIFE Programme - Adapting to Climate Change in Time (ACT) 2010/2012[15], involves the Italian Institute ISPRA[16] and the FAIC[17], this study has addressed the climate changes impacts on the **cultural heritage of the city of Ancona**, with its local effects (Cacace et al., 2011).

Regarding the local initiatives, such as at national and regional levels, in the last few years several Italian projects have been undertaken in order to evaluate and manage climate change effects on cultural heritage.

For instance, in the POR CALABRIA FESR 2007/2013 - SIstemi e tecnologie per il MONitoraggio di Aree culturali in ambiente subacqueo e terrestre (SIMONA) the possible risks related to man-made and natural disasters have been evaluated and predicted through realizing **damages maps** in consideration of possible deterioration phenomena

[13] http://cordis.europa.eu/project/rcn/106872_en.html
[14] http://cordis.europa.eu/result/rcn/195491_en.html
[15] http://www.actlife.eu/EN/index.xhtml
[16] Istituto Superiore per la Protezione e la Ricerca Ambientale
[17] Forum delle Città dell'Adriatico e dello Ionio

linked to slow changes (e.g. in levels of precipitation and temperature variations), resulting in surface recession and biomass accumulation on the cultural heritage materials. Moreover, additional analysis has been carried out in order to determine the seismic response of specific zones[18].

In addition in Italy, the ISCR-MiBACT achieved a territorial information system of risk maps for cultural heritage called "Carta del Rischio"[19] by adopting a **holistic multi-risk approach**, including previously un-assessed impact of volcanic and storm hazard.

Considering other areas, mention can be made of the research work realized in collaboration between the Institute of Atmospheric Sciences and Climate of the National Research Council of Italy (CNR-ISAC, Italy), the Department of Physics and Earth Sciences of the University of Ferrara (Italy) and the Patronage of Panama Viejo, the Patronage of Portobelo and San Lorenzo (Panama), aimed at studying the Environmental impact on the UNESCO heritage sites located in Panama. Taking into account the slow changes, such as variation in rainfall amount, relative humidity and temperature, the work produced evaluation and predictions of possible future damages, such as **surface recession, biomass accumulation and salt crystallization-dissolution cycles** through the use of damage functions (Ciantelli, 2017).

Resilience strengthening and risk management

In order to discuss preparation, response, and mitigation measures to address the growing incidence of natural disasters, the first UN World Conference on Disaster Risk Reduction was held in Yokohama (Japan), in May 1994, this as followed by other two, in Kobe, Japan (January 2005), that adopted the Hyogo Framework for Action 2005 – 2015[20], and then in Sendai, Japan (March 2015), adopting the Sendai Framework for Action 2015 - 2030[21,22].

For the first time, the Hyogo Framework for Action 2005 – 2015 mentions the risk of disasters to the cultural heritage, in particular, in section 3, "Use knowledge, innovation and education to build a culture of safety and resilience at all levels", "Key activities":

> (i) Information management and exchange:
>
> (a) Provide easily understandable information on disaster risks and protection options, especially to citizens in high-risk areas, to encourage and enable people to take action to reduce risks and build resilience. The information should incorporate relevant traditional and indigenous knowledge and **culture heritage and be tailored to different target audiences, taking into account cultural and social factors**."

Following this policy, the Strategy for Risk Reduction at World Heritage Properties was presented by UNESCO and approved by the World Heritage Committee at its 31st session in 2007[23]. According to the five main objectives defined by the Hyogo Framework for Action, the priority measures of the Strategy have been structured and here listed:

- Strengthen support within relevant global, regional, national and local institutions for reducing risks at World Heritage properties;

[18] http://www.laboratorisilpa.com/laboratori/index.php?option=com_content&view=article&id=34&Itemid=180

[19] http://www.cartadelrischio.it/

[20] http://www.unisdr.org/files/1037_hyogoframeworkforactionenglish.pdf

[21] http://www.unisdr.org/files/43291_sendaiframeworkfordrren.pdf

[22] http://whc.unesco.org/en/disaster-risk-reduction/

[23] http://whc.unesco.org/archive/2007/whc07-31com-72e.pdf

- Use knowledge, innovation and education to build a culture of disaster prevention at World Heritage properties;
- Identify, assess and monitor disaster risks at World Heritage properties;
- Reduce underlying risk factors at World Heritage properties;
- Strengthen disaster preparedness at World Heritage properties for effective response at all levels.

Addressing disaster risks that threaten the integrity and/or authenticity of World Heritage sites, the Strategy is in line with Article 5 of the World Heritage Convention[24] and the Strategic Objectives established by the Budapest Declaration[25]. Importanltly, for the first time, **cultural heritage is considered as an incentive for enhancing the reduction of the impact of catastrophic events**, also in order to protect goods and services, which it provides to local communities.

Nevertheless, it is in the Sendai Framework for Action 2015 – 2030, where the new international DRR policy includes several important references for the protection of culture and heritage from disaster risks (e.g. paragraphs 4, 5, 14, 16, 16, 17, 19-c, d, 24-d, 29, 30-d, 33).

In 2008, in Regensburg (Germany), the Regensburg Recommendation "Earth, Wind, Water, Fire – Environmental Challenges to Urban World Heritage"[26] resulted by the Organization of World Heritage Cities Northwest-European Regional Conference. During this event participants recommended, the need to:

- Emphasize the importance of safeguarding the world's cultural heritage for present and future generations.
- Highlight that climate change and environmental challenges like storms, flooding, fire, earthquakes, weathering, erosion and landslides pose one of the most important threats to World Heritage cities, especially given the more frequent extreme weather situations.
- Emphasize that the loss and deterioration of the built cultural heritage due to natural disasters and climate change affects all people.
- Recall that the safeguarding of the urban cultural heritage is the shared responsibility of citizens, local and regional authorities, national governments and international organisations.
- Take into account the following documents (Figure 2.2):

[24] http://whc.unesco.org/en/conventiontext/
[25] http://whc.unesco.org/archive/2002/whc-02-conf202-25e.pdf
[26] https://www.regensburg.de/sixcms/media.php/280/Regensburg%20Recommendation.pdf

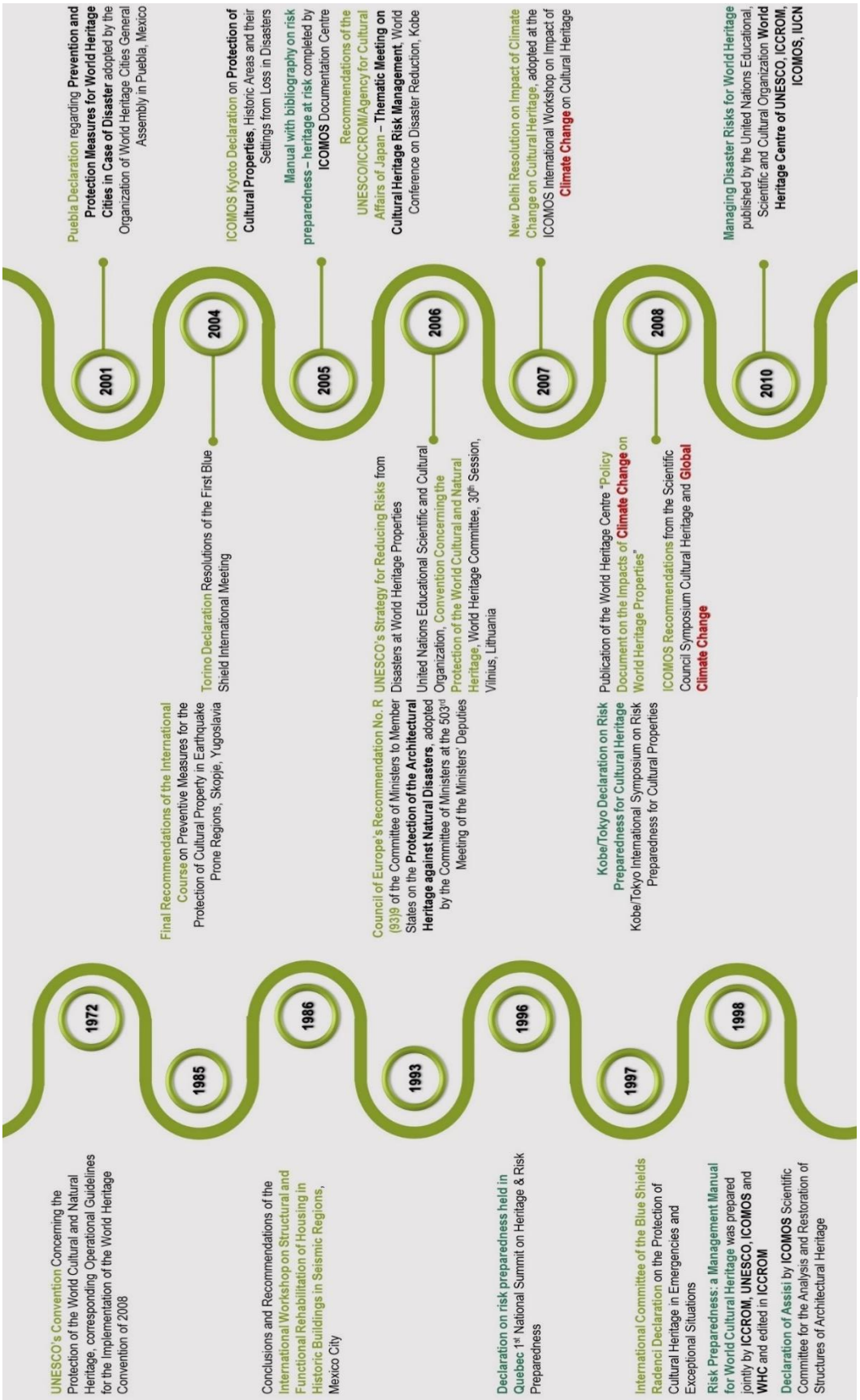


Figure 2.2 Chronology, 1972-2010, of the documents regarding the disaster risks reduction and protection of CH (**in green**), the risk preparedness and management of CH (**in blue**). As clearly evident (**in red**), the concept of Climate Change has been considered since 2007

Considering the World Heritage Committee, the following Decisions have been adopted, relevant to risks and disasters (Figure 2.3)[27]:

Figure 2.3 Decisions adopted, relevant to risks and disasters.

Regarding the **environment and risk prevention** of cultural heritage for preserving the socio-economic and sustainable tourism development, EC Regulation, No 1080/2006 of the European Parliament and of the Council (5 July 2006), on the European Regional Development Fund and repealing Regulation (EC) No 1783/1999 was designed, as reported in the following extract of the Art.5 - Regional competitiveness and employment:

> 2. Environment and Risk Prevention:
>
> (e) developing plans and measures to prevent and cope with natural risks (e.g. desertification, droughts, fires and floods) and technological risks;
>
> (f) **protection and enhancement of the natural and cultural heritage** in support of socio-economic development and the promotion of natural and cultural assets as potential for the development of sustainable tourism.

[27] http://whc.unesco.org/en/disaster-risk-reduction/

In addition, in 2007, the European Parliament, realized a study examining current national and international instruments and activities to protect cultural heritage from natural disasters, that gave **examples of best practices,** and described problems and shortcomings, defining priorities for action based on an analysis of current and forthcoming EU legislation (Drdácký et al., 2007).

On 25 September 2015, the United Nations adopted the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development[28], aimed at ending poverty, fighting inequalities and injustices and tackling climate change. In particular, the Goal n. 11 and specifically in Target 11.4, contains an explicit reference to cultural heritage, in terms of "Strengthen efforts to protect and safeguard the world's cultural and natural heritage"[29]. In the same year, in November 2015, the 38th General Conference of UNESCO adopted a Strategy for the reinforcement of the Organization's actions for the protection of culture and the promotion of cultural pluralism in the event of armed conflict (38/C48)[30]. Two years after, and precisely on 14 November 2017, the 39th session of the UNESCO General Conference adopted an Addendum[31] to this Strategy, proposing to **consider also emergencies associated with disasters caused by both natural and human-induced hazards**. This implementation was included in the document of the UNESCO Executive Board 201 EX/5, entitled Follow-up to Decisions and Resolutions adopted by the Executive Board and the General Conference at their previous sessions - Part I[32]. Within it, the final draft for an updated UNESCO Strategy for Action on Climate Change[33] is also present.

Finally, in the EEA Report No 12/2016, Urban adaptation to climate change in Europe 2016, Transforming cities in a changing climate, cultural heritage is mentioned twice in section 3.2 Transformational adaptation: a systemic approach turning challenges into opportunities, p. 31 and in 5.3.1 Planning and implementing approaches for urban adaptation, p. 79 (European Environment Agency, 2016).

Considering the indoor environment mention can be made of the long-term Museums Emergency Programme (MEP), launched in 2002. This was **aimed at responding to the global need for museums to develop expertise in the areas of disaster risk management** and to strengthen the dynamism of the International Committee of the Blue Shield (ICBS)[34] (which works for the protection of the world cultural heritage by coordinating preparations to meet and respond to emergency situations as well as post-crisis support[35]). In order to create self-sustained regional networks equipped with basic tools and essential reference materials, the Programme emphasized training and collaboration in regional communities, and encouraged awareness raising on the vulnerability of museums. The MEP target group includes museums, cultural heritage professionals, local communities and other professionals with links to the programme, such as firemen and volunteers[36].

At national level, as illustrated in Figure 2.4, sporadic recent attempts to integrate cultural heritage into the wider national and international policies have also been made.

[28] http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E
[29] http://www.un.org/sustainabledevelopment/cities/
[30] http://unesdoc.unesco.org/images/0023/002351/235186e.pdf
[31] http://unesdoc.unesco.org/images/0025/002598/259805e.pdf
[32] http://unesdoc.unesco.org/images/0024/002477/247706e.pdf
[33] http://unesdoc.unesco.org/images/0025/002592/259255e.pdf
[34] http://www.icbs.com
[35] http://icom.museum/programmes/museums-emergency-programme/international-committee-of-the-blue-shield/
[36] http://icom.museum/programmes/museums-emergency-programme/

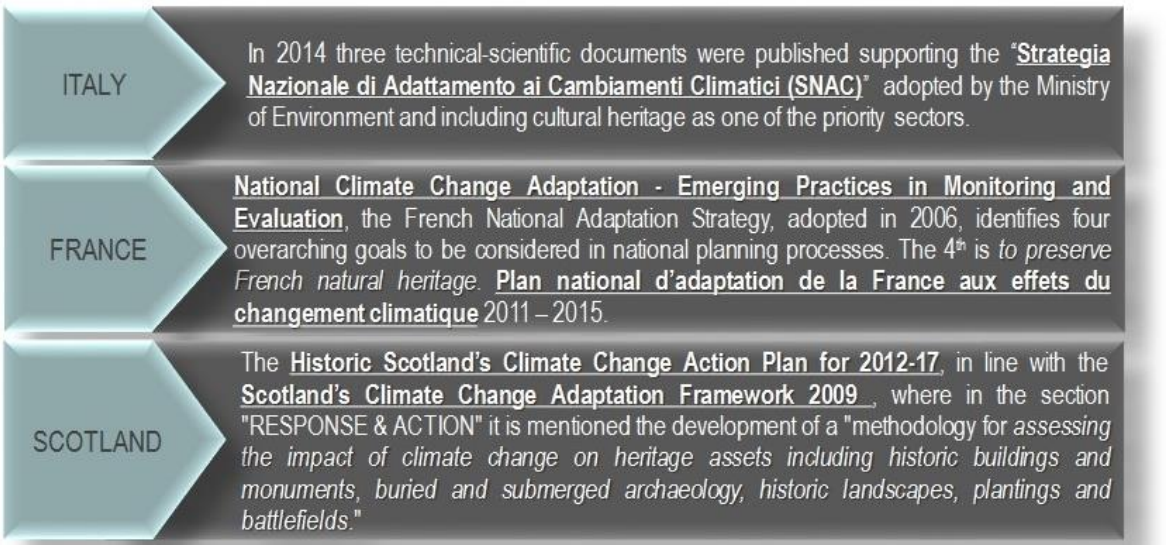


Figure 2.4 Encouraging examples of National Climate Change Action and Adaptation Plans, that considers cultural heritage needs.

Training and Dissemination Actions

During recent decades, several activities have been carried out in order to promote an awareness to the wider public of the effects of climate changes on cultural heritage.

Since 2000, ICOMOS periodically publishes the World Reports Heritage at Risk[37]. These reports offer a **compendium about the dangers threatening cultural heritage**, in order to provide awreness of the risks and to promote practical measures to avert or at least allay these risks, to help protect humanity's cultural heritage for future generations.

In 2001 the EUR-OPA Major Hazards Agreement of the Council of Europe (a platform for co-operation in the field of natural and technological disasters-knowledge, prevention, risk management, post-crisis analysis and rehabilitation) and the International Organisation for Migration (IOM) produced a series of handbooks of School of Civil Protection[38] with one dedicated to the Protection of Cultural Heritage, in order to **enhance the risk preparedness for the protection of cultural heritage** (Massue and Schvoerer, 2001).

In Davos (Switzwerland), in 2006, a special session entitled Integrating traditional knowledge systems and concern for cultural and natural heritage into risk management strategies (King et al., 2006) was organized by ICCROM and the World Heritage Centre for the International Disaster Reduction Conference (IDRC). It produced **proceedings and the** IDRC Davos 2006 Declaration, with the purpose of promoting the **integration of the traditional knowledge systems into risk management strategies**, and of the concerns for cultural heritage into broader national and regional **risk management plans**. This was a unique opportunity for deliberation and awareness-raising on both themes not only for heritage professionals, but also for many other sectors of the disaster in the disaster reduction community (attended by more than 1.000 international participants). Within the declaration **both tangible and intangible** cultural heritage were considered essential to be incorporated into disaster risk reduction strategies and plans.

[37] http://www.icomos.org/en/get-involved/inform-us/heritage-alert/heritage-at-risk-reports
[38] http://www.coe.int/en/web/europarisks/school-of-civil-protection-handbook

The European Commission, the United Nations Development Group (UNDG) and the World Bank signed a joint declaration in 2008 for assessing, planning and mobilizing recovery support for countries and populations affected by disasters, and developed **guidelines for the** Post-Disaster Needs Assessments (PDNAs) for **encouraging the resilience of social systems to disasters, considering also culture, as social sector**[39].

In 2010, the UNESCO, ICCROM, ICOMOS and IUCN (International Union for Conservation of Nature) published the **Resource Manual** on the Managing Disaster Risks for World heritage Sites, that provide for the first time a **stepped guidance for site managers to develop disaster risk management plans** as part of an overall site management system (UNESCO et al., 2010).

Noteworthy, iat the same years, a PhD Thesis (Tuscia University, Italy) was dedicated to Disaster Risk Management of Cultural Heritage, with the objective of exploring how from the **origins of preventive conservation** we are currently **dealing with disaster risk management issues** (Menegazzi, 2010).

After the 4th Session of the Global Platform for Disaster Risk Reduction, held in Geneva on 19-23 May 2013, a document entitled Heritage and Resilience – Issues and Opportunities for Reducing Disaster Risks[40] has been prepared by the International Scientific Committee of ICOMOS for Risk Preparedness (ICOMOS-ICORP) in collaboration with the United Nations Office for Disaster Reduction (UNISDR), UNESCO and ICCROM. This document presents **how heritage can be better protected** from disasters while contributing to the **resilience of societies** and supports the integration of these issues within both **disaster risk and heritage conservation policies and practices**. Furthermore, the 5th Global Platform on Disaster Risk Reduction was held in Cancun (Mexico) on May 22-26, 2017 where a working session was dedicated to Cultural Heritage and Indigenous Knowledge for Building Resilience, in order to "promote the need to mainstream cultural heritage considerations in national and local policies and strategies and the fuller engagement of indigenous peoples and local communities in disaster risk reduction. The session will also **identify practical measures to catalyze actions** that build capacities of the concerned authorities, local communities and indigenous peoples, **to reduce disaster risks, protect cultural assets and to draw on heritage for resilience**."[41]

In 2015, the World Heritage Journal published Review, n°74, entitled Fostering Resilience[42], treating issued as i) Fostering resilience: Towards reducing disaster risks to World Heritage; ii) Post-disaster reconstruction: Xijie historic quarter in Dujiangyan, Sichuan province; iii) Building resilience at iSimangaliso Wetland Park and iv) Post-disaster heritage initiative in Pakistan.

According to the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development, in 2015 the Ecological Sequestration Trust published a **report**, the Integrating Sustainable Development and Disaster Risk Management of Historic Urban Areas (Ecological Sequestration Trust, 2015), with a holistic approach to urban planning for sustainability and disaster risk reduction of historic settlements (an evolution from the conventional Master Planning approach). In this case, the concept of cultural heritage includes not only monuments and museum, but also the evolution of human relationships with the natural environment, thus **considering tangible as well as intangible aspects**. Led by Professor Peter Head, Chief Executive of the Ecological Sequestration Trust, the report was written at the 2015 UNESCO Chair Program on

[39] https://gfdrr.org/sites/gfdrr/files/WB_UNDP_PDNA_Culture_FINAL.pdf
[40] https://www.unisdr.org/we/inform/publications/33189
[41] https://www.unisdr.org/conferences/2017/globalplatform/en/programme/working-sessions/view/597
[42] http://whc.unesco.org/en/review/74

cultural heritage and Disaster Risk Management, International Training Course at Ritsumeikan University Kyoto during the sessions on 16 September 2015.

The Ritsumeikan University of Kyoto also produced the R-DMUCH Interactive Training Guide on Disaster Risk Management of Cultural Heritage in Urban Areas (2013) (Jigyasu and Arora, 2013), as a **guide for conducting courses** on this thematic. In 2007, the research center founded an **annual dedicated journal**, entitled Journal of Disaster Mitigation for Historical Cities[43], and in the same year, an Introductory Volume to Cultural Heritage Disaster Mitigation Studies was published[44]. The UNESCO headquarter authorized the Ritsumeikan University as a UNESCO Chair, and in 2006 R-DMUCH implemented an international training program on disaster mitigation for cultural heritage whilst also producing **proceedings of the courses**. This annual training course, like the 2015 event, follows the Hyogo Framework for Action 2005 – 2015 recommendations, and as a result the centre developed the previously cited training guide (Institute of Disaster Mitigation for Urban Cultural Heritage, Ritsumeikan University, 2016).

Finally, UNESCO has recently published a report on the increasing vulnerability of World Heritage sites to climate change impacts and the potential implications for and of global tourism, that includes another fundamental factor - the "final user" (Markham et al., 2016).

The publications produced by UNESCO on this issue is illustrated in Figure 2.5.

Figure 2.5 UNESCO publications Climate Change effects on cultural heritage from 2006 to 2016[45].

[43] http://r-dmuch.jp/en/results/archives.html
[44] http://r-dmuch.jp/en/results/kotohajime.html
[45] http://whc.unesco.org/en/climatechange/

UNESCO, in cooperation with its partner institutions, has also organized a number of workshops on the subject of disaster risk reduction[46]. Moreover, they produced **proceedings and resource materials** that may help managers of World Heritage properties and other cultural professionals in developing DRR strategies:

- Regional Conference on Harmonizing Actions to Reduce Risks for Cultural Heritage in Asia and the Pacific, December 2015, Georgetown, Penang, Malaysia, at which an Outcome Document structured along the four priority areas of the Sendai Framework was adopted. This Conference's scope was not limited to built heritage[47].
- Session on Resilient Cultural Heritage, March 2015, Sendai, Japan. A special session on Resilient Cultural Heritage was organized within the framework of the Third United Nations World Conference on Disaster Risk Reduction (WCDRR). The meeting produced important recommendations based on the priority areas identified by the Sendai Framework for Disaster Risk Reduction 2015 – 2030.
- Session on Heritage and Resilience: Issues and Opportunities for Reducing Disaster Risks (Geneva, Switzerland, 22 May 2013). The session emphasized the intrinsic value of heritage for building resilient communities. Video of the session and more information.
- Capacity-Building Workshop on Assessment of Vulnerability of Cultural and Natural World Heritage Properties to Disasters and Climate Change (Beijing, China, 6-12 December 2009).
- Second International Workshop on Disaster Risk Reduction to Cultural Heritage (Acre, Israel, 14-17 November 2009).
- International Workshop on Disaster Risk Management at World Heritage Properties (Olympia, Greece, 2008). Consult the Proceedings of the Workshop, including the Olympia Protocol.
- International Conference on Earth Wind Water Fire - Environmental Challenges to Urban World Heritage (Regensburg, Germany, 2008). Organized by the Organization of World Heritage Cities (OWHC) to discuss innovative protective measures for historic cities.
- Workshop on Risk Reduction for Caribbean Heritage (Havana, Cuba, 2008). This event aimed to exchange experiences in heritage conservation and risk reduction in the region. As a result, a Risk Reduction Network for the Caribbean Heritage was created.
- The International Training Course on Disaster Risk Management of Cultural Heritage (Ritsumeikan University, Japan). This two-week, yearly training course provides interdisciplinary training for heritage professionals.
- Integrating Traditional Knowledge Systems and Concern for Cultural and Natural Heritage into Risk Management Strategies (International Disaster Reduction Conference, Davos, Switzerland, 2006).

[46] http://whc.unesco.org/en/disaster-risk-reduction/

[47] http://www.unescobkk.org/fileadmin/user_upload/culture/DRM/DRM_Penang_Conf_report.pdf

- Special Thematic Session on Risk Management for Cultural Heritage (UN World Conference on Disaster Reduction, Kobe, Japan, 2005).

In consideration of how to **evaluate the climate change and environmental effects on the cultural heritage**, other courses include the Ravello International Workshops, on the climate change and cultural heritage topics held in Ravello (Salerno, Italy) since 2009. These have been realized with the support of the *Centro Universitario Europeo per i Beni Culturali* and the *Council of Europe* (*EUR-OPA Major Hazards Agreement)* and have also provided proceeding of the lectures given (Lefèvre and Sabbioni, 2016).

The International Summer School Environment-Material Interaction (ENVIMAT[48]), organized by CNR-ISAC and University of Calabria, has reached its 4th cycle addressing: scientists, architects, engineers, archaeologists, site curators, cultural heritage managers, conservators, restorers, graduate students and post-doctoral fellows. The topics treated are the characterization and provenance of building materials; building materials deterioration processes in outdoor environments; **climate and pollution changes and their effects on building materials**; **mitigation and adaptation strategies**; archaeological sites, conservation and the visitor; archaeological sites and their shelters.

With regard to the "**post-disaster**" theme, in order to further reduce damage to cultural heritage in the event of a natural disaster or an armed conflict, there is the course entitled First Aid to Cultural Heritage in Times of Crisis (FAC)[49]. In the framework of the Disaster Risk Management programme, this hands-on training is aimed at **preparing proactive cultural first-aiders** who will have the ability to assess risks to cultural heritage and reduce the impact of such events.

Considering the **post-trauma situation**, the Post-Trauma Reconstruction was organized by ICOMOS colloquium, on the 4 March 2016 with its published proceedings[50].

Finally, the European Commission Directorate General for Research and Innovation organized a full day event, on the Cultural heritage, disaster resilience and climate change: the contribution of EU research and innovation, with policy makers, stakeholders and researchers and innovators to discuss **the latest developments on cultural heritage at risk**. in Brussels on the 7 December 2016, it considered as topics of debate: how to increase disaster resilience of cultural heritage sites facing natural hazards and extreme climate-related events; what other risks are threatening cultural heritage sites and what the innovative solutions are to prevent and mitigate their environmental, economic and social impacts; what are the recent results from EU research and innovation projects, what is the potential use of earth observation and smart technologies and what will be the next steps[51].

Regarding the indoor environment, ICOM organised, under the framework of Museums Emergency Programme (MEP), the International Symposium on Cultural Heritage Disaster Preparedness and Response in 2003 in India. As a result of this event, participants developed **recommendations**, several of which concerning **training and capacity building activities** were addressed to organisations such as ICOM, ICOMOS, ICCROM and the general museum community. (Menegazzi, 2010).

Considering museum collections the Mesa Técnica de Atenção ao Patrimônio Museológico em Situação de Risco (Technical Group for Museum Heritage Risk

[48] http://www.envimat.it/
[49] http://www.iccrom.org/courses/first-aid/
[50] http://openarchive.icomos.org/1707/
[51] https://europa.eu/newsroom/events/cultural-heritage-disaster-resilience-and-climate-change-contribution-eu-research-and_en

Management) was created in 2010 in Santiago of Chile. Annual meetings held by the Technical Group are aimed to **promoting and articulating the training of Ibero-American professionals responsible for managing museum heritage in situations of emergency**, to offer practical care in the institutional and technical arena, whilst creating specialized networks.

Iin 2011 the Museum Heritage Risk Management Professional Training Institute was held in Brasília (Brazil) and reunited international and Ibero-American specialists for theoretical presentations and specific cases relating to **risk diagnosis and analysis, preventive actions, objective actions in times of disaster, and rescue and recovery actions**, publishing essays[52]. In 2016, an Action Plan was designed by the Technical Group representative from Brazil, Chile, Costa Rica, Mexico and Spain, creating short, medium and long term of action objectives [53].

As example of local level dissemination activity addressed to a wider public highlights the publication produced by the Historic Environment Scotland entitled Climate change adaptation for traditional buildings (Curtis and Hunnisett Snow, 2016). This short guide is addressed to homeowners, building professionals and landlords for maintaining and improving the buildings' protection, for both the out-door and in-door environment against the elements, and considers how these can be improved or adapted to increase a building's resilience to extreme weather events and cope with changing environmental conditions.

[52] http://www.ibermuseus.org/wp-content/uploads/2014/09/PATR.RIESGO_Gestao-do-Patrimonio-Museologico-em-Risco-2011-WEB-reduzido.pdf
[53] http://www.ibermuseus.org/wp-content/uploads/2016/04/Plano-de-Acao-PR-2016.pdf

2.2 Air pollution changes and Environmental degradation

Introduction to air pollution changes and environmental threats and protection

Considering that most buildings of cultural/historical interest are located in urban environments, it is important to consider local-scale variations within the urban context, such as changes in pollutants, temperature field, relative humidity cycles, wind field, urban heat island effect etc. For instance, the available scenarios of multi-pollutants trends, not only in Europe but also in a global level, indicate that the effects of industrial, civil and transport emissions on corrosion and soiling will constitute a serious threat to cultural heritage. Such effects require improved methods of quantification to arrive at a more accurate damage assessment, diagnosis and monitoring of the movable and immovable cultural heritage.

In order to clarify the interaction between pollutants, contextually with climate parameters, and materials belonging to cultural heritage, Figure 2.6 summarizes them, selecting the ones involved in the damage processes on different materials, in relation to their relevance of occurrence outdoor and indoors. Materials mainly affected by each deterioration process are also specified.

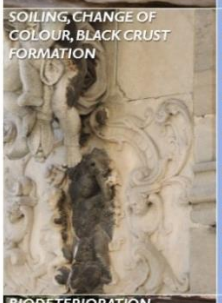
DAMAGE PROCESS	MATERIALS MAINLY AFFECTED	CLIMATE AND POLLUTION PARAMETERS
 SURFACE RECESSION	**OUTDOORS** • MARBLE • LIMESTONE • SANDSTONE WITH CARBONATE MATRIX • AIR-SETTING AND HYDRAULIC MORTAR • CEMENT MORTAR AND CONCRETE **INDOORS** N. R.	• RAIN AMOUNT • RAIN PH • SO_2 • HNO_3 • CO_2 • TIME OF WETNESS (T AND RH) • PM, PM_{10}, $PM_{2.5}$
 SOILING, CHANGE OF COLOUR, BLACK CRUST FORMATION	**OUTDOORS** • MARBLE • LIMESTONE • SANDSTONE WITH CARBONATE MATRIX • AIR-SETTING AND HYDRAULIC MORTAR • CEMENT MORTAR AND CONCRETE • GLASS **INDOORS** • TEXTILE • PAPER • PAINTINGS • FRESCOES • GLASS	• RAIN AMOUNT • SO_2 • NO_2 • PM, PM_{10}, $PM_{2.5}$ • CARBON FRACTIONS OF PM: EC AND OC • SOLUBLE SALT FRACTION OF PM: SO_4^{2-}, SO_3^{2-}, NO_3^-, NO_2^- BR^-, HPO_4^{2-}, Cl^-, CHO_2^-, $C_2H_3O_2^-$ AND $C_2O_4^{2-}$ • TIME OF WETNESS (T AND RH) • VOC • LIGHT
 BIODETERIORATION	**OUTDOORS AND INDOORS** • CARBONATE AND SILICATE STONES • AIR-SETTING AND HYDRAULIC MORTAR • CEMENT MORTAR AND CONCRETE • WOOD • PAPER • TEXTILE	• RAIN AMOUNT • T • RH • SOLAR RADIATION • OC FRACTION OF PM • SOLUBLE SALT FRACTION OF PM: NO_3^-, $C_2H_3O_2^-$
 CORROSION	**OUTDOORS AND INDOORS** • METALS: STEEL, ZINC, COPPER, BRONZE, LEAD **OUTDOORS** • GLASS	• RAIN AMOUNT • RAIN PH • T • RH • SO_2 • HNO_3 • O_3 • PM, PM_{10}, $PM_{2.5}$ • SOLUBLE SALT FRACTION OF PM: SO_4^{2-}, NO_3^-, Cl^- • H_2S • COS • CH_3COOH AND CH_2O_2 • NH_3
 LEACHING	**OUTDOORS** • GLASS **INDOORS** N. R.	• RAIN AMOUNT • RAIN PH • T • RH • SO_2 • HNO_3 • O_3 • PM, PM_{10}, $PM_{2.5}$ • SOLUBLE SALT FRACTION OF PM: SO_4^{2-}, NO_3^-, Cl^-
 SALT CRYSTALLISATION	**OUTDOORS AND INDOORS** SANDSTONE LIMESTONE AIR SETTING AND HYDRAULIC MORTAR CEMENT MORTAR AND CONCRETE BRICK	• RH CYCLES • RAIN PH • T • PM, PM_{10}, $PM_{2.5}$ • SOLUBLE SALT FRACTION OF PM: SO_4^{2-}, Cl^-, NO_2^-, NO_3^-, Ca^+, Na^+, Mg^{2+}, K^+
 SWELLING/SHRINKAGE, LOSS OF STRENGTH, CRACKING, EMBITTERMENT	**OUTDOORS** • CLAY-CONTAINING MATERIALS • WOOD **INDOORS** • WOOD • PAPER	• RAIN AMOUNT • NUMBER OF RAINY DAYS • T • RH CYCLES • T CYCLES • LIGHT (ON PAPER) • NO_2 (ON PAPER) • O_3 (ON PAPER)

Figure 2.6 Summary of the climate and pollution parameters involved in damage processes on cultural heritage materials (immovable and movable) (n. r. = not relevant). Selecting the deterioration phenomena due to the pollutants action (Modified by TeACH Deliverable 2.1[54]). Legend: Acetates = $C_2H_3O_2^-$; Acetic acid = CH_3COOH; Ammonia = NH_3; Bromides = Br^-; Calcium = Ca^+; Carbon dioxide = CO_2; Carbonyl sulphide = COS; Chlorides = Cl^-; Elemental carbon = EC; Formates = CHO_2^-; Formic acid = CH_2O_2; Hydrogen sulphide = H_2S; Magnesium = Mg^{2+}; Nitrates = NO_3^-; Nitric acid = HNO_3; Nitrites = NO_2^-; Nitrogen dioxide = NO_2; Organic carbon = OC; Oxalates = $C_2O_4^{2-}$; Ozone = O_3; Particulate matter = PM; Phospates = HPO_4^{2-}; Potassium = K^+; Sodium = Na^+; Sulphates = SO_4^{2-}; Sulphites = SO_3^{2-}; Sulphur dioxide = SO_2; Volatile organic compounds = VOC. Relative Humidity = RH and Temperature = T.

[54] http://cordis.europa.eu/result/rcn/162482_en.html

Assessment of the impact, Monitoring and Early Warning system related to air pollution effects on cultural heritage

Over the last few decades, a strong scientific effort has been made in order to address the problem of the conservation and restoration of indoor and outdoor cultural heritage, through studying environmental and polluting effects.

In Europe, from the FP1 to FP4 programme (1986–98) the EU initiated projects on the environmental impact and, specifically, effects of air pollution on cultural heritage. This is clearly reported in the European Commission summary volume, where 20 years of EU research into cultural heritage is described (Chapuis, 2009). Here, it is noticeable that the first approach focused on gaseous pollutants, with attention being subsequently paid to particulate matter and, later, to aerosol carbon fractions. Extracts from this volume follow, highlighting projects that considered the pollution and environment effects on cultural heritage:

FP1: Effects of air pollution on historic buildings (1986–90)

1. The inter-relationship of **air pollution** levels on stone decay rates at historic monuments.
2. Kinetic studies of **SO**, reactions with marble.
3. Reactions of **nitric acid** and **nitrates** with pentelic marble.
4. Case studies in the deterioration of stone monuments in Italy.
5. Application of advanced methods of chemical analysis to stone conservation.
6. Chamber studies on **air pollution** damage to stone conservation.
7. Ultrasounds applied to the non-destructive examination of stone structures.
8. **Biodeterioration** studies on stone monuments.
9. **Environmental deterioration** and the Monastery of Jeronimos: a case study.
10. Non-destructive evaluation of stone monuments in Pavia: a case study.

STEP programme FP2: Protection and conservation of the European cultural heritage (1989–92)

1. **Effects of airborne particulate matter** on building surfaces.
2. The effects of **air pollutants** on the accelerated ageing of cellulose containing materials.
3. Granitic materials and historical monuments: study of **weathering** and application conservation.
4. Physicochemical parameters, including **pollutants interaction**, affecting the rates of dry deposition on stone surfaces.

Environmental programme FP3 (1991–94) – 1st and 2nd phases Environmental protection and conservation of the European cultural heritage

1. **Marine spray** and **polluted atmosphere** as factors of damage to monuments in the Mediterranean coastal environment.
2. Non-destructive testing and system identification to evaluate diagnostics methods and reinforcement techniques applied to historical buildings.

3. **New conservation methods for outdoor bronze** sculptures.
4. Expert system for **evaluation of deterioration** of ancient brick masonry structures.
5. Interactive **physical weathering** and bioreceptivity study on building stones, monitoring by computerised X-ray tomography (CT) as a potential non-destructive research tool.
6. Rôles des **apports atmosphériques solides et gazeux**, et de la nature du substrat dans les altérations superficielles des monuments – approche expérimentale et modélisation
7. **Assessment and monitoring the environment** of cultural property.
8. Microstructural decay of lithoid monuments, caused by **environmental factors**, studied using a newly developed, radar-aided methodology.
9. **Deterioration and conservation** of vegetable tanned leather.
10. Soil archive classification at European excavation sites in terms of **environmental impacts** and conservability of cultural heritage.
11. **Particulate pollution** and stone damage
12. **Deposition of gases and particles** and their corrosive effect on surfaces of cultural and artistic value inside museums.
13. **Environmental research** for art conservation – ERA.
14. Atmospheric eutrophication and secular **organic pollution** (biological and mineralogical reactions of Mediterranean monuments).

Environment and climate programme FP4 (1994–98) - 1st phase Technologies to protect and rehabilitate the European cultural heritage

1. Archaeometric study to reconstruct the **pollution and the climate of the past and their effects** on cultural heritage – ARCHEO.
2. **Environmental deterioration** of ancient and modern hydraulic mortars – EDAMM.
3. Development of new non-destructive method for analysis of the **atmospheric corrosion** and corrosion protection of copper and copper alloys – CONTACTLESS CORROSION ANALYSIS.
4. Development of evaluation criteria, prediction and control methods concerning **sea-salt effects** on monument stones – SEA-SALT CONTROL IN MONUMENTS.
5. Baroque artificial marble: **environmental impacts, degradation and protection** – ENVIART.
6. System and methods for **assessing the conservation state and environmental risks** for outer wooden parts of cultural buildings - WOOD-ASSESS.
7. An expert chemical model for determining the environmental conditions needed to **prevent salt damage in porous materials** – CONTROL OF SALT DAMAGE.

During the FP5 Environment and Sustainable Development (ESD: 1999–2002): Key action City of tomorrow and cultural heritage, projects addressed this issue were:

1. Assessment of suitable products for the conservation treatments of sea-salt decay – ASSET.
2. Preserving cultural heritage by **preventing bacterial decay** of wood in foundation poles and shipwrecks – BACPOLES.
3. Novel approaches to conserve our European heritage: **Bioremediation** for Building Restoration of the Urban Stone Heritage in European States – BIOBRUSH.
4. **Inhibitors of biofilm** damage on mineral materials – BIODAM .
5. Biomediated calcite precipitation for monumental **stones reinforcement** – BIOREINFORCE.
6. **Carbon content and origin of damage layers** in European monuments – CARAMEL.
7. **Cyanobacteria and associated micro-organisms** in roman hypogean monuments – CATS.
8. Concerted action on molecular **microbiology** as an **innovative conservation strategy for indoor and outdoor** cultural assets – COALITION.
9. **Corrosion** of lead and lead-tin alloys of organ pipes in Europe – COLLAPSE.
10. Compatibility of plasters and renders with **salt loaded substrates** in historic buildings – COMPASS.
11. Development of a **monitoring system** for cultural heritage through European Co-operation – DEMOTEC.
12. Improved **damage assessments** of parchments – IDAP.
13. Innovative modelling of **museum pollution and conservation thresholds** – IMPACT.
14. A light **dosimeter for monitoring cultural heritage**: development, testing and transfer to market – LIDO.
15. **Preventative Conservation Strategies** for Protection of Organic Objects in Museums, Historic Buildings and Archive – MASTER.
16. **Microclimate indoor monitoring** in cultural heritage preservation – MIMIC.
17. **Monitoring of damage** in historic tapestries – MODHT.
18. Model for **multi-pollutant impact and assessment of threshold levels** for cultural heritage – MULTI-ASSESS.
19. **On-site investigation** techniques for the structural evaluation of historic masonry buildings – ONSITEFORMASONRY.
20. Determination of **conditions to prevent weathering due to condensation, particle deposition and micro-organism growth** on ancient stained glass windows with protective glazing – VIDRIO.

Then, under FP6 managed by the Environment Directorate of EC-DG Research Programme ”Specific Support to Policy” (SSP: 2003–07), cultural heritage projects on the topic decay due to environmental and pollution interaction with materials are listed as:

1. **Assessment of air pollution effects** on cultural heritage – CULT-STRAT.
2. **Assessment of desalination mortars and poultices** for historic masonry- DESALINATION.

3. Multifunctional encoding system for assessment of movable cultural heritage – MULTI-ENCODE.
4. **Global climate change impact** on built heritage and cultural landscapes – Noah's Ark.
5. Evaluation of mass **deacidification** processes – PAPERTREAT.
6. Pro-active management of the impact of cultural tourism upon urban resources and economies – PICTURE.
7. **Improved protection of paintings** during exhibition, storage and transit – PROPAINT.
8. **Prevention of salt damage** to the built cultural heritage by the use of crystallisation inhibitors – SALTCONTROL.
9. Sensor system for detection of **harmful environments** for pipe organs – SENSORGAN.
10. Seminars **preventive conservation and monitoring** of the architectural heritage – SPRECOMAH.

In particular, the most recent studies recognized and addressed what the climate and pollutant parameters were with changes over time that have an impact on cultural heritage conservation. (i.e. CARAMEL[55], MULTI-ASSESS[56], CULTSTRAT[57], Noah's Ark[58], etc.) Specifically the following outcomes were evidenced:

- **Atmospheric concentrations of SO_2 and sulphur compounds have been significantly reduced**, thanks to a strict abatement policy applied over the past four decades to polluting combustion and industrial emissions, especially in urban areas. This implies a decline in the role of SO_2 as the controlling factor in the sulphation of carbonate materials and metal corrosion.
- **Pollutant variations**, in particular those related to **NO_x and O_3**, still need to be investigated, since the adoption of overly optimistic forecasts, in terms of pollutant reductions, can underestimate the degradation effect on metals and polymers, especially in urban areas. In addition, increasing account needs to be taken of the role of NO_x and O_3 in SO_2 oxidation and the consequent acceleration of metal and stone damage.
- **Traffic** is the main cause of **urban particulate pollution**, emitting carbonaceous particles mostly in the fine fraction, which are demonstrated to be the driving factor of surface blackening and soiling.
- Even though **elemental carbon (EC)** is recognised to be responsible for the blackening of monument surfaces, its measurement is still far from being a normal procedure adopted to monitor cultural heritage conservation.
- **Organic carbon (OC)** is increasing both in atmospheric carbonaceous particles and in damage layers.

The shift in modern urban atmospheres from an SO_2 dominated situation to a multipollutant situation implies a change in the chemical processes involved in damage layer formation:

- **Modern deposits and damage layers** on monuments are expected to be richer in organic compounds, necessitating an accurate quantification of water soluble and volatile organic compounds (VOCs).
- **A less phytotoxic environment**, due to the decrease of SO_2, and the increased concentration of organic compounds (nutrients) can enhance biological activity and, consequently, the accumulation of biomass on monuments.

[55] http://cordis.europa.eu/project/rcn/54203_en.html
[56] http://cordis.europa.eu/project/rcn/60386_en.html
[57] http://cordis.europa.eu/project/rcn/73914_en.html
[58] http://cordis.europa.eu/project/rcn/73915_en.html

- **Elemental (EC) and organic (OC) carbon** must be measured, as their relative concentration in damage layers is also responsible for colour changes on monument surfaces and the consequent aesthetic impact. In particular, the OC increase will lead to a surface yellowing.

Consequently, the causes of decay and the kind of pollutants affecting indoor and outdoor heritage assets are rapidly undergoing variation, and attention must be focused on new challenges for monuments, complexes and cultural objects. In order to fill this gap, two recent projects, belonging to the 7th FP have been progressed, in particular the Technologies and Tools to prioritize assessment and diagnosis of air pollution impact on immovable and movable Cultural Heritage (TeACH)[59](Ozga et al. 2013, 2011; Strlic et al., 2011). This had as main objectives: the **identifications of the multi-pollutants and the prioritization** of the principal ones; identification of ways of improving the more reliable and efficient among existing technologies and tools, developing new devices and tools, particularly a new a compact and economical kit of instruments; **production of guidelines** for the future prioritization of air pollution and disseminate the results. The second project, SYstem for Digitization and Diagnosis in ART Applications (SYDDARTA)[60], although tested on paintings, developed a methodological approach that can be usefully applied in others sectors. In particular, the production of new portable equipment for use in preventive conservation and the monitoring of movable cultural assets, by the acquisition of 3D-hyperspectral imaging provides useful data sets through using non-destructive scanning techniques.

Resilience strengthening and risk management

In 1979, the Convention of Long-range Transboundary Air Pollution (CLRTAP)[61] established a broad framework for the region of Europe, Central Asia and North America working cooperatively to address the transport of pollutants through the atmosphere and over borders, oceans and continents. The Convention defines the term of "acceptable levels" of air pollutants that damage materials and cultural heritage and proposes rates for certain others, through the International Cooperative Programme (ICP) on the Effects of Air Pollution on Materials, Including Historic and Cultural Monuments (ICP Materials) that started in 1986. With Sweden as lead country 19 parties participate in work, with the purpose of evaluating the effects of air pollutants and climate parameters on the corrosion of important materials, including cultural heritage. Additionally, dose-response functions for evaluating and measuring the effects of pollutants on materials have also been developed (Johansson et al., 2004).

Undertaken within Noah's Ark project for the evaluation of their impact on cultural heritage, the 2020 projection of pollutants (SO_2, HNO_3 and O_3), used the dataset available from the Convention on Long-range Transboundary Air Pollution (CLRTAP) and European Monitoring and Evaluation Programme (EMEP). This incorporates information on the implementation of current legislation (Amann et al., 2004) and changes in emission distributions at a sub-European level. Regarding the longer timescale (i.e. 2085), air pollution projections were developed using the Clean Air for Europe Program (CAFÉ, MFTR=Maximum feasible technical reduction).

Training and Dissemination Actions

Regarding the publications illustrated in Figure 2.7, the volume published by Peter Brimblecombe (2016) on the urban pollution effects on materials and building surfaces is relevant. Specifically considering metallic artefacts Tidblad published work on their

[59] http://cordis.europa.eu/project/rcn/89329_en.html
[60] http://cordis.europa.eu/project/rcn/100977_en.html
[61] Convention on Long-range Transboundary Air Pollution, www.unece.org/env/lrtap

atmospheric corrosion in 2013 (Tidblad, 2013). Four years earlier the same author, with Watt, Kucera and Hamilton, published a volume on the effects of air pollution on cultural heritage (Watt et al., 2009) as final products of the CULT-STRAT project, MULTI-ASSESS, REACH, PPASDC and EAPMBSP projects.

Considering conferences and workshops, the Annual Conference Stone Weathering and Atmospheric Pollution Network (SWAPNET) was initiated in 1999 at the University of Wolverhampton (UK) regularly producing proceedings, with a volume entitled Stone Weathering in Polluted Urban Environments appearing in 2004 (Mitchell and Searle, 2004).A workshop on air pollution and cultural heritage was held in Sevilla (Spain) in 2003 with its proceedings being published (Saiz-Jimenez, 2003).

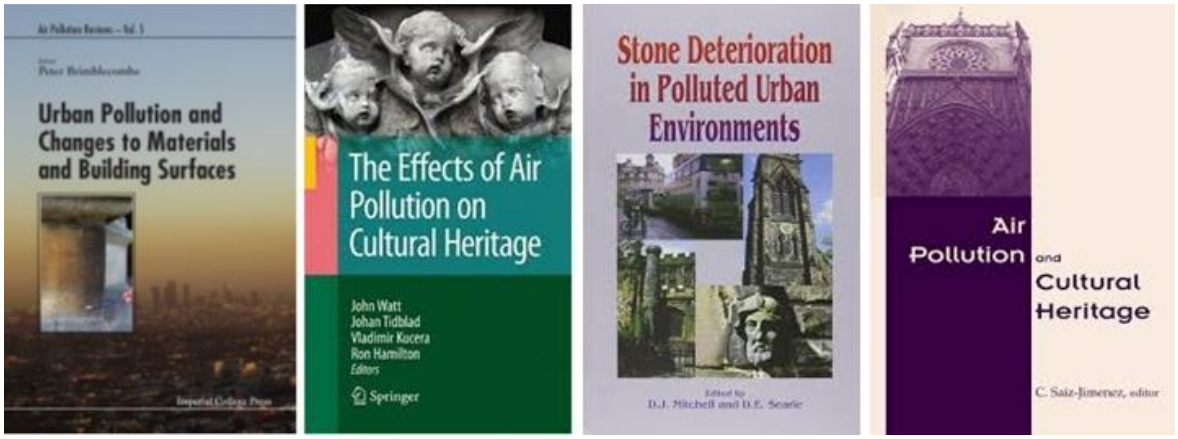


Figure 2.7 Publications on pollution effects to Cultural Heritage, from the oldest to the most recent.

The European Environmental Bureau realized 12 factsheets on air pollution in the EU, including also Air & Cultural Heritage, which easily summarizes, utilizing captivating infographic, as showed below (Figure 2.8)[62].

[62] http://www.cleanair-europe.org/fileadmin/user_upload/redaktion/downloads/EEB/Air_Cultural_Heritage.pdf

Figure 2.8 Example of infographic utilized by the European Environmental Bureau, on the thematic: Air and Cultural Heritage.

Furthermore, mentioned needs to be made of the Norwegian Institute for Air Research (NILU) Air Quality Division whose field of research includes Air quality and Climate effects on materials and cultural heritage sector - especially on the indoor air quality and climate valuation of relative degradation risks for heritage objects[63]. Related to this area of study several research works have been published[64].

Finally, it deserves to be cited the "7 Most Endangered" Programme, launched in January 2013 by Europa Nostra with the European Investment Bank Institute and supported by the Creative Europe Programme[65] of the European Union as part of Europa Nostra's networking project "Sharing Heritage – Sharing Values (2017-2020)". It aims to attract the attention of governments, political and business leader for action and to promote "the power of example". Multidisciplinary teams are identified to asses endangered heritage sites and to support the formulation of feasible action plans for each of them, in close cooperation with national and local public and private stakeholders. The results and recommendations of these missions are summarised in technical and financial Reports[66].

[63] http://www.nilu.no/Forskning/Luftkvalitet/Klimaeffekterpakulturminner/tabid/263/language/en-GB/Default.aspx

[64] http://www.nilu.no/Publikasjoner/tabid/62/language/en-GB/Default.aspx

[65] https://ec.europa.eu/programmes/creative-europe/

[66] http://7mostendangered.eu/reports/

2.3 Flood

Introduction to flood threats and protection

Floods are the most frequent natural disasters that create an increasing adverse impact in urbanized territories. According to data from the International emergency disasters database[67] the number of floods is constantly growing with the highest rate amongst all of the natural disasters, see Figure 2.9. The peak year was in the 2006 with nearly 230 recorded intenational floods. During recent years this number oscillates between 140-160.

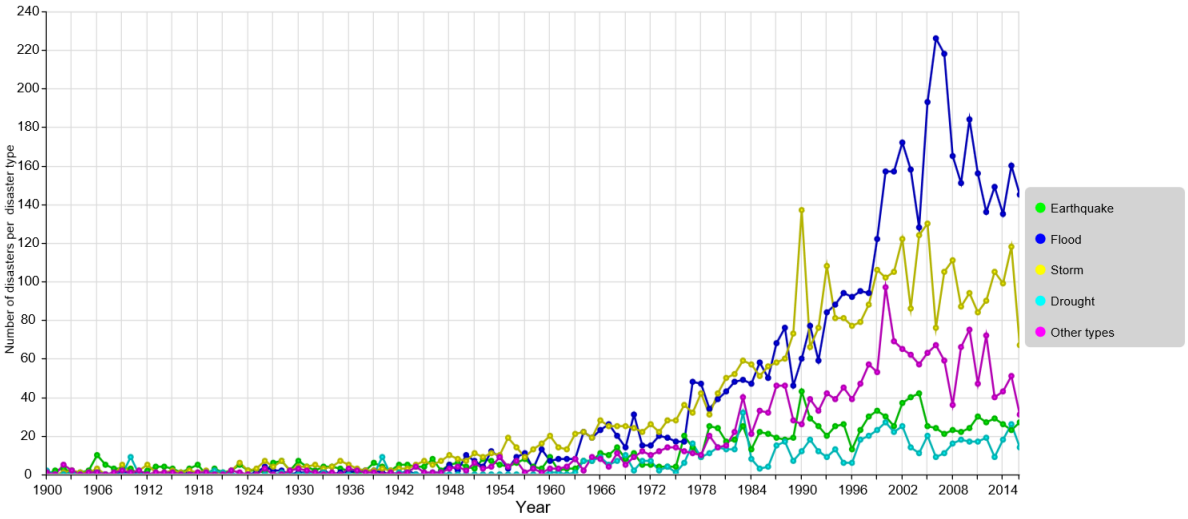


Figure 2.9 Development of number of disasters per year. EM-DAT: The OFDA/CRED International Disaster Database - Universite Catholique de Louvain, Brussels – Belgium.

Total economic damage does not follow the above summary development. The floods in 1990's initiated many flood protection measures, which decreased the total economic damage from a rough average of 40 USD billions per year to less than 20 USD billions per annum during the first decade of the 21st millennium. However, events in recent years has turned the economic damage back to approximately 50 USD billions per annum even though the number of floods have decreased in relation to previous records.

There are **no reliable available data** that would determine the **share of cultural heritage losses**. This is not only due to a **lack of data collecting** and the **logging of damage** on the affected **cultural heritage assets**, but also due to a **lack of methodology for assessing damage** in **monetary terms** that take into account **cultural heritage values**. As a pointer and according to an evaluation of the disastrous flood in the Czech Republic in 2002, the share of damage on cultural heritage was estimated less than 0,5 % of the overall damage of CZK 73,4 billions.

But due to their high economic and social impact floods have been the subject of thorough research in numerous world-wide projects and programmes for several decades. The volume of books, papers, various recommendations and other documents, concerning impact, protection and resilience measures of flood is enormous (Bolt et al., 1997; Casale and Margottini, 1999), unfortunately, this is **without special focus on cultural heritage** issues.

The European Commission have supported several projects generally focused on floods, which have produced many useful documents for flood management, warning, resilience

[67] www.emdat.be/

and training (see below). However, these also have been **without explicit focus on cultural heritage protection** and safeguarding.

But, there is available information on changes in flood risk issues in 12 European countries and two regions. In particular in II National and Regional Perspectives on Floods (Kundzewicz, 2012) involves Austria, Czech Republic, France, Germany, Greece, Iceland, Italy, the Netherlands, Norway, Poland, Switzerland and the UK. In addition, two European regions are reviewed in separate chapters: the multi-national Alpine region and the Iberian Peninsula (Portugal and Spain). These contributions typically report on independently conducted national studies where Regional and national specifics, priorities, and availability of material clearly differ between the countries, hence, no attempt was made to impose a rigid formalism of structure. Any heterogeneity of the material and different perspectives are again incorporated **without any relation to cultural heritage specific features**.

Assessment of the impact of floods on cultural heritage

Floods vary considerably in extent and duration, ranging from small inland or coastal locations, with only a local impact, to disastrous events affecting large territories and several countries. They cause damage and failures due to static and dynamic loads (water pressure, water flow, uplift forces), due to impacts from floating objects, due to wetting of building materials (which are difficult to treat), and due to the effects of soluble salts, chemical pollutants and biological infection. Though floods are usually of short duration, repairing the consequences can take a very long time and require enormous efforts. **Floods can damage or even destroy historic buildings,** infrastructure, cultural landscapes and gardens, and in many cases **also moveable cultural heritage.** Timbers can subsequently rot and masonry materials affected by salt transport can suffer long-term damage, with little possibility of repair and protection. Therefore, activities aiming at **protection of cultural heritage** against flood actions have been supported within several national and international projects.

For example the most important EC FP7 CHEF project (Cultural Heritage Protection against Flood, 2007-2010) (Drdácký et al., 2011) provided **detailed analyses of flood impacts** on **architectural heritage**, **landscape** and **moveable heritage** and generated results focused on all aspects of **cultural heritage damage** (Drdácký, 2010a, b). Similarly, the Czech the Ministry of Culture supported two **national research** projects – Methodology and instruments for protection and safeguarding cultural heritage threatened by floods[68] and Identification of important territories with cultural heritage values endangered by natural and anthropogenic influences[69], which delivered important results applicable in flood management. Those projects were specifically designed to study **complex problems of floods impacting cultural heritage**. Limited **historical data** are available from another project supported from the Grant Agency of the Czech Republic (Brázdil et al., 2006).

Assessment of impact of floods on cultural heritage was analysed in detail in the study prepared for the EU Parliament in 2007 (Drdácký et al., 2007). It took advantage of the largest EC supported integrated project, FP6 FLOODsite[70] - Integrated Flood Risk Analysis and Management Methodologies (2004-2009), which had some sections that took into account **cultural heritage issues** in relation to socio-economic evaluations of flood damage. Further, the national German project DISFLOOD - Disaster Information System for Large-scale Flood Events using Earth Observation (2005-2008) contained

[68] http://www.bh2013.polimi.it/papers/bh2013_paper_335.pdf
[69] https://www.dul-michal.cz/publikace/metodika-hodnoceni-miry-potencialniho-ohrozeni-pamatek-antropogennimi-a-prirodnimi-vlivy.pdf (in Czech)
[70] http://cordis.europa.eu/project/rcn/74268_it.html

elements that supported the **cultural heritage stock at risk inventory** in flooded areas. This project focused on **urban territories** and involved many **historic cities**. Another German URBAS[71] project was concentrating on the urban occurrence of flash floods and was supported by the German Ministry of Research in the framework of the RIMAX project cluster. RIMAX grouped together more than 30 projects that were all investigating aspects of extreme floods in Germany. Case studies involved several **historic cities** and thus indirectly contributed to the cultural heritage protection. A very recent EC FP7 supported project STARFLOOD[72] (2012-2016) generated considerable reports and documents. In some of them **cultural heritage issues** are mentioned, however, **no focused measures are suggested**. (For example, in comparison of approaches in six EU countries: **Prevention** has become the most articulated in discourse in both the Flanders and Walloon regions, and in Flanders it has also been given new regulation, *i.e.* art. 136 **Walloon code of spatial planning, urbanization and cultural heritage**, CWATUP). This project elaborated very detailed and useful analyses of various approach to **flood risk management**[73].

There is still a need to develop maps of the European cultural heritage stock at risk which must be related to existing maps of natural and man-made hazards and potential risks. This will enhance the assessments of the risks, and can help to predict the extent of catastrophic events. Such information is lacking over most of the European territory, though it is a fundamental need for establishing risk management strategies and activities.

Inaddition to Italy some parts of France are also covered by PPR (Plan de Prévention des Risques) **maps**, and the Swiss protection programme includes detailed maps on which inventoried cultural properties are located, depicting properties in both urban and rural settings. However, any financial assessment of disaster impacts on cultural heritage is still not available, and research in this direction would be useful.

An EU Flood CBA[74] (2013-2014) project was aimed at establishing a sustainable **Knowledge Platform** for the use of stakeholders dealing with the **cost-benefit analysis of flood prevention** measures in the context of different socio-economic environments within the EU. Its continuation Flood CBA 2[75] (2016-2017) is a knowledge exchange project, designed to introduce some member states to a more rigorous assessment of flood protection and flood risk management schemes, with an emphasis on both economic efficiency and the maximisation of public safety. The countries involved are the UK, Greece, Portugal and Spain, and the working method is to select case studies in each country to analyse the costs and benefits of flood risk management measures there as a vehicle for training programmes for stakeholders and users of project appraisal techniques and methods. In the UK, Oxford is being used as the case study, illustrating the potential for implementing a major bypass channel to reduce flood risk in the **historic city**, but also the problems of doing so in terms of benefits and costs, stakeholder agreements and funding opportunities. The project is funded from the DG-ECGO (European Commission Humanitarian Aid & Civil Protection)[76].

Recent EU supported projects

The FRAMAB[77] H2020 (2015-2017) project aims to develop novel modelling strategies for **masonry arch bridges** and a comprehensive framework for the flood risk evaluation for these heritage structures. Although masonry arch bridges are very

[71] http://www.urbanesturzfluten.de/project/index_html/view?set_language=en
[72] http://www.starflood.eu/
[73] http://www.starflood.eu/documents/2016/04/comparison-of-countries.pdf
[74] http://www.floodcba.eu/main/
[75] https://www.mdx.ac.uk/our-research/centres/flood-hazard/projects/flood-cba-2
[76] http://ec.europa.eu/echo/index_en
[77] http://cordis.europa.eu/project/rcn/195375_en.html

vulnerable to flood effects, no accurate procedures have been proposed so far to systematically assess the risk of their damage and failure due to flood hazard. The procedures to be implemented into a flood risk assessment framework should combine a realistic description of the hazard (probability of exceeding a given flood discharge) with an accurate assessment of the structural vulnerability (probability of exceeding a given damage level in the bridge components for a flood with a given intensity). The development of such a **risk assessment framework**, which is the main objective of this research, requires a strong multi-disciplinary approach and will entail i) the advancement of computational tools for the response prediction of masonry bridges subjected to flood-induced actions and ii) the accurate propagation of uncertainties inherent in the loading, the problem parameters and the simulation models. In particular with reference to the first point, innovative nonlinear analysis capabilities for masonry arch bridges under flood effects will be implemented within the computational framework already available at Imperial College. This will allow an accurate yet computationally efficient prediction of the **most critical flood-induced actions** (e.g. flow pressure, floating debris impact, scouring). With reference to the second point, advanced probabilistic techniques will be developed to enable the prediction of the effects of the relevant sources of uncertainty on the bridge vulnerability. The project outcomes will contribute to the **preservation of cultural heritage** and to the development of **innovative solutions for reducing the flood risk** of infrastructural systems by promoting the unbiased allocation of the economic resources for flood risk mitigation.

Overall losses due to the large European summer floods of 2013 reached almost 15 billion Euros. H2020 INUNDO[78] - The European Flood Database (2016) provides accurate, current and historical flood spatial information for risk modelling to help **insurance companies** improve their existing **risk assessment** processes. INUNDO fills the geospatial information gap missing in today's risk models and facilitates the impact assessment during and after large flood events. The objective of INUNDO is to create, validate, update, organise, license, and provide access to **geospatial flood disaster information** based on Earth Observations, meteorological data, and social media for the insurance industry to enhance their risk modelling and reduce their expenses.

The overall objective of H2020 FLOOD-serv[79] - Emergency and Awareness SERVice (2016-2019) is to develop and to provide a pro-active and personalised citizen-centric public service application that will enhance the **involvement of the citizen** and will harness the collaborative power of **ICT networks** (networks of people, of knowledge, of sensors) to raise awareness on flood risks and to enable collective risk mitigation solutions and response actions.

H2020 UNEXMIN[80] - Autonomous Underwater Explorer for Flooded Mines (2016-2019) is a project that develops a novel robotic system for the **autonomous exploration and mapping** of Europe's flooded mines. The Robotic Explorer (UX-1) will use non-invasive methods for autonomous 3D mine mapping for gathering valuable geological and mineralogical information. This will open new exploration scenarios so that strategic decisions on the re-opening of Europe's abandoned mines could be supported by actualised data that cannot be obtained by any other ways.

The overall objective of IMPROVER[81] - Improved risk evaluation and implementation of resilience concepts to Critical Infrastructure (2015-2018) is to improve European

[78] http://cordis.europa.eu/project/rcn/207424_en.html
[79] http://cordis.europa.eu/project/rcn/204804_en.html
[80] http://www.unexmin.eu/
[81] http://improverproject.eu/discover/

critical infrastructure resilience to crises and disasters through the implementation of resilience concepts to real life examples of pan-European significance, including cross-border examples. The improvement will arise through the development of a methodology for implementing combinations of societal, organisational and technological resilience concepts to critical infrastructure based on risk evaluation techniques and informed by a review of the positive impact of different resilience concepts on critical infrastructure.

The main strategic objective of EU-CIRCLE[82] is to move towards infrastructure network(s) that is **resilient to today's natural hazards** and prepared for the future changing climate. Furthermore, modern infrastructures are inherently interconnected and interdependent systems; thus extreme events are liable to lead to "cascade failures".

Every major flood provokes the organization of **conferences** frequently printed documentation. Few of these events are **intentionally focused on cultural heritage issues** and the evaluation of protection measures (Will and Lieske, 2015), however, many more events aim at discussing of risk management issues (see below), producing abundant literature on risk management, flood preparedness and protection or mitigation measures.

Estimating the scale of loss and assets in flood danger

No systematically organized collection of data on damage and loss of cultural heritage objects from any natural disaster over Europe exists. In individual countries disaster statistics and their financial impact are created by **Civil Protection** systems and their organizations. The results serve for planning protections measures by owners and stakeholders of cultural heritage assets, e.g. monument management authorities (for examples the National Heritage Institute in the Czech Republic).

A similar situation exists in the assessment of assets under flood threat even though the so called Flood Directive[83] helped in this regard. EU Member States are obliged to elaborate inundation maps in which important objects endangered by flood are displayed. Cultural heritage are among the marked objects, (however, this is mostly recorded without data on their condition and/or value).

Impact assessment is closely linked to **flood (disaster) vulnerability of cultural heritage**. This matter has been analysed in some papers mentioned above in relation to typical high water actions and its effect on materials, structures and landscape (Drdácký, 2010b). The meaning of the vulnerability (Green, 2004) term has changed in recent years from its historic definition, especially when used for **resilience studies**. At present the term means the extent to which a system is **susceptible to floods** due to **exposure**, a **perturbation**, in conjunction with its **ability (or inability) to cope**, **recover**, or **basically adapt**, i.e. mathematically expressed: the Vulnerability = Exposure + Susceptibility – Resilience. **Exposure** is defined as the predisposition of a system to be disrupted by a flooding event due to its location in the same area of influence. Exposure can be understood as the values that are present at the location where floods can occur. These values can be goods, infrastructure, **cultural heritage**, agricultural fields or mostly people. The indicators for this component can be separated in two categories; the first covers the exposure of different elements at risk and the second give details on the general characteristics of the flood. **Susceptibility** relates to system characteristics, including the **social context** of flood damage formation[84]. Especially the awareness and preparedness of affected people regarding the risk they live with (before the flood), the **institutions** that are involved in **mitigating and**

[82] http://www.eu-circle.eu/eu-funded-projects/
[83] http://ec.europa.eu/environment/water/flood_risk/key_docs.htm#Directive
[84] http://unescoihefvi.free.fr/flood_vulnerability_factors.php

reducing the effects of the hazards and the existence of possible measures, such us **evacuation routes** used during floods. An overview to flood vulnerability assessment methods has been published recently (Nasiri et al., 2016).

Probably the most developed country in its availability of data for estimating the scale of possible loss is Italy, a country that owns a significant number of world cultural heritage listed by UNESCO under the Convention concerning the protection of the world cultural and natural heritage as ratified in 1972. The Italian territory is also particularly prone to natural hazards such as landslides, floods, earthquakes, volcanic eruptions, subsidence and coastal erosion, all of which can undermine the protection and preservation of cultural heritage. A recent study was aimed at achieving an estimate of architectural, monumental and archaeological **heritage exposed to landslide and flood risk** at national scale (Spizzichino et al., 2013). Combining input data from the Italian Cultural Heritage database (Carta del Rischio del patrimonio culturale, see section on Climate Change of this Chapter) prepared by ISCR (Central Institute for the Conservation and Restoration), the **Italian Landslide Inventory** (Progetto IFFI, Inventario dei fenomeni franosi in Italia[85]) developed by ISPRA (Italian National Institute for Environmental Protection and Research) and the Regions and Self-Governing Provinces of Italy, and the **flood hazard zones** defined by the Italian River Basin Authorities. Italian landslide inventory contains more than 486,000 landslides affecting an area of about 20,800 km^2, equal to 6.9% of Italian territory. In order to estimate the number and type of cultural heritage at risk some GIS processing has been carried out, overlapping information with the above mentioned databases. The analysis provided the following results: cultural heritage exposed to landslide risk was estimated at 5,511 items (6.6%) whilest the ones exposed to flood risk resulted in 9,859 items (11.7%). Two case studies concerning landslide phenomena affecting important Italian municipalities and the flood risk of historical centre of Rome, have also been analysed.

In addition, an exemplary flood **risk assessment to cultural heritage** was carried out recently in a rich art city of Florence in Italy (Arrighi et al., 2016). The adopted risk assessment method borrows the most common definition of flood risk as the product of hazard, vulnerability and exposure, with some necessary adjustments. The risk estimation is carried out at the **building scale** for the **whole UNESCO site**, which embraces with the historical city centre. A distinction in macro- and micro-damage categories has been made according to the vulnerability of the objects at risk. **Two damage macro-categories** are selected namely **cultural buildings** and **contents**. Cultural buildings are classified in damage micro-categories as churches/religious complexes, libraries/archives and museums. The damages to the contents are estimated for four micro-categories: paintings, sculptures, books/prints and goldsmith's art. Data from hydraulic simulations for different recurrence scenarios, historic reports of the devastating 1966 flood, and cultural heritage recognition sheets allow **estimating** and mapping of the **expected annual** number of works of art **lost in absence of risk mitigation strategies**.

Flood monitoring and early warning systems

The importance of having **effective early warning flood systems** is widely accepted as one necessary **component to manage disaster risk**. Systematic disaster early warning system comprises four key elements: **knowledge of the risks**; **monitoring, analysis** and **forecasting** of the **hazards**; **communication or dissemination of alerts** and **warnings**; and **local capabilities to respond** to the warnings received (Basher, 2006). Any early warning system will only be effective if all components are effective. The subject has been studied and results widely published (Sene, 2008; Wogalter et al., 1999).

[85] http://www.isprambiente.gov.it/it/progetti/suolo-e-territorio-1/iffi-inventario-dei-fenomeni-franosi-initalia

Kevin Sene outlined a short history of developments warning starting with the "introduction of telegraph transmission in the mid to late 19th century, followed by telephone and radio telemetry early in the 20th century, and accelerated in the 1950s and 1960s as the computer and electronic industries developed. Developments have included the introduction of operational computer models of the atmosphere (from the 1950s), weather radar and satellite based observations of rainfall (from the 1970s), and **automated and internet based methods of warning dissemination** (from the1990s). The widespread ownership of televisions, radios and telephones and cell (mobile) phones and computers, has increased the range of methods which can be used for issuing warnings, supplementing traditional door knocking, loud hailer, siren and other techniques".

From October 2012, a special service under the umbrella of the C**opernicus Emergency Management Service**[86]**(CEMS)** became operational for monitoring and forecasting floods across Europe. This first European Flood Awareness System (EFAS)[87] provides early flood warning information to its partners up to 10 days in advance: the National/Regional Hydrological Services and the European Response and Coordination Centre (ERCC[88]). The Operational EFAS consists of four centres executed by different consortia: **EFAS Computational** centre - European Centre for Medium-Range Weather Forecasts[89] (UK) executes forecasts and hosts the EFAS-Information System platform; **EFAS Dissemination** centre - Swedish Meteorological and Hydrological Institute[90], Rijkswaterstaat (NL) and Slovak Hydro-Meteorological Institute[91] analyse EFAS on a daily basis and disseminate information to the partners and the ERCC; **EFAS Hydrological data collection** centre - REDIAM[92] (ES) and ELIMCO[93] (ES) collect historic and realtime discharge and water level data across Europe; **EFAS Meteorological data collection** centre – KISTERS AG[94] and Deutscher Wetterdienst[95] collect historic and realtime meteorological data across Europe.

The CEMS is complementary to national and local **flood warning systems and these efforts** are increasingly considered as part of **multi-hazard response** to natural, technological and other risks. If sufficiently **accurate**, **reliable** and providing **sufficient lead time** the flood warning can be one of the **non-structural measures** which can be used to **manage or reduce flood risk** in river catchments or along coastlines, together with other measures such as land use planning, and tax and insurance incentives to limit development in flood prone areas. A flood warning system can include rainfall and tidal detection systems, river and coastal flood forecasting models, flood warning dissemination systems, and emergency response procedures. Each link in this chain is important, and the modern emphasis is on a **Total Flood Warning System** or **people-centred approach**, in which **communities provide inputs** to the design of flood warning systems, and help with their continuing operation, (e.g. Basher, 2006).

According to Guidelines for Reduction Flood Loss[96], establishing a viable flood forecasting and warning system for communities at risk requires the combination of data, forecast tools, and trained forecasters. A flood forecast system must provide sufficient lead time for communities to respond. **Increasing lead time** increases the potential to lower the level of damages and loss of life. It is important also for **cultural**

[86] http://www.copernicus.eu/main/emergency-management
[87] https://www.efas.eu/
[88] http://ec.europa.eu/echo/en/what/civil-protection/emergency-response-coordination-centre-ercc
[89] http://www.ecmwf.int/
[90] http://www.smhi.se/
[91] http://www.shmu.sk/
[92] http://www.juntadeandalucia.es/medioambiente/rediam
[93] http://www.elimco.com/
[94] http://www.kisters.eu/
[95] http://www.dwd.de/
[96] http://www.un.org/esa/sustdev/publications/flood_guidelines_sec03.pdf

heritage safeguarding as it **prolongs time** for possible **evacuation**. Forecasting must be sufficiently accurate in promoting confidence so that communities will respond when warned. If forecasts are inaccurate, then credibility of the programme will be questioned and no response actions will occur.

Flood management and prevention is at the heart of the Imprints project, which has developed an early warning platform to cut responses to flash floods down to about two hours. The platform is based on better rainfall predictions and uses meteorological models and weather radar networks. The software is able to predict water flows on the ground and provide a full **early warning system for flash floods, the amount of debris** they might carry and any potential damage to local infrastructure.

Meanwhile, WeSenseIt makes good use of the power of human observation as an essential part of an early warning system. People contribute by taking measurements using new apps currently being developed by the project to send **information and images by mobile phone**. The new technologies and approaches are being tested in Italy, Netherlands and the UK.

The UrbanFlood project has developed **integrated sensors** and related technology to monitor flood embankments and provide early warning of their risk of failing. The underground sensors monitor the state of embankments, changes to water levels, and other factors such as temperature, moisture and Earth movements. The information is then assessed by the project's modelling software, which can trigger an alert if a problem is detected. **The software calculates how fast the site will be flooded if the dam fails and even suggests the best ways to move citizens to safer areas.**

The above mentioned guidelines provide detailed recommendations for establishing warning systems. A need for the creation of a Centre for warning is underlined. Similarly detailed advice is given in a Flash Flood Early Warning System Reference Guide[97].

Good practice and **case study** examples should be analysed for possible implementation in the **protection of cultural heritage**. For example, Australia has successfully implemented a telephone based community warning system that enables its emergency services in any life-threatening situation to send warning messages by fixed line and mobile telephones to the public in the affected area. The system is the only one in the world that is fully inclusive. Everyone with access to a telephone in Australia, whether at home, travelling or an international visitor roaming on Australia's mobile phone networks has the capability as standard to receive a location based warning[98].

It should be mentioned that the **UN** supported Hyogo Framework for Action (2010 – 2015)[99] made early warning a Priority for Action and the Post 2015 framework for Disaster Risk Reduction is expected to continue this focus "Continuing to further strengthen early warning systems and tailoring them to users' needs, **including social and cultural requirements**".

The January 2018 **release in error** of an electronic warning that an in-coming ballistic missile attack on Hawaii was imminent, and that the population should take immediate cover, illustrates, however, that there are lessons to be learnt from this mistake in how to make such warning systems robust, fool-proof and totally reliable.

[97] COMET. Warning dissemination & notification. In: Flash Flood Early Warning System Reference Guide. [online]. Boulder (CO): University Corporation for Atmospheric Research, 2010. 6.1-6.16. ISBN 978-0-615-37421-5. http://www.meted.ucar.edu/communities/hazwarnsys/ffewsrg/FF_EWS.Chap.6.pdf

[98] http://wp.preventionweb.net/wcdrr/wp-content/uploads/sites/2/Australian-Case-Study-Emergency-Alert-FINALSUBMITTED-TO-UNISDR.pdf

[99] https://www.unisdr.org/we/coordinate/hfa

Resilience strengthening and risk management

Resilience is defined as "the capacity of a system to endure any perturbation, like floods, maintaining significant levels of efficiency in its social, economical, environmental and physical components".

Resilience to flood damages can be considered only **in places with past events**, since the main focus is on the experiences encountered during and after the floods.

Hyogo Framework for Action (HFA) has a continuation in the Sendai Framework for Disaster Risk Reduction 2015-2030[100]. This UN initiated document represents a further step in safeguarding cultural heritage during disastrous situations and supporting resilience. It preserves the HFA principles namely by statement that "managing the risk of disasters is aimed at protecting i. a. **cultural and environmental assets**…" In its priority 1 focused on risk understanding the generation of necessary data is ensured: *(d)* "**Systematically evaluate, record, share and publicly account for disaster losses** and understand the economic, social, health, education, environmental and **cultural heritage impacts**, as appropriate, in the context of event-specific hazard-exposure and vulnerability information". Further, in priority 3 which invests risk reduction for resilience it demands "*(d)* protect or support the **protection of cultural and collecting institutions** and other **sites of historical, cultural heritage** and religious interest".

Flood risk management has a longer history and development based on serious national or international – mostly EC supported – research (*Einfalt et al., 2009; Samuels et al., 2009)* and lessons from historic floods (*van Alphen et al, 2006;* Saul, 1992*)*. Even cultural heritage protection against natural disasters including flood has been treated in proceedings of a workshop organized by **Council of Europe** in Ravello[101]. Later other international organizations and national governmental bodies have issued **guidelines, conventions and national action plans on risk management of cultural heritage** against different types of natural hazards and man-made disasters.

Historically one of the most important documents Risk Preparedness: a Management Manual for World Cultural Heritage was prepared jointly by **ICCROM, UNESCO, ICOMOS** and **WHC** and edited in ICCROM in 1998 (Stovel, 1998). This publication took advantage of previous declarations on risk preparedness held in Quebec (1996 – 1st National Summit on Heritage & Risk Preparedness), in Kobe and Tokyo (1997 – Kobe/Tokyo Declaration on Risk Preparedness for Cultural Heritage) and Declaration of Assisi (1998). In all these activities input by the International Committee of the Blue Shield (ICBS) was substantial. The **ICOMOS Documentation Centre** completed the Manual with bibliography on risk preparedness – heritage at risk[102]. In 2010 other guidelines on Managing Disaster Risks for World Heritage[103] were published jointly by UNESCO WHC, ICCROM, ICOMOS, IUCN (International Union for the Conservation of Nature). It can be seen therefore that the World Heritage stock at risk attracts the attention of professionals to write guidelines and recommendations for their protection and safeguarding. This is understandable, nevertheless, the **objects of UNESCO listed heritage under threats** from **natural hazards** represent **only about 0,2% of the total World Heritage** (Matiz López, 2016). However, taking into account **all protected cultural heritage**, the situation may reach **much higher values**, (see Will and Lieske, 2015).

[100] http://www.ifrc.org/docs/IDRL/Sendai_Framework_for_Disaster_Risk_Reduction_2015-2030.pdf
[101] La protection du patrimoine architectural contre les désastres naturels en Europe, Patrimoine architectural No. 21, Lés editions du Conseils de l´Europe, 1992, 110 p., ISBN 92-871-2004-8
[102] http://www.icomos.org/centre_documentation/bib/riskpreparedness.pdf
[103] http://whc.unesco.org/uploads/activities/documents/activity-630-1.pdf

In 2004 the EU issued Communication[104] from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions - **Flood risk management - Flood prevention, protection and mitigation was** still **without an explicit inclusion of cultural heritage** amongst protected priorities, even though natural conservation was included. Flood risk management aimed to reduce the likelihood and/or the impact of floods. The recommended approach was based on the development of flood risk management programs incorporating the following elements:

Prevention: preventing damage caused by floods by avoiding construction of houses and industries in present and future flood-prone areas; by adapting future developments to the risk of flooding; and by promoting appropriate land-use, agricultural and forestry practices;

Protection: taking measures, both structural and non-structural, to reduce the likelihood of floods and/or the impact of floods in a specific location;

Preparedness: informing the population about flood risks and what to do in the event of a flood;

Emergency response: developing emergency response plans in the case of a flood;

Recovery and lessons learned: returning to normal conditions as soon as possible and mitigating both the social and economic impacts on the affected population.

However, later **European Commission** activity contributed substantially to the **protection of cultural heritage against flood** when it issued the **Directive 2007/60/EC** of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks – so called Flood Directive. In its Chapter IV, Article 7(2) Member States are asked to establish appropriate objectives for the management of flood risks for the areas identified under Article 5(1) and the areas covered by Article 13(1)(b). It aims at reduction of potential adverse consequences of flooding for human health, the environment, **cultural heritage** and economic activity, and, if considered appropriate, on non-structural initiatives and/or on the reduction of the likelihood of flooding. The supporting viewer[105] shows the **authorities** which are **responsible for the implementation of the Floods Directive** in all EU Member States.

This Flood Directive (FD) is applied in three stages:

Stage I: Preliminary flood risk assessment (Articles 4 and 5 of the FD)

The first stage of the FD has come and gone: a preliminary flood risk assessment had to be carried out by the MSs for each of their river basin districts by 22 December 2011. The assessment had to be based on available or readily derivable information, such as records and studies on long-term developments. The assessment of the potential adverse consequences of future floods, which cannot be derived from floods that have occurred in the past, was optional. The preliminary flood risk assessment has to be reviewed, and if necessary updated, by 22 December 2018 and every six years thereafter (Article 14.1 FD).

Stage II: Flood hazard maps and flood risk maps (Articles 6 and 7 of the FD)

The second stage, which had to be completed by 22 December 2013, is the drafting of flood hazard maps and flood risk maps for the areas with potential significant flood risks. These maps must be reviewed, and if necessary updated, by 22 December 2019 and every six years thereafter (Art. 14.2 of the FD). The flood hazard maps cover

[104] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52004DC0472
[105] http://www.eea.europa.eu/themes/water/interactive/floods-directive-viewer

geographical areas, which could be flooded according to three scenarios (Art. 6.3 of FD). No requirement concerning cultural heritage is expressed here but the following Stage III supposes availability of data on cultural heritage flood hazards and risks.

Stage III: Flood Risk Management plans (Articles 7 and 8 of the FD)

The third stage contains the preparation of Flood Risk Management plans. These plans had to completed and published by 22 December 2015 and be reviewed, if necessary updated, by 22 December 2021 and every six years thereafter (Art. 14.3 of the FD).

The MS must establish Flood Risk Management plans for each river basin district. The basis of these plans should be provided by the flood hazard maps and the flood risk maps. In the Flood Risk Management plans the MSs have to establish "appropriate objectives for the management of flood risks" for the areas with potential significant flood risks. The focus hereby must be on "the **reduction** of potential **adverse consequences of flooding** for human health, the environment, **cultural heritage** and economic activity, and, if considered appropriate, on non-structural initiatives and/or on the reduction of the likelihood of flooding". The measures for achieving these objectives must also be included in the plans. Where **international river basin districts** (IRBDs) fall entirely within the territory of the EU, the MSs should aim to draft a single **international Flood Risk Management plan**, or a set of Flood Risk Management plans coordinated at the level of the IRBD (Art. 8.2 of the FD). However, if the MSs are not able to produce such plans, they should produce Flood Risk Management plans covering the part of the IRBD located within their territory, and as far as possible coordinated at the level of the IRBD (Art. 8.2 of the FD).

Article 10 of the FD states that "In accordance with applicable Community legislation, Member States shall make available to the public the preliminary flood risk assessment, the flood hazard maps, the flood risk maps and the flood risk management plans." Furthermore, "Member States shall encourage active involvement of interested parties in the production, review and updating of the flood risk management plans". Thus, **public participation** can and ought to take place during **every phase of the implementation of the FD**. The format in which this should take place, however, is not specified.

According to the Floods Directive (2007/60/EC), Member States had to prepare their Preliminary Flood Risk Assessments (PFRAs) and Flood Hazard & Risk Maps (FHRMs) before 22 December 2011 and 22 December 2013 respectively. Furthermore, according to Article 10, Member States should make available to the public the preliminary flood risk assessment, the flood hazard maps, the flood risk maps and the flood risk management plans. Overview reports on both the PFRA and FHRM were issued in 2016[106]. They underline contents of the Flood Risk Management Plans (FRMPs) that must set out appropriate objectives for the management of flood risk within the areas covered by the plan. The objectives must focus on **reducing the adverse consequences of flooding for** human health, the environment, **cultural heritage** and economic activity. **Cultural heritage** is also amongst the aspects which are to be included in the **preliminary assessment of the risk of flooding** as one of the special tasks along with Human Health, Environment and Economic activity. The potential adverse consequences on cultural heritage were considered in the risk maps produced by Member States. Cultural heritage could be reported generically or it could be disaggregated into cultural assets such as archaeological sites/monuments, architectural sites, museums, spiritual sites and buildings or landscape and other cultural heritage. **Only 13 out of the 27 Member States** reported **adverse consequences on cultural assets**, **6 with adverse consequence on landscape**.

[106]http://ec.europa.eu/environment/water/flood_risk/pdf/pfra_reports/EU%20PFRA%20Overview%20Report.pdf

There are some problems with collection of data because, for example, cultural heritage sites are said to be included in flood maps in AT, CZ, FR, HR, IE (maps being developed), NL, PL and UK, though these consequences were not reported to Water Information System for Europe.

Specific flood related issues are mostly treated in specialized books or reports analyzing major disasters. They **seldom concern cultural heritage protection**. Nevertheless, **cultural resilience is understood as a European feature**: „Cultural factors are critical. In the UK, traditionally, the stated objective in public policy has been to determine the national or public interest. Conversely, in much of continental Europe, the aim is social solidarity (Pender and Faulkner, 2011; Consedine and and Bowen, 1999).

Following the 2005 tragedy of Hurricane Katrina the U.S. Army Corps of Engineers asked ASCE to convene a panel of experts to provide an objective review of the findings of the Corps's Interagency Performance Evaluation Task Force (IPET). The IPET was established by the Corps to conduct a federal investigation into the failure of the New Orleans hurricane protection system during and following the Hurricane. Following the review, the ASCE External Review Panel (ERP) prepared the report The New Orleans Hurricane Protection System: What Went Wrong and Why (ASCE 2007)[107]. This study culminated in identifying 10 critical actions: 1. Keep safety at the forefront of public priorities. 2. Quantify the risks. 3. Communicate the risks to the public and decide how much risk is acceptable. 4. Rethink the whole system, including land use in New Orleans. 5. Correct the deficiencies. 6. Put someone in charge. 7. Improve the interagency coordination. 8. Upgrade engineering design procedures. 9. Bring in independent experts. 10. Place safety first. The report considers the **risk to cultural heritage** as the chance that a community will **lose tangible or intangible** attributes of their culture due to flooding.

Hurricane Sandy further initiated a further relevant and useful report (Traver, 2014) with the following conclusions. Now is the time to accelerate progress and move aggressively forward to address the challenges of flood risk management. To do so the nation must:

- Develop a unified national (not federal) vision and supporting organizational framework for flood risk management.
- Define, apply, and evolve best practices in flood risk management.
- Identify and communicate flood risks to all affected parties.
- Provide adequate resources to support flood risk reduction strategies.
- Focus attention on the challenge of flood risk management and its evolution.

For the general management of flood risks the previously mentioned STARFLOOD project supported under the EC FP7 generated many useful deliverables[108]. It should be noted that flood risk management is an integral part of integrated river basin management, and the Floods Directive shall therefore be coordinated with the **Water Framework Directive**[109]. Further, **Civil protection** is also a **crucial component of flood risk management**.

[107] https://biotech.law.lsu.edu/katrina/reports/ERPreport.pdf
[108] http://www.starflood.eu/faqs-2/
[109] http://ec.europa.eu/environment/water/water-framework/info/intro_en.htm

In Europe specific guidelines were issued in Switzerland in which an **inventory of landscape** and **nature conservation** requirements was included[110]. However, the measures focused on **cultural heritage** were mostly the result of discussions and proceedings emanating from **specialised conferences and workshops** [111] (Meier et al., 2008) in addition to individual papers (Drdácký and Slížková, 2012).

In disaster risk management **insurance companies** play important roles **mostly outside Europe**. Their reports provide data on insured costs and also contain recommendations for prevention measures, such as the Australian Zürich Insurance report on storms and flood (Hancock and Rea, 2013).

The majority of guidelines issued by international organizations help to safeguard architectural heritage. The **Getty Conservation Institute** has prepared a useful guide for museums and galleries (Dorge and Jones, 1999), which helps to create emergency plans – a substantial and necessary general risk preparedness and management tool. Based mainly on Australian and USA experience, Kay Söderlund Consulting Pty Ltd. designed very detailed guidelines (Söderlund, 2000) for **small museums**. In Australia the Blue Shield (ICBS) is also very active in contrast to other part of the World. ICBS was created in July 1996 from the activities and ideas of the International Inter-Agency Task Force IATF for Risk Preparedness for Cultural Heritage that, was initiated by UNESCO, ICCROM, ICOMOS[112], ICOM[113], ICA[114], IFLA[115] and other organizations in 1994. The ICBS acts internationally, mainly outside the EU, and its involvement has been important both in natural emergencies and in war emergencies. Working nationally, in some countries ICBS help identify built cultural heritage with a special sign, or providing assistance to museums in preparing emergency plans. ICBS national committees act as important partners to the **national rescue systems** providing **professional advice in emergency situations**, organizing education, training and workshops and issuing publications and emergency manuals.

ICBS brings together five international organizations (CCAAA - Co-ordinating Council of Audiovisual Archives Associations, ICA, ICOM, ICOMOS and IFLA), and it has a structure that could be developed for educational and awareness-raising activities in the EU. They operate within the framework of some of the funding bodies, where their International Committee for Museum Security (ICMS)[116] is quite active.

Resilience is or was previously supported by several EU projects. FLOODIS[117] (2013-2015) features three kind of map products: (i) flood delineation **maps** that are **automatically fetched** from **Copernicus EMS** and dynamically visualized on a map; (ii) flood nowcast maps that are created from crowdsourced reports; (iii) and flood forecast maps that are based on a 2-D flood model (LISFLOOP-FP) taking into account EFAS sensor forecasts and the Corine Land Cover. Both nowcast and forecast are computed considering elevation making use of a Digital Elevation Model.

A new project has been founded by the European Commission under the H2020 Secure Society work Programme (DRS-1-2015) that further extends the FLOODIS approach to all phases of the emergency and covers multiple type of hazards. It is I-REACT: Improving Resilience to Emergencies through Advanced Cyber Technologies (2016-

[110] https://www.swv.ch/Dokumente/Empfehlungen2C-Richtlinien-28Download-Ordner29/Wegleitung-Hochwasserschutz_BAFU.pdf
[111] http://cordis.europa.eu/project/rcn/195375_en.html
[112] International Council on Monuments and Sites
[113] International Council of Museums
[114] International Council on Archives
[115] International Federation of Library Associations and Institutions
[116] http://user.chollian.net/~pll/public_html/icms
[117] http://www.floodis.eu/

2019)[118]. The proposed system targets public administration authorities, private companies, and citizens in order to provide increased resilience to natural disasters though better analysis, **anticipation, effective and fast emergency response, increased awareness and citizen engagement**. I-REACT integrates existing local and European services into a platform that supports the entire **emergency management cycle**. Leveraging on innovative cyber technologies and ICT systems, I-REACT will enable early planning of disaster risk reduction actions, achieve effective preparedness thanks to risk assessment and early warnings, and efficiently manage emergency responses by empower first-responders with up-to-date situational information and by engaging with citizens through crowdsourcing approaches and social media analysis. I-REACT will **integrate multiple systems and European assets**, including the Copernicus Emergency Management Service, the European Flood Awareness System (EFAS), the European Forest Fire Information System (EFFIS), and European Global Navigation Satellite Systems (E-GNSS), such as Galileo and EGNOS.

Training and dissemination actions

Communication and dissemination has been recognised as a key component that lacks sufficient attention and this creates in a huge gap between the information produced by national level forecasting agencies and that actually received and acted upon by the flood affected communities. However, many references exist – from PhD Thesis (for example van Herk, 2014) through books and papers (e.g. Lin Moe and Pathranarakul, 2006) to practical guidelines and training programmes, these are generally informative. In 2013 UNISDR (United Nations International Strategy for Disaster Reduction) supported a very useful training programme[119] that prepared professionals and volunteers for risk and assessment mapping of impacts, unfortunately without any cultural heritage specialisation. Similarly other international projects such as EURANED (Barteleit, 2009) and EVANDE[120] take into account typical aspects of disaster prevention and protection measures without any cultural heritage interest.

It seems that, yet again, the most useful activities are related to local or regional events to give a special focus to cultural heritage protection. Case studies and demonstration and verification activities created a local level shown to bring about the most effective results. These help to develop alternative and innovated approaches (Ortiz et al., 2016). The Czech Ministry for Environment, with financial support of the EU Cohesion Fund issued a booklet (Dráb et al., 2014) on anti-flood measures to protect cultural monuments, together with a CD-ROM presenting anti-flood measures in seven selected historic cities of national or international significance (UNESCO list).

[118] http://cordis.europa.eu/project/rcn/203294_en.html

[119] UNISDR. International training programme on flood risk mapping and modeling and assessment. http://www.unisdr.org/we/inform/events/33552

[120] EVANDE - Enhancing Volunteer Awareness and education against Natural Disasters through E-learning. Civil protection volunteers and local authorities staff training. Floods. Course 6: Recovery, 2016. http://evande.coursevo.com/?course_id=266

2.4 Landslide

Introduction to landslide threats and protection

Landslides are a complex-disaster phenomenon that can be caused by earthquakes, volcanic eruptions, sustained or heavy rainfall (typhoons, hurricanes), large snowmelt, unregulated anthropogenic developments, mining, and other factors such as volcanic eruptions and human activities. Landslides may also result from natural weathering and, therefore, can occur almost everywhere in the world. They most commonly impact onresidents living on and around slopes and are a natural phenomenon that can only be effectively studied in an integrated, multi-disciplinary fashion, that includes contributions from different natural and engineering sciences (earth and water sciences), and various social sciences. This is because landslides are **strongly related to cultural heritage** and the environment.

The socio-economic impact of landslides on the world population are dramatic (Canuti et al., 2000). Loss of lives and high economic damage accompany these natural phenomena each year. In spite of the recent scientific and technical progress the effects of climate change seems to be accelerating this negative trend, although not all parts of the world are equally endangered. Hotspot regions with a moderate to very high hazard of landslide disasters are mostly concentrated in high mountainous areas (Nadim et al., 2005).

Fast slope movements and debris flows are often caused by rainfall. Infiltrated water causes a reduction in the confining stresses in the ground (suppression of capillary cohesion) and changes the drained behaviour into an undrained one (Anderson, Sitar 1995). Additionally, water flowing downhill introduces seepage forces parallel to the slope surface, further contributing to the destabilization. Nevertheless, long-term and relatively slow slope movements also often correlate with rainfall regimes and piezometric groundwater levels. A common case is the reactivation of a pre-existing landslide event.

Various types of slope instabilities can be distinguished according to the type of movement and material. Falls are abrupt movements of geological masses of materia, such as rocks and boulders that become detached from steep slopes or cliffs. They are strongly influenced by gravity, mechanical weathering, and the presence of interstitial water. Rockfalls can be induced by climatic factors, such as heavy rainfalls, thawing and freeze-thaw cycles. Although many types of mass movements are included in the general term "landslide", the more restrictive use of the term refers only to mass movements, where there is a distinct zone of weakness that separates the slide material from more stable underlying material.

The two major types of slides are rotational slides and translational slides. There are also three basic categories of flows that fundamentally differ from one another. A debris flow is a form of rapid mass movement in which a combination of loose soil, rock, organic matter, air, and water is mobilized as a slurry that flows down slope. Debris flows include <50% fines and are commonly caused by intense surface-water flows, due to heavy precipitation or rapid snowmelt, that erodes and mobilizes loose soil or rock on steep slopes. Earth flows have a characteristic "hourglass" shape. The slope material liquefies and runs out, forming a bowl or depression at the head. The flow itself is elongate and usually occurs in fine-grained materials or clay-bearing rocks on moderate slopes and under saturated conditions. A mudflow is an earth flow consisting of material that is wet enough to flow rapidly that contains at least 50% of sand, silt, and clay-sized particles.Assessment of the impact of landslides on cultural heritage

Assessment of the impact of landslides on cultural heritage

There were numerous national and international research projects on landslides that cannot be all listed here. A cooperative scheme of United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Union of Geological Sciences (IUGS) called International Geological Correlation Programme (IGCP) exists. Since 1998 its IGCP-425 project has dealt with **Landslide Hazard in Cultural Heritage Sites** (Sassa et al., 2000a, b). The IGCP-425 structure is based on the results of national projects involving over 50 national and regional institutions and universities. It contributed to the development of a public access landslide database in Japan that enables data sharing between various interest groups (SLIDELinks). In 2002 IGCP-425 also initiated the creation of the International Consortium on Landslides that transformed into a profit lobby organization[121]. It promoted the 2006 Tokyo Round Table Discussion Strengthening Research and Learning on Earth System Risk Analysis and Sustainable Disaster Management within UN-ISDR as Regards Landslides and established the dynamic global network of the International Programme on Landslides (IPL) at the United Nations University, Tokyo, to formulate a framework for cooperation and identified focus areas to reduce worldwide landslide risks.

The emerging Tokyo Action Plan[122] in 2006 was adopted as a summary of the meeting, to be implemented within the scope of the Hyogo Framework. This plan included in its development a **vulnerability assessment** to consider human life, land resources, structures, infrastructure, and **cultural heritage**. It was also intended to contribute to Global Landslide Issues through the IPL mobilization of global cooperation to strengthen research and learning on risk reduction for landslides and related earth system **disasters at sites** of **great concern to the global community**, such as Macchu-Picchu, the Kashmir, Central Asia high mountainous area, and Bamiyan.

In 2011 IPL joined 42 projects promoted by the IPL Global Promotion Committee (UNESCO, WMO, FAO, UNISDR, UNU, ICSU, WFEO and ICL) through the 2006 Tokyo Action Plan. Activities involved organizing the World Landslide Forums (Sassa et al., 2013a) with the fourth WLF in May 2017 dealing with The 2017 Ljubljana Declaration on Landslide Risk–Contributing to the Sendai Framework for Disaster Risk Reduction. It will also discuss strengthening Intergovernmental Network and the International Programme on Landslides (IPL) for ISDR-ICL SENDAI PARTNERSHIPS 2015-2025 for global promotion of understanding and reducing landslide disaster risk. For the upcoming WLF5, the concept of a Kyoto 2020 Commitment of the World Landslide Community has been prepared (Sassa, 2017).

Many cultural monuments and sites are located in mountainous regions, where landslides pose a major threat. The 2002 UNESCO conference World heritage mountain cities and natural hazards was organized in Chambery, France. It brought together various stakeholders in the exchange of information and experience, and examined possible ways for future world-wide cooperation that also helped to involve cultural heritage in the initiative.

ProVention Consortium of the World Bank started a collaborative project in 2001 on the Identification of Global Natural Disaster Hotspots. The contributing members were Columbia University, Norwegian Geotechnical Institute and UN Environmental Program (UNEP). One output is a **general landslide hazard map** of the world (van Herk, 2014).

Examples of rock deformations affecting **cultural heritage** objects are included in the book Progress in Landslide Science (Sassa et al., 2013b), describing in one chapter only 7 cases from Slovakia. K. Sassa also reported on activities for **landslide risk**

[121] http://icl.dpri.kyoto-u.ac.jp

[122] http://iclhq.org/Tokyo_Action_Plan.pdf

assessments at three major cultural heritage sites in China (Lishan, Xian), Peru (Machu Picchu), and Japan (Unzen volcano) (Sassa, 2015). Since 1991 a series of studies have been conducted at these locations as part of the International Decade for Natural Disaster Reduction (IDNDR), the International Geoscience Programme (IGCP) and the International Programme on Landslides (IPL). The success of the landslide hazard assessment at the Xian cultural heritage site in China greatly contributed to the establishment of ICL and IPL.

A number of **historical sites endangered by landslides** has been documented in Italy (AGI 1991): In Agrigento, the pre-roman Temple of Hera is located on a slope disturbed by a landslide with a deep slip surface in a stiff blue clay formation covered by a calcarenitic plateau. The historical town Civita di Bagnoregio is located on a hill of pyroclastic soils with upper layers of over consolidated clays. The erosion of the surrounding valley increases the steepness of the slopes, resulting in a critical stability of the perimetrical buildings. Similar problems are encountered in the town of Voltera and at the Fiorenzuola di Focara Castle standing on a hill scoured by the Adriatic Sea. Clay slopes affected by landslides touch the historical town of Orvieto founded on a protruding tufaceous slab. Further problematic fields include instability, toppling and weathering of rock slopes (Tommasi et al., 2005; Canuti et al., 2003).

In Bulgaria, several cultural heritage monuments are threatened by the deterioration of rock slope formations and by landslides in deluvial slopes (Konstantinov et al., 2003). In Slovakia, many medieval castles suffer from creep movements of rock blocks resting on weak claystone strata (Vlčko, 2004; Vlčko and Holzer, 1999;). Such processes also endangers the World Heritage village of Hallstatt in Austria (Ehret et al., 2005). In Spain, seepage and erosion of the 65 m high conglomerate cliff at Alhambra the outer walls of the castle are approaching the cliff edge with an average velocity of 8 cm/year (Justo et al., 2005). The present horizontal distance amounts to 24 m but a high risk of a potential landslide induced by an earthquake also exists. The instability of the Lishan slope in China was created by subsidence due to strong groundwater pumping with a negative impact on the Huaqing Palace from the Tang dynasty.

Slope deformation also correlates with precipitation. Movement of the hill of Changunarayan Temple in Nepal, a UNESCO World Heritage Site since 1979, is causing twisting and tilting of the masonry walls (Shrestha, 2005). This movement has been probably activated by river and surface erosion, sand mining and changes in the groundwater level in the lower part of the hill that is composed of loose alluvial deposits. The World Heritage Inca Citadel at Machu Picchu in Peru is also threatened by mass movements (Lin Moe and Pathranarakul, 2006). Several systems of rock discontinuities and river erosion at the toe of the hill creates the risk of block sliding that could destroy the site. Locke Island on the Columbia River (U.S.) is a National Monument containing prehistoric village sites. Due to intensive irrigation, erosion of the river shoreline creates landslides that are affecting the archaeology (Poston et al., 2004). In addition, the salmon habitats are also negatively influenced by partial river blockages.

Earthquakes contribute to slope movements by producing horizontal acceleration forces. Besides water infiltration into slopes, earthquakes can be considered as a major triggering factor for the initiation of landslide. In Japan, during earth shaking, an ancient tomb embankment was displaced by more than 2 m and cracked due to sliding on an almost horizontal surface (Shuzui and Kamai, 2004).

These examples show that a threat of landslide and other earth or rock failure phenomena can endanger or damage cultural heritage. In common with other natural disasters, no systematic collection of relevant data is available.

GIS methods brought rapid progress into **hazard assessment and mapping**. Usually, they are based on multivariate statistics revealing the most important impacts and assigning probabilities to them. These impacts can include geometrical

characteristics (slope inclination, height, position, surface), geological and hydrological conditions or climatic data. Two study in Germany and New Zealand, respectively, found that **slope angle, slope position, soil type and rainfall probability** are the most important factors (Glade, 2001). Prediction can be improved further by including historical data. A detailed GIS analysis was done of the Piemonte region (Colombo et al., 2005) in Italy that includes a more specific description and classification of slide mechanisms, and the GIS database is coupled with a monitoring network warning system.

There is no inventory of cultural heritage items endangered by landslide and similar phenomena covering Europe. The recent Itallian study (mentioned above), discovered that listed and legally protected cultural heritage exposed to landslide risk amounts to 5,511 items (6.6%). However, it is still accepted that "effective risk management of cultural assets is rare because of **inadequate knowledge of the assets**, **failure to calculate the true cost** of loss and damage, and **difficulty in putting a value on the non-market nature of many cultural heritage values**" (Taboroff, 2000).

Landslide monitoring and early warning systems

The study of archive data on stability of landslide prone areas is a basic monitoring step and a useful source of information (Agostini et al., 2002).

Proposals exist for early warning systems in case of large fast earth movements depending on rainfall intensity (Figure 2.10), accumulated rain and period of rain (Marín-Nieto, 2005). On understanding the principles of pore pressure evolution in a slope a warning system, based on monitoring water content in the soil, can be designed (Orense et al., 2005). The key issue is the application of the critical relationship between hourly rainfall (mm/h) and accumulated rainfall (mm).

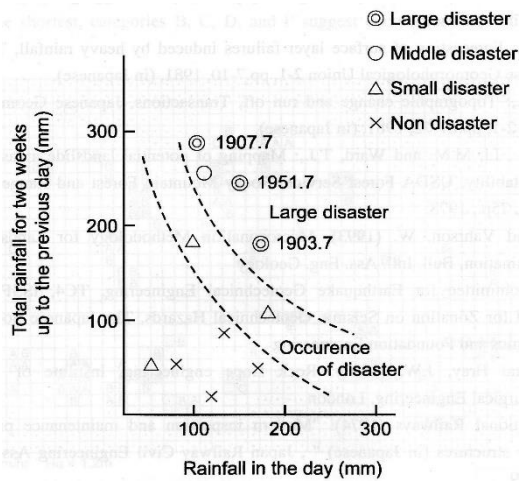


Figure 2.10 Landslide risk related to increased rainfall.

Further factors include slope geometry, soil type, permeability and penetration resistance.

Studies of landslide activities show that the trigger factors are the amount of rainfall on the day of the landslide and the total rainfall over the previous two weeks. However, more realistic methods incorpoarate other factors in the evaluation, especially soil type (at least sandy versus cohesive, or soil permeability) and slope inclination.

It is interesting to reflect on the experience of ancient people residing in regions endangered by mudflows due to intensive rainfall (El Niňo) built protection dams up to

a height of 2 m over the length of several kilometers as a protection. (Brooks et al., 2005).

Training and dissemination actions

Due to the location of potential landslides the public can be trained for emergency situations. It is desirable that all countries have landslide risk maps integrated with locational maps of their cultural heritage stock that is at risk. Landslides usually do not cross state borders and can be managed on a regional level, although international consulting centres, training and demonstration programmes are available.

EU is paying attention to the improvement of disaster data supply, and the **Disaster Risk Management Knowledge Centre**, launched in September 2015, provides EU Member States, and the Disaster Risk Management community, with an **online repository of disaster related research results** and **access** to a range of **networks and partnerships**. A technical support system helps EU Member States carry out **assessments of risks and risk management** capability.

2.5 Wind Risk

Introduction to the wind and storm threats

Natural disasters present a major threat to cultural heritage. Flood, earthquake, fire, wind, environmental fatigue and related long-term climatic effects can cause irreversible damage to that heritage or completely destroy entire areas of it, both movable and immovable. Many heritage objects are also further impaired by inadequate and ill-prepared emergency interventions.

One main threatening factor results from storm force wind. This primarily causes **loading and mechanical damage** of structures and can also increase or decrease the chemical action of water and gases on the heritage object whilst amplifying the direct threat through imposed enormous loading. But, the effects of airflow on historical structures or sculptures in the external environment can be quite disparate. In an effort to systematically describe the negative impacts with the intention of anticipating hypothetical risks two basic groups of possible failures can be defined which, fundamentally, differ in their causal relationship (Drdácký et al., 2006; Pospíšil et al., 2006).

Deterioration caused by wind erosion is the first category of damage (Yates et al., 2009; Pospíšil et al., 2007; Drdácký et al., 2005)**.** Even a small breeze can waft/dislodge small parts of hard solids such as sand particles. With long term action the accumulative **abrasive impact** can be very strong, creating significant changes on the exterior of structures. On the other hand, there are also some perceived positive aspects of such change. Often the authentic impression of ancient architecture is emphasized by its "gentle weather-worn look".

In the process of properly maintaining cultural heritage monuments, the one of the most difficult tasks it is to find right balance between sustainable technical conditions and appropriate levels of intervention. The slow progress of wind erosion affords time to prepare sufficient protection against the risk. Preventive maintenance and routine monitoring of weather conditions and changes can considerably reduce future financial outlay.

The **second cartegory of damage relates to the bearing capacity** of construction materials being **critical exceeded** by wind loading. An acute enhancement of material stress can cause local mechanical damages or, in case of extreme events (windstorms, hurricanes), even lead to structural collapse. The characteristic of such consequences is generally sudden and unexpected, so taking precautionary actions are much more difficult. Strong wind storms cause damage and failure on both the cultural and natural heritage. Windstorms are particularly dangerous for tall buildings, high or lightly constructed roofs, loose or slender building elements. Large trees growing in the vicinity of valuable buildings, monuments or sculpture can cause serious damage if they are felled or have their heavy branches broken off.

In the past serious damage to buildings caused by climatic effects – windstorms, hurricanes or floods – were amongst the most remarkable events noted in chronicles and other written sources. Together with large fires, often started by thunderstorms, these incidents are the numerous of records in the archives. As such historical research shows, the windstorm damage to roofs were recorded quite often, although some descriptions of the damage may have been exaggerated, and even overestimated on purpose, to obtain funding for repairs more easily (Berz, 1994).

On the other hand, detailed and reliable descriptions of particular incidents are valuable in helping define the weak points in typical building structures. **Churches with high roofs and, in particular, steep spires** are the largest group of buildings mentioned

in the written sources. Timber outlook tower structures located on hill-tops and mostly separated from traditional settlements were perhaps the most endangered building type, especially around 1900. A report from 1842, speaks of the menhir in Klobuky (Central Bohemia) collapsing due to a hurricane. To this category belongs **failure of freestanding walls, including attic gables, ruins, fencing etc.**

Most damage caused by strong winds relates to **roof covering** (Parmentier et al, 2000). Wooden shingles were, in this sense, much more resistant than ceramic or slate tiles. Copper sheets used on large pitched roofs can also cause serious problems.

The total collapse of an all-timber roof spire structure was often not the result of structural faults in the construction but was generally connected with established existing problems, such as rotten wall plates or roof leaks. To avoid this requires the **essential periodic monitoring and inspection** of the condition of the timbers within the construction to prevent future damage. An unchecked combination with other structural failures such as fractured masonry or vaulting can be dangerous and lead to a collapse of the building as a whole.

Assessment of the impact related to wind effects on cultural heritage

There are several historic reports that describe wind damage to structures but **only a very few of them focus on the tangible historic assets.** In this sense, relevant research is necessary in order to compile events specifically related to the cultural values. Reported significant storms in chronological order were:

- **Grote Mandrenke**, 1362 – A southwesterly Atlantic gale swept across England, the Netherlands, northern Germany and southern Denmark, killing over 25,000 and changing the Dutch-German-Danish coastline.
- Burchardi Flood, 1634 – Also known as "**second Grote Mandrenke**", hit Nordfriesland, drowned about 8,000–15,000 people and destroyed the island of Strand.
- Great Storm of 1703 – Severe gales affect south coast of England.
- **Night of the Big Wind**, 1839 – The most severe windstorm to hit Ireland in recent centuries, with hurricane-force winds, killed between 250 and 300 people and rendered hundreds of thousands of homes uninhabitable.
- Baker (2005) refers to a catastrophic windstorm from 1703 which caused in London alone 21 deaths, and damages estimated at £2 million, (in all UK about £100 millions), and which was described in records by the following words: "the streets lay so covered with tiles and slates, from the tops of the houses, especially in the out-parts, that the quantity is incredible, and the houses were so universally striped, that all the tiles in fifty miles round would be able to repair but a small part of it".
- **Bohemia** 1614-1929: around 50 roofs and attic gables collapsed and 8 outlook towers were torn down (1890-1916) in the country. In 1852 a menhir tumbled to the ground due to a hurricane. Damage occurred in 1897 to the architectural heritage due to strong winds (the roof on the church tower collapsed, as did some light timber houses; most roofs lost their cover).
- **Royal Charter Storm**, 25–26 October 1859 –was considered to be the most severe storm to hit the British Isles in the 19th century, with a total death toll estimated at over 800. It takes its name from the Royal Charter ship, which was driven by the storm onto the east coast of Anglesey, Wales with the loss of over 450 lives.

- The **Tay Bridge Disaster**, 1879 – Severe gales (estimated to be Force 10–11) swept the east coast of Scotland, infamously resulting in the collapse of the Tay Rail bridge and the loss of 75 people on board an ill-fated train that was crossing the bridge at the time.
- 1928 **Thames flood**, 6–7 January 1928 – Snow melt combined with heavy rainfall and a storm surge in the North Sea led to flooding in central London and the loss of 14 lives.
- North Sea flood of 1953 – Considered **the worst natural disaster of the 20th century** both in the Netherlands and the United Kingdom, claiming over 2,500 lives, including 133 lost when the car ferry MV Princess Victoria sank in the North Channel east of Belfast.
- **North Sea flood** of 1962 – The Storm affected the North Sea German coast with wind speeds up to 200 km/h. The accompanying storm surge combined with the high tide pushed water up the Weser and Elbe, breaching dikes and caused extensive flooding, especially in Hamburg. 315 people were killed, around 60,000 were left homeless.
- Gale of January 2–5, 1976 – Widespread wind damage was reported across Europe from Ireland to Central Europe. **Coastal flooding occurred** in the United Kingdom, Belgium and Germany with the highest storm surge of the 20th century recorded on the German North Sea coast.
- **Great Storm** of 1987 – This storm affected southeastern England and northern France. In England maximum mean wind speeds of 70 knots (an average over 10 minutes) were recorded. The highest gust of 117 knots (217 km/h) was recorded at Pointe du Raz in Brittany. In all, 19 people were killed in England and 4 in France. 15 million trees were uprooted in England.
- 1990 storm series – Between 25 January and 1 March 1990, eight severe storms crossed Europe including the **Burns' Day storm**. The total costs resulting from these storms was estimated at almost €13 billion.
- **Braer Storm** of January 1993 – the most intense storm of this kind on record.
- In 1998, a windstorm lifted and destroyed the steel sheet roof insulation of Sofia University (the building being gift from the American Carnegie Foundation in the early 1920s).
- Lothar and Martin, 1999 – France, Switzerland and Germany were hit by severe storms **Lothar** (250 kmh/160 mph), and **Martin** (198 kmh/123 mph). 140 people were killed during the storms. Lothar and Martin together left 3.4 million customers in France without electricity. It was one of the greatest energy disruptions ever experienced by a modern developed country. The effects of poor repair in combination with strong winds were recorded at the Hospice de Charenton, France, which was hit by two windstorms (in 1990 and 1999). The storm in 1999 damaged the same improperly repaired parts that had been affected by the earlier storm of 1990 (Schmuckle-Mollard, 2006). On the other hand, a central part of the building, properly restored shortly before the storm, held up well. The total cost resulting from both storms was estimated at almost **19.2 billion US$.**
- Xynthia, 2010 – A severe windstorm moved across the Canary Islands to Portugal and western and northern Spain, before moving on to hit south-western France. The highest gust speeds recorded at Alto de Orduña (228 km/h/ 142 mph). 50 people were reported to have died.

- 2013–14, Atlantic winter storms in Europe saw a "**conveyor belt**" series of high-precipitation storms (that were unexceptional for their winds) explosively deepened by a strong jet stream. The repeated formation of large deep lows over the Atlantic brought storm surges and large waves which coincided with some of the highest astronomical tides of the year and led to coastal damage. The low-pressure areas brought heavy rainfalls and flooding, which became most severe over parts of England such as the Somerset Levels.
- The property insurance money paid out almost 6 billion US$ for Tyhoon **Mireille** in September 1991, 18 billion US$ for Hurricane Andrew in August 1992, and almost 8 billion US$ for 10 typhoons that attacked Japan in 2004.
- Hurricane **Katrina** killed 2,541 people in August, 2005 and caused a 28 billion US$ economic loss in the US, Cyclone Sidr in November, 2007 killed 4,234 people and caused 1.7 billion US$ economic loss in Bangladesh, and Cyclone Nargis in May, 2008 killed 138,366 people and caused 10 billion US$ economic loss.
- Very recently, Typhoon **Morakot** struck Taiwan and neighbouring countries in August, 2009, the fatalities and those missing numbered 732. It recorded 2,888mm intense rainfall over four days in Chiayi Province, Taiwan.
- In January 2017 one of the first Gothic cathedrals in France, the cathedral at Soissons, was seriously damaged in a strong storm known as **Egon** by hurricane-force winds which reached 154 km per hour. Its rosette stain glass window was broken.

Almost all of these disasters result from the combined effects of strong wind and accompanying water hazard due to heavy rainfall and storm surge. **The social impact caused by these "wind-related" disasters were some of the most severe in our human society.**

Wind damage monitoring and early warning system

Site monitoring starts from a very basic determination of geography and terrain properties. A site visit may give some indication of potential wind speed and the predominant or strongest wind direction. Observing vegetation and features on the site, talking to neighbours and observing how neighbouring properties deal with the effects of wind can assist. Indicators of high wind speeds include:

- A general lack of developed planting.
- Stunted tree and shrub growth.
- Wind break fences on adjacent properties.
- Wind shaping of existing planting.

For a deeper analysis of possible wind effects and inclusion into a more sophisticated warning system, an **analysis of wind maps should be carried out**. To estimate wind load distributions on a tall structurethe following is required: firstly, local meteorological records giving information on wind velocity and direction, secondly, theoretical wind velocity profiles (velocity variations with height) and wind pressure distribution calculations based upon the fore-going data and geometry of the building. This is scarcely known for historic structures (Mark and Jonas, 1970) and is the reason why wind tunnel tests are indispensable that focus on an analysis of wind loadings on historical structures with complex shapes (Hanazato et al. 2010; Drdácký et al., 2005; Taranu at al., 2000).

With earth observation and communication satellite data, the warning systems improve. In the case of 2007 storm "Kyrill" storm warnings were given for many countries in western, central and northern Europe with severe storm warnings issued

for some areas, although least 53 people were killed in northern and central Europe, and travel chaos emerged across the region. Presently, local authorities issue warnings based on modern technologies to make people aware of coming storms. The **monitoring of historical buildings and damage due to wind** is however **still insufficient**. Examples and case studies in this respect are very necessary (Caselles et al., 2017; Berz, 1997)

Resilience strengthening and risk management

While wind-related monitoring and other organizations have been effectively working to develop technologies, codes and standards for wind hazard mitigation, there has been a dearth of coordinated activities with other international groups such as the UN and NGO. There is a need to collaboratively bring these technologies together to aid less fortunate communities in low lying areas that are often struck by devastating wind storms, hurricanes and typhoons with escalating losses, including those on cultural heritage.

In order to address this previous lack of coordination, and to benefit from a large database of technologies developed over recent decades, an **International Group** working on Wind-Related Disaster Risk Reduction WRDRR (IG-WRDRR)[123] was launched in June 2009 in Geneva, Switzerland. The participant organizations are International Association for Wind Engineering (IAWE), International Center for Water Hazard and Risk Management (ICHARM), United Nations/International Strategy for Disaster Reduction (UN/ISDR) Secretariat, United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), United Nations University Institute for Environment and Human Security (UNU-EHS), World Meteorological Organization (WMO), International Federation of Red Cross and Red Crescent Societies (IFRC), Yayasan HOPE Indonesia, Development Workshop France (DWF), Asia Disaster Reduction Center (ADRC), SEEDS INDIA, SEEDS Asia, Bangladesh Disaster Management Bureau (DMB), Bangladesh Disaster Preparedness Center (BDPC), and L.R. of Iran Meteorological Service. It has also been agreed that the IAWE President will serve as Chairman of IG-WRDRR and lead the activities.

Training and dissemination actions

International organizations and national governmental bodies have issued various guidelines and national action plans on the risk management of cultural heritage against different types of natural hazards and man-made disasters, including wind. These existing papers discuss recent wind-induced damage to buildings and structures, including the consequences of tropical cyclones and severe local storms. Importance is placed upon **the design of cladding and components to minimize wind-induced damage**. Some special features of wind-induce damage such as coherent phenomena and damage chain, the role of wind-borne debris creating further damage, and climate change issues are also discussed. An agreement exists regarding the necessity for collaboration amongst multiple academic associations for different natural disasters and a academic societies, and non-academic organizations working on disaster risk reduction is also emphasized. Recently, the launch of the IG-WRDRR under the umbrella of the UN/ISDR was introduced (Tamura, 2009).

The main objectives of the **IG-WRDRR** are outlined below:

- Implement the Hyogo Framework for Action in the area of WRDRR.
- Establish a database/warehouse of the latest information/technologies relevant to wind.
- Related effects and their mitigation.

[123] http://www.iawe.org/WRDRR/

- Facilitate convenient technology transfer that is attentive to the needs of local communities exposed to disasters around the world.
- Provide assistance to international organizations in the preparation of guidelines to manage the impact of wind-related disasters including recovery and reconstruction.
- Organize, dispatch and facilitate ground logistics for quick-response post-disaster investigation teams.
- Establish an international consensus for extreme winds based on damage relevant to different construction practices.
- Establish international guidelines to prepare for wind-related disaster reduction activities.
- Harmonize wind-loading codes and standards including environmental specifications.

2.6 Earthquake

Introduction to Earthquake Risk Assessment

Earthquakes constitutes one of the natural disasters that could have the most devastating impact in terms of loss of lives and damage to structures. Frequently, they are followed by other disasters (as side effects) such as fire, floods, landslides or tsunamis. Combined, the effects can result in a large number of fatalities and catastrophes in just a single event. This is what makes earthquakes one of the most serious natural hazards. Thus, it is important to deal the natural disaster "earthquake" by adopting a more holistic approach that goes beyond the structural restoration/strengthening of cultural heritage buildings and takes into account the **synergy and effect of other natural disasters too**.

Although a large number of scientific studies have been dedicated to the prediction of seismic actions, earthquakes still cannot be predicted: they occur without any previous warning. They last a few seconds and may cause significant human losses and damage on the built environment, including assets (moveable or unmovable). It should also be noted that, even if a seismic event is predicted, unless specific measures are taken for the purpose, this does not provide any protection to the structures (such as maintenance, repair of previous damage, pre-earthquake strengthening, etc.).

As shown in Figure 2.11, in which European seismicity is presented, earthquakes are widespread. The countries that suffer the most (with earthquakes having magnitudes above 6M) are those around the Mediterranean (Italy, Greece, Turkey, Spain) and Iceland, but France, Albania, Bulgaria and Romania have also experienced major earthquake events. Smaller earthquakes have been recorded in other European countries, although they generally cause only minor damage.

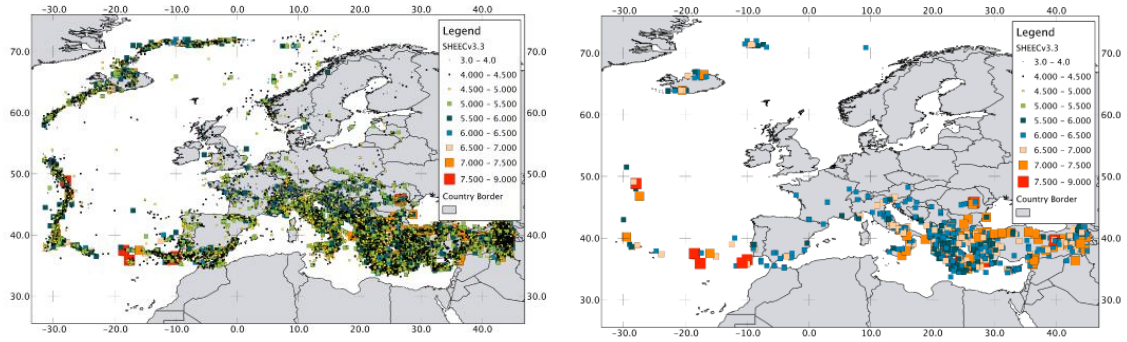


Figure 2.11 New European Seismic Hazard Maps according to SHARE-EU project (2016): European Earthquake Catalog: a) All events of MW≥3.5 and b) All events of MW≥6.0.

Although, seismic events are not predictable or preventable, their **effect on cultural heritage buildings and their content may be minimized through prevention measures** that aim to reduce their vulnerability.

Estimating the Scale of Loss

For years 1980-2008 the number and effect of earthquakes (including tsunamis) is illustrated in UN Report statistics, and from the Red Cross for the 2004-2013 period (both reports are based on the International Disasters Database[124]). These statistics refer to the effect of all seismic events and not only to those that have affected cultural

[124] www.emdat.be

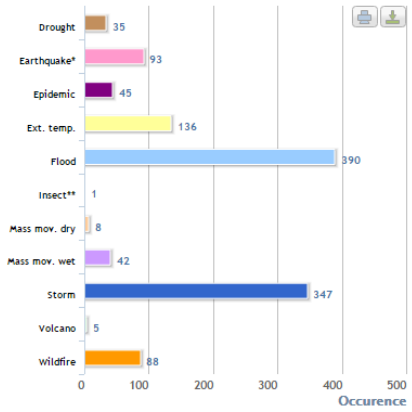
heritage assets. As shown in Figure 2.12, "Earthquake" is ranked as the fourth most frequent natural disaster (after floods, storm and extreme temperatures) during the period 1980-2008, whereas in terms of human loss and consequences, and economic damage, "Earthquake" is placed at the second position amongst the most crucial natural hazards.

Region Profile for Natural Disasters from 1980 - 2008

Overview

No of events:	1,190
No of people killed:	121,644
Average killed per year:	4,195
No of people affected:	33,031,632
Average affected per year:	1,139,022
Ecomomic Damage (US$ X 1,000):	266,918,923
Ecomomic Damage per year (US$ X 1,000):	9,204,101

Natural Disaster Occurence Reported



Average Disaster Per Year

Drought:	1.21
Earthquake*:	3.21
Epidemic:	1.55
Extreme temp:	4.69
Flood:	13.45
Insect infestation:	0.03
Mass mov. dry:	0.28
Mass mov. wet:	1.45
Volcano:	0.17
Storm:	11.97
Wildfire:	3.03

Statistics Per Event

Killed People

Drought:	0.06
Earthquake*:	352.80
Epidemic:	9.78
Extreme temp:	602.98
Flood:	6.14
Insect infestation:	...
Mass mov. dry:	28.38
Mass mov. wet:	27.98
Volcano:	...
Storm:	6.25
Wildfire:	4.77

Affected People

Drought:	299,513.40
Earthquake*:	33,174.73
Epidemic:	4,212.36
Extreme temp:	6,179.60
Flood:	22,258.42
Insect infestation:	...
Mass mov. dry:	1,283.88
Mass mov. wet:	774.55
Volcano:	1,400.00
Storm:	24,253.84
Wildfire:	14,622.27

Economic Damages

Drought:	561,580.26
Earthquake*:	548,347.05
Epidemic:	...
Extreme temp:	113,784.93
Flood:	234,215.49
Insect infestation:	...
Mass mov. dry:	325.00
Mass mov. wet:	73,283.07
Volcano:	3,920.00
Storm:	217,419.73
Wildfire:	123,906.94

Figure 2.12 European Natural Disaster Statistics for years 1980 to 2008.[125]

During that period, approximately 350 human lives have been lost and more than 33,000 humans have been affected per seismic event, whilest the financial damages exceed 500,000 USD. The more recent data issued by the Red Cross for the period 2004-2013 repeat the previous period observations.

The recent catastrophic earthquake that demonstrated, once again, the close correlation between safety of citizens, loss of cultural heritage value, and increased danger caused by wrong interventions occurred in L'Aquila, Abruzzo (2009, Italy). The effects of this earthquake were devastating: it caused 300 casualties and some 100.000 people had to be evacuated. The damage to cultural heritage buildings was quantified in more than 3.000.000.000 €, with inspections revealing **only 23% of cultural heritage buildings were adequate for use**.

[125] http://www.preventionweb.net/english/countries/statistics/index_region.php?rid=3

It should be mentioned that in case of cultural heritage assets (built or movable), the economic damage caused by a catastrophic seismic event are difficult to assess given that the **historic value of such assets are very difficult to be measured or quantified**.

Addressing Complacency

Despite these statistics, and the catastrophic effect of the recent earthquakes on Italian built heritage (L'Aquila in 2009, and Accumoli in 2016) stakeholders can still believe that their area and buildings will probably not be hit by an earthquake and, if they are affected by a seismic event, their buildings will remain intact and safe. This belief, together with the rather limited available seismic codes and high cost that could accompany seismic upgrading of the cultural heritage built, is what leads stakeholders not to proceed with restoration works. However, this is not the case: **historic buildings are constructed using materials and applying techniques, that make them quite vulnerable to seismic action**. This is an issue of major significance that should be taken into consideration by the Member States and the EU. Promoting financial measures that facilitate the **upgrading of buildings** against seismic actions and official Guidelines that could be used for the assessment of cultural heritage buildings before and after interventions are considered to be practical solutions for such stakeholders.

Assessment of the impact related to seismic effects

Related to the protection of infrastructures and cultural heritage from earthquake induced risks, practical information, guidelines and valuable research work findings can be found in the EU Framework Programme outcomes. As these programmes were/are funded by the European Commission, they provide the EU with powerful tools for mapping, monitoring and predicting natural disasters and their territorial impact, as well as guidelines for the protection of cultural heritage assets from earthquakes.

Some of these of these 6th and 7th Framework projects are listed below:

- The vulnerability of cultural heritage to natural disasters and similar threats was discussed in the ARCCHIP project[126] workshops which revealed a number of examples of **good and ill-informed practice**; they also revealed gaps in scientific knowledge. The effect of climate change on the frequency of occurrence of some natural hazards, such as windstorms, floods and landslides was identified.
- LESSLOSS[127] integrated project dealt with landslides and **multi-risk situations** (together with earthquakes), studying cultural heritage vulnerability and protection strategies and assesses historic bridges in accordance with European standards.
- Protection of cultural heritage against earthquakes has been also studied in the ongoing 6th FP project PROHITECH[128.] This project delivered several useful outputs in both the nonstructural measures (**guidelines and assessment tools**) and offered proposals for structural strengthening.
- The project entitled Management of Natural and Technological Risks[129] under the JRC Enlargement action within FP6 dealt with investigation risk mapping practices and policy for priority hazards in several Central European countries. With the help of a questionnaire, the survey focused on several hazards. The respondents

[126] http://cordis.europa.eu/project/rcn/52609_it.html
[127] http://cordis.europa.eu/project/rcn/74272_en.html
[128] http://cordis.europa.eu/project/rcn/75643_en.html
[129] https://www.preventionweb.net/files/1608_PECO2003.pdf

assigned a lower level of importance of cultural heritage exposed to landslide risk than infrastructure or private property objects.

- A methodology for the evaluation and mitigation of seismic risk to cultural heritage assets was proposed in the PERPETUATE Project[130] funded in FP7. The final aim was the development of European **Guidelines** for the achievement of a homogenous and reasonably low seismic risk to cultural heritage in European and Mediterranean countries. In particular, the Italian Guidelines for the evaluation and mitigation of seismic risk to cultural heritage was the framework for drawing up this document. Focusing attention on masonry structures, the project has addressed the problem of both architectonic assets (historic buildings or parts of them) and artistic assets (frescos, stucco-works, statues, pinnacles, etc.).
- NIKER[131] project that tackled the **earthquake-impact problem on cultural heritage assets** started from a basic assumption that efficient protection, with substantial guarantee of compatibility and low-intrusiveness, can only be achieved on the basis of the "minimum intervention" approach. This required that the potential of existing (authentic) materials and components are exploited as far as possible in terms of their strength and energy dissipation, and that specific interventions are validated and optimized under relevant, real life conditions.
- SHARE[132] is a Collaborative Project in the Cooperation programme of FP7. SHARE's main objective is to provide a community-based seismic hazard model for the Euro-Mediterranean region with update mechanisms. The project aims to establish new standards in **Probabilistic Seismic Hazard Assessment** (PSHA) practice through a close cooperation of leading European geologists, seismologists and engineers.
- PROTHEGO[133] project, funded in the framework of the Joint Programming Initiative on Cultural Heritage and Global Change (JPICH) – HERITAGE PLUS, under ERA-NET Plus and the Seventh Framework Programme (FP7), aims to make an innovative contribution towards the **analysis of geohazards in areas of cultural heritage in Europe**. The goals of the project are oriented towards: the enhancement of cultural heritage management practices at national level; the reinforcement of institutional support and governance through knowledge and innovation; the identification, the assessment and the monitoring of risks in order to strengthen disaster preparedness at heritage properties in the future.

Resilience strengthening and risk management

Policy for the prevention and mitigation of earthquake disaster

As mentioned above, the short and medium term impact of earthquake disasters are very crucial for both society and the economy. This has been recognized by State Members and thus, national policies and national agencies have been established towards developing proper strategies and measures to mitigate the effect of seismic disaster, and plan for risk management. Along the same lines, the European Community supported a common policy on prevention, mitigation and response on earthquake disasters and tried to facilitate the co-operation between State Members, to promote technical expertise in the field. Finally, International Organizations have also introduced technologies and policies to deal with the effects of earthquake disasters and have proposed measures for their reduction.

Related documents and issues are summarized as:

[130] www.perpetuate.eu
[131] http://cordis.europa.eu/project/rcn/93572_en.html
[132] http://cordis.europa.eu/project/rcn/92303_en.html
[133] http://www.prothego.eu/

a) **The national policies and agencies** [including: National approaches and platforms for disaster risk prevention and reduction; Local governments and disaster risk reduction; Development and implementation of seismic codes and National earthquake-resistant building codes etc], (Gountromichou et al., 2014; Meier et al., 2008; Indirli et al., 2005; Indirli et al., 2002; Indirli et al., 2001; NARPIMED[134]; PPRD East[135]; Agencies[136]: Red Cross, European Centre on Prevention and Forecasting of Earthquakes[137]).

b) **The EU natural risk prevention framework** [including Community directives and member states legal basis; European community directives and documents on natural disaster prevention; EU civil protection structure/mechanism/risk management/financial instruments/prevention policies and natural risk reduction strategies; Monitoring and Information Centre (MIC), Trans-national cooperation between the State Members, Development and implementation of seismic codes] (European Commission, 2010; European Parliament, 2007; Vatavali, 2003).

c) **The International organizations policies** in the field of prevention and mitigation of earthquake disasters and the earthquake emergencies (UNESCO, ICCROM, ICOMOS, IUCN, 2013; UNESCO 1972a, b; UNESCO 2007a, b; UNESCO, 2008a, b; Jigyasu and Arora, 2013; ICOMOS 2011-2013; 2008-2010; 2007; 2006-2007; UNESCO- WORLD HERITAGE CONVENTION-ICOMOS- ICCROM- IUCN, 2010; Jokilehto, 2011; ICCROM, 2006; Stovel, 1998; Feilden, 1987).

It should be noted that most of the documents do not specifically refer to the protection of cultural heritage assets from earthquake disasters. However, **they could also apply to cultural heritage**, with adequate adjustment.

Published Practical Guidance and Seismic Codes

A large number of international technical Reports that can be found on-line. These provide **guidelines and emergency plans** for the protection and risk management of cultural heritage assets, and the measures that should be taken before, during and after a seismic event. A listed of some of them include:

- for **Movable cultural heritage assets** (Guidelines for Disaster Preparedness in Museums[138], A Guide for Museums and Other Cultural Institutions[139]).
- and **Unmovable cultural heritage assets** (Managing Disaster Risks for World Heritage[140], Managing Cultural World Heritage[141]).

Regarding the measures that should be taken to improve the response of structures prior to a seismic event, these should respect and comply with the historic preservation values that were first declared in the Venice Charter for the Conservation and Restoration of Monuments and Sites (1964), updated by the following ICOMOS and ICCROM Conferences and Meetings. For the assessment and the upgrading of the built cultural heritage against earthquakes, the available regulations/guidelines are rather limited. It should be noted that according to the available documents, such Regulatory documents were developed at the level of Member States (mainly Italy and Greece), or

[134] http://ec.europa.eu/echo/files/civil_protection/civil/prote/pdfdocs/2008_narpimed_manual_en.pdf
[135] http://phase1.pprdeast2.eu/assets/files/Publications/CPO%20Guidebook.pdf
[136] http://www.wcpt.org/disaster-management/Organisations-involved-in-disaster-management
[137] http://ecpfe.oasp.gr/en
[138] http://icom.museum/fileadmin/user_upload/pdf/Guidelines/guidelinesdisasters_eng.pdf
[139] https://www.getty.edu/conservation/publications_resources/pdf_publications/pdf/emergency_plan.pdf
[140] http://whc.unesco.org/en/managing-disaster-risks/
[141] http://whc.unesco.org/en/managing-cultural-world-heritage/

by International Institutions (e.g. ICOMOS). Some of those documents are: D.M 24/01/1986[142]; D.M 16/01/1996[143]; O.P.C.M. 3274, 20/03/2003[144]; O.P.C.M. 3431, 03/05/2005[145]; Research Programs of the European Centre on Prevention and Forecasting of Earthquakes[146]; ICOMOS - International Scientific Committee for Analysis and Restoration of Structures of Architectural Heritage (ISCARSAH)[147], document approved in June 2005.

Training and dissemination

The significant number of conferences, workshops, symposium, seminars and other events that are being organized on a regular basis evidences illustrates an awareness and interest on the subject of the protection and management of cultural heritage assets by the scientific community. Such events are numerous at an international, European and national level. The contribution to the conservation of cultural heritage, from those scientific events, is very significant through:

a. The study of **compatible materials and techniques** for the restoration/strengthening of structures.
b. The development and **application of innovative documentation methods.**
c. The investigation and assessment of several cultural heritage assets used as **Case Studies** etc.

A selection of relevant scientific events include the:

- International Conference on Structural Analysis of Historical Constructions (SAHC).
- International Conference on Studies, Repairs and Maintenance of Heritage Architecture (STREMAH).
- International Workshops on disaster risk reduction at world heritage properties.
- Earthquake related Conferences and Workshops that have special sessions dedicated to the protection of cultural heritage (such as the World Conference Earthquake Engineering and the European World Conference Earthquake Engineering).
- Geotechnical Engineering for the Preservation of Monuments and Historic Sites Symposiums.
- International Symposiums on Studies on Historical Heritage.
- Masonry structures related Conferences and Workshops that have special sessions dedicated to the protection of cultural heritage, such as the International Masonry Conference, and the International Brick and Block Masonry Conference.
- Cultural heritage protection in times of risk: challenges and opportunities conference.
- Historic Mortars Conference.
- Seminars on PREventive COnservation and Monitoring of the Architectural Heritage (SRPRECOMAH seminars).

[142] http://www.staticaesismica.it/normative/DM_24_01_1986.pdf
[143] http://www.gazzettaufficiale.it/atto/stampa/serie_generale/originario
[144] http://zonesismiche.mi.ingv.it/documenti/gazzetta.pdf
[145] http://zonesismiche.mi.ingv.it/documenti/ordinanza_3431.pdf
[146] http://ecpfe.oasp.gr/en/node/89
[147] https://www.icomos.org/en/pub/181-english-categories/about-icomos/committees/international-scientific-committees

- Innovative Techniques and Materials for the Conservation of Monuments (ITECOM seminars).

2.7 Volcanic eruption

Introduction to volcanic eruption and geological hazard threats and protection

According with the European Spatial Planning Observation Network (ESPON), the highest volcanic eruption hazard is concentrated in southern Europe, i.e. Italy, Greece, and in the overseas territories (Canarias and the French Antilles), as showed in Figure 2.13.

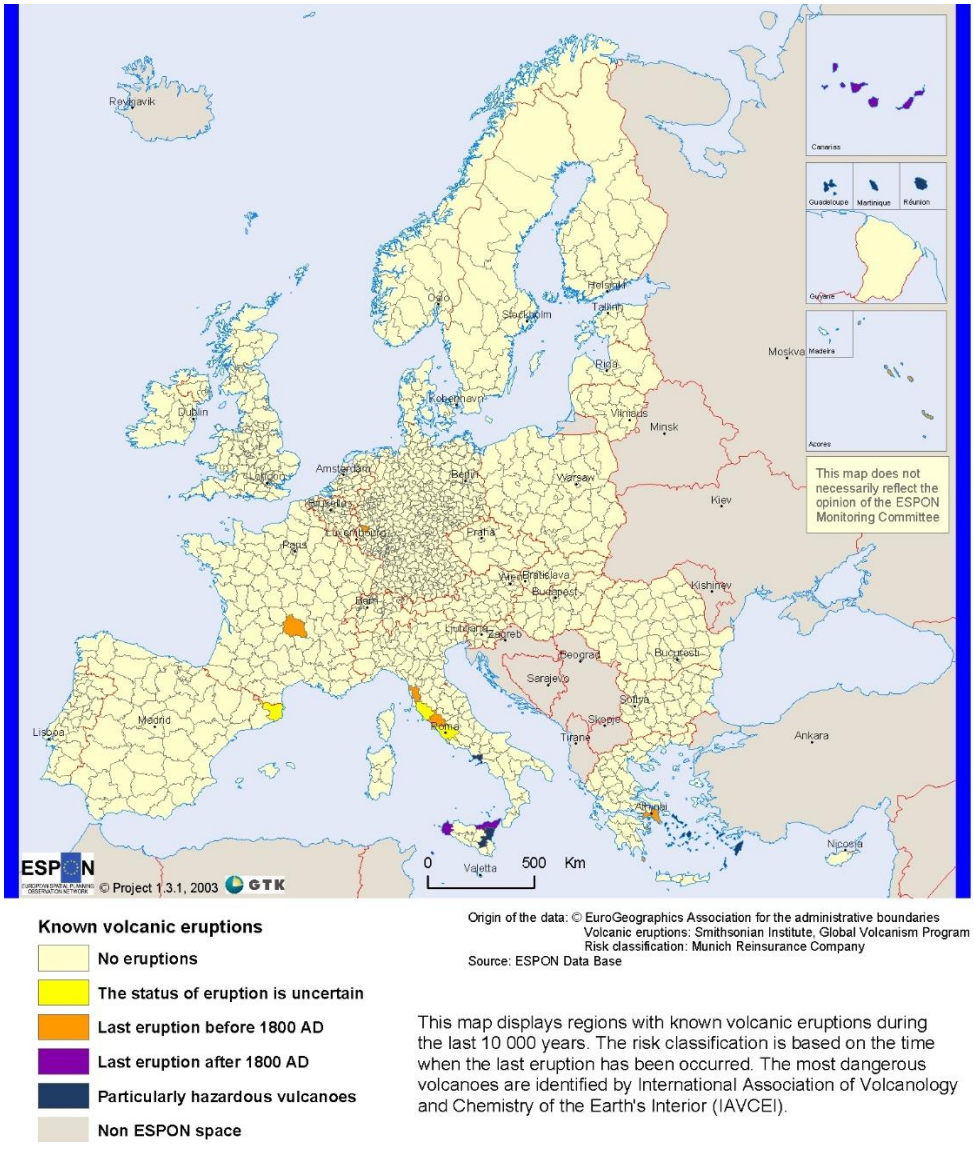


Figure 2.13 European map of volcanoes distribution developed by the European Spatial Planning Observation Network (ESPON)[148], up to 2003.

Comparing this with the distribution of World Heritage, shown on the map in Figure 2.14, the heritage exposed to this hazard is elevated.

[148] http://www.preventionweb.net/english/professional/maps/v.php?id=3832

Figure 2.14 Map of the World Heritage (2016-2017) modified from © 2016 UNESCO.

Nevertheless, few studies have ever been addressed on how the volcanic eruption hazard affects the cultural heritage.

Training and Dissemination Actions

In 2005, the International seminar Volcanic risk management in urban areas was organized in Ravello at the Centro Universitario Europeo per i Beni Culturali, in cooperation with the University Federico II of Naples and the Council of Europe. Within the seminar, the Session 2 was dedicated to the thematic Volcanoes and Archeological Remains.

According to the **AUGUSTUS method** produced by the Department of Civil Protection, a study was carried out on the Technologies and community mechanism for civil protection assistance and cultural heritage conservation. The project also concerned the realization of a database and the implementation of the appropriate technological support for the conservation of cultural heritage specifically oriented to the activities of the **forecast and prevention of volcanic risk** (Giuffrida and Lo Tauro, 2006).

2.8 Fire Risk

Introduction to Fire Risk Assessment

Across all European countries, in terms of built heritage disaster, Fire is collectively the most universally common catastrophe that will be encountered. Significant conflagrations have frequently occurred in the past and they continue to remain a threat to valuable and culturally important historic assets and their surroundings. When such an incident occurs it is generally proclaimed to be "unacceptable" yet a fully comprehensive overview of the number of incidents and the issues involved is persistently lacking. This remains the situation despite a significant number of **international conferences and events that aimed to create a greater awareness of the concerns**. This approach was particularly prevalent during the 1990's when the following events took place:

- 1987 Thessaloniki, Greece: Fire Protection of Historical Buildings and Urban Complexes.
- 1990 Risor, Norway: Fire Protection of Historic Buildings and Towns.
- 1990 Karlsruhe, Germany: Fire Safety and Conservation of Cultural Heritage.
- 1994 Kalithea, Greece: Fire Protection of Historic Buildings and Sites.
- 1994 Krakow, Poland: Fire Protection of Ancient Monuments.
- 1996 Santorini, Greece: Fire in Historic Buildings.
- 1998 Duff House, Scotland: Fire Protection and the Built Heritage.
- 1998 Versailles, France: Fire Risk Assessment in Historic Buildings 1.
- 1999 Schonbrunn, Austria: Fire Risk Assessment in Historic Buildings 2.
- 1999 Rome, Italy: Fire Protection of Cultural Resources.
- 1999 Zestochowa, Poland: Fire Protection of Historical Monuments.
- 2000 Thessaloniki, Greece: Fire Protection of Cultural Heritage.
- 2001 Stockholm, Sweden: Protection of Cultural Heritage Values.
- 2001 Schonbrunn, Austria: European Network for Fire Risk Assessment in Historic Buildings.

Published proceedings offered a preliminary understanding of the issues although, at the time, many pragmatic aspects remained un-resolved in practical application terms. But, these occasions did provide the mechanism for some coordination and related project developments, particularly with the emergence of COST Action C17: Built Heritage: Fire Loss to Historic Buildings in 2002.

Estimating the Scale of Loss

Despite being identified in 1986 by the **UK's Fire Protection Association** as a key need, problems still exist in obtaining reliable comprehensive statistical information regarding the scale of loss to the built heritage to the effects of fire. There are no uniform European fire statistics, and many countries do not publish any data at all. Where reported, Fire Brigade data is generally based on the use of the building - dwelling, school, office, factory - and **provided information does not include a specific category for historic or listed buildings**. In much of Europe, the Volunteer Fire Brigades do not provide authenticated data, and there may also be an element of "national pride" or "embarrassment" implicit in under-reporting. Crucially, no single EU

DG coordinates fire issues, and there appears to be little centralised interest in the establishing a European dimension on fire safety or loss associated with its built historic assets.

Therefore, statistically, **it is not possible to identify across Europe the true scale of loss for the built heritage due to the effects of fire**. At best, only a few reliable pointers can be identified to indicate the potential scale of destruction.

The UK Fire Protection Association's Heritage Under Fire: A Guide to the protection of historic buildings (Kidd, 1995) contained 12 case studies of significant fire incidents. Covering the period 1979 –1992, these included the Palace of Hampton Court, 1986 (estimated loss at £20m); Uppark House, 1989 (estimated loss at £20m); Windsor Castle, 1992 (estimated loss at £37m). The point was made that, due to fire, **loss of original historic heritage was inevitable**, whilst the cost of reconstruction was considerable. This fundamental aftermath remains as true today as it did then.

Building up support from promoting the need for action at a number of the 1990's conferences COST Action C17 - Built Heritage: Fire Loss to Historic Buildings, as a European research initiative, directly involved 20 participating countries and included corresponding links with contacts in the Baltic States, Russia and the USA. Through mutual collaboration the aim was to **reduce the significant physical and cultural loss of Europe's built heritage** to the damaging effects of fire. It involved a wide range of experts in a multidisciplinary manner through the collaboration and integration of a variety of related research and practical projects. It ran from mid December 2002 to mid December 2006.

During the 4-year programme a note was kept of significant international fire losses reported in the press. As a result, 25 serious incidents were recorded during 2003; 16 in 2004; 36 in 2005; and 17 up to August 2006 – a total of 94. Specifically, in 2005 fire destroyed the north tower of the recently 7.3 million euro renovated St Johannis Church in Gotteingen, Germany; the 1916 Schloss Hotel Kruen, Bavaria; and the 200 year-old Gasthofs Lowen (redundant) restaurant, Oberrohrdorf, Switzerland. In 2006 fire destruction occurred in the 400 year-old Hapsburg Reinertonishof Farm, Schonwald, Germany; the 17th century baroque residence of the Bishop of Tenerife, La Laguna, Tenerife; the 18th century Vosshaus, Lubech, Germany; the 1930s Pravda newspaper offices, Moscow; the 13th century Provoo Cathedral, Finland; the 1835 Trinity Cathedral, St Petersburg, Russia; and 14 historic buildings in Flims Old Town, Graubunden, Eastern Switzerland (estimated loss of 10MEuro).

It was reported to the *Action* that, over the period 1992 – 1994, some 40 Norwegian Stave Kirks were destroyed/damaged as a result of arson attacks, and prior to 1992 the loss rate ran at one church per annum. In 2004 the Finnish National Board of Antiquities, Department of Monuments and Sites, Publication no 26 (Laurila, 2004) offered 10 case studies describing serious incidents, including those at the 17thc Churches at Innest, Norway in 1995; Tyrvää, Vammala, Finland in 1997; Katerina, Stockholm in 1990, and the 14thc Södra Råda Church, Sweden in 2004.

As part of the *Action C17* work, a number of Fires Occurring in Historic Buildings lists had been compiled and these were included in the Part 2 Research Report Annex of 2007. These significant chronological lists included contributions from Scotland (1996 - 2006); England (1996 - 2006); Bulgaria (1985 - 2003); Spain (1991 - 2006); Norway (1983 - 2003); USA (1999 - 2003) in addition to describing a number of specific cases (13). Perhaps offering the most comprehensive awareness of the scale of loss at the time, the compiled statistics were still considered by the *Action* to be significantly under-reported. For example, a compilation of incidents reported in the UK Press indicated that almost 400 separate historic building fires were noted between January 2002 and June 2006. Significant as this was, it was also recognised that the Press did not report on every fire incident that occurred during that period.

A slightly more accurate Scottish assessment took place during the period 1 April 2005 - 31 March 2006. Here, a collaborative agreement involved the exchange of data between the Scottish Fire and Rescue Services on the location of listed historic buildings held by Historic Scotland (the official heritage authority) and any fire incidents at them attended by the Services. As reported in the **Scottish Historic Buildings National Fire database Annual Report 2005-06**, some 210 fire related incidents were attended as reported on by 4 out of the then 8 Services, but, this only covering half the country. The **SHBNFD Annual Report for 2007-08**[149] was informed by all the Services and noted 495 fire incidents in historic listed buildings across Scotland. The reported causes were:

- Electrical appliances/Installation 137
- Cooking 163
- Wilful 57
- Smoking materials 44
- Unknown 23
- Heating appliance 21
- External source 21
- Unknown 7
- Blow Torch/Hot work 15
- Candles 9
- Chemical Reaction 5

Statistically noted in the 2010 Historic Scotland **Guide for Practitioners 7: Fire Safety Management in Traditional Buildings** (Kidd, 2010), this continuing collaborative exchange of information also hinted at the previous level of under-reporting by indicating that, in the 2008 – 2009, 12 month period, the Scottish Fire and Rescue Services dealt with 418 fire related incidents in heritage assets across the country, with a not too dissimilar breakdown of causes. (Part 1 page xiii)

There is no reason to doubt that similar, or significantly increased, figures could well have emerged from over the past decade if a standardised reporting system across Europe had been in operation. As a brief indication of this continuing concern, a selected list of 40 international fire loss incidents, over the period 2007 – 2015, was published in the COTAC 2015 report **Fire and Flood in the Built Environment: Keeping the Threat at Bay Part 1: Fire** (Maxwell, 2015).

Addressing Complacency

Collectively, these known statistics offer a bleak picture and readily illustrate a steady downward drift in the physical remains, significance and original value of European patrimony. It might be reasonably suggested that a significant degree of widespread complacency lies at the heart of this consequence.

Most property owners believe that their buildings will be sufficiently protected as long as they comply with current legislation. But that is not the case. **The primary aim of most official legislation is to save life, not to save buildings or their contents**.

[149]http://www.frsug.org/reports/Scottish_Historic_Buildings_National_Fire_Database_Annual_Report_2007-08.pdf

The fundamental aim is to rightly focus on safely evacuating people. Consequently the result is to place saving buildings and their contents into being a secondary consideration.

There is also an instinctive denial by owners that fire "will not happen to us" and consequently, at best, only half-hearted measures are taken to deal with the consequences of a fire taking hold. Within the built heritage sector, this complacency is compounded by **an irrational fear that discharging water-based suppression systems will create more damage than the fire itself**!

Many historic buildings are also constructed of materials that are easily ignitable and are often located in isolated places some distance away from fire stations in locations where there is no easily available supply of fire fighting water. Consequently, the response time taken for Fire Brigade appliances to attend incidents could readily result in considerable degrees of loss and damage. Any such loss results in a permanent demise of our collective historic identity and physical links with the past.

Historic Values

A significant undercurrent in determining an approach to understanding "value" is the fundamental issue that all national legislation and regulations predominantly (and understandably) cater for life safety, not building safety. But, should a shift in emphasis occur to better incorporate the need for building and content safety, life safety would be also greatly enhanced. With the potential of a developing internal fire reaching temperatures over 1000° Celsius within a 3-4 minute window, speed is of the essence in tackling an early conflagration. With fire-fighting crews taking at best times well in excess of 5-10 minutes (more usually 10 – 20 minutes) to start fire-fighting operations, irretrievable historic asset damage and loss will have occurred.

Where installed, combined early automatic detection and suppression technologies can significantly eliminate this threat – providing that there is some form of organused response on site and from a nearby Fire Brigade. Consequently, a **more integrated approach needs to be developed** to achieve a better balance in the legislation that guides and requires a more comprehensive approach to better support our current temporary custodianship of that heritage.

Just as we might judge the actions of those who held responsibility for caring with the physical heritage in the past, the future will also judge our current temporary custodianship of how well we address such issues today. Accepting that challenge, there are a number of key issues that need to be considered to ameliorate the concerns. Fortunately within the fire engineering and some heritage disciplines, a growing awareness of the scale of loss has also created the need to offer pragmatic technical guidance on how the associated issues might be addressed.

In the process there is a need for all involved to readily understand what constitutes historic significance and value and how these factors relate to specific buildings, their content and setting. But such circumstances are never straightforward. The underlying necessity is to recognise that a formula should exist which considers the pre-incident cost of incorporating full relevant fire protection compared to the potential cost of a post-incident restoration using the skills, materials and techniques characteristic of the original. Here, this is where an incorporated consideration of the real significance and recognised value of the historic asset could be crucial in determining the best route to follow.

Resilience strengthening and risk management

In philosophical conservation terms the following retrofit principles will usually apply. Whilst alternative approaches should be considered any adopted **fire engineering solution** should be:

- Essential to meet the protection needs of life, building and contents
- Appropriate to the risks being considered
- Compliant with legislation
- Minimally invasive on the historic fabric, detail and finishes
- Sensitively integrated with minimal intervention
- Reversible, adopting a "plug-in plug-out" installation philosophy

Within a developing framework of risk assessment and fire engineering protection, then following may be considered valid within such guidance - the:

- Significance and value of the historic structure
- Structural features, details and finishes
- Activities taking place within the asset
- Vulnerability of the historic asset to fire
- Probability of ignition
- Likelihood of fire propagation
- Relevant protection of fabric and content
- Relevant compartmentation of fire and fire spread
- Possible detection and suppression requirements
- Fundamental insurance considerations
- Essential training and management of staff
- Capability of firefighting and evacuation by staff
- Time taken for the Fire Brigade to arrive at an incident
- Setting and location
- Accessibility and access restrictions for deploying equipment
- Availability of reliable water supplies

A number of online international technical volumes are currently available that offer sound and relevant practical guidance to conservation professionals, historic building owners and users. To different degrees, they carry a common message and incorporate many of the above issues. Specifically, the following volumes might be instanced as being particularly relevant:

- Brandskydd I kulturbyggnader – handbok om brandsyn och brandskyddsåtgärder i kulturhistoriskt värdefulla byggnader Räddningsverket och Riksantikvarieämbetet, 1997 (in Swedish).
- Lessons Learnt from Fires in Buildings Edited by Javier Hervas, European Commission Directorate-General Joint Research Centre, 2003.
- Can we learn from heritage lost in fire? Experiences and practises on the fire protection of historic buildings in Finland, Norway and Sweden National Board of

Antiquities, Department of Monuments and Sites, Publication no 26, 2004.

- Historic buildings and fire safety: Exova Warrington, 2006.
- IRMP Policy Guidance: Protection of Heritage Buildings and Structures: Integrated Risk Management Planning Steering Group: DCLG, 2008.
- Guide for Practitioners 7 - Fire Safety Management in Traditional Buildings *Parts 1 + 2*: Historic Scotland, 2010.
- NFPA 914 Code for fire Protection of Historic Structures – 2015 Edition, National Fire Protection Association.
- Fire Safety and Heritage Places*:* New Zealand Historic Places Trust Pouhere Taonga Sustainable Management of Historic Heritage Guidance Series, 2012.
- European Guideline*: Managing Fire Protection of Historic Buildings* CFPA-E No 30: 2013 F: Slovenian Fire Protection Association/CFPA Europe, 2013.
- Heritage and Buildings of Special Interest LFB Guidance Note 80: London Fire Brigade, 2015.
- NFPA 909 Code for the Protection of Cultural Resource Properties - Museums, Libraries, and Places of Worship - 2017 Edition, National Fire Protection Association.

Further practical information and support can be sourced in the many additional publications and references held on the Fire Risk Heritage website[150].

Perhaps of less practical use to the pragmatic conservationist, from a Fire Safety Engineering perspective profoundly scientifically and academically orientated methodological approaches can be found in the following EC supported research projects and reports:

- BENEFUE The Potential Benefits of Fire Safety Engineering in the European Union EC contract EDT/01/503480, 2002.
- FIRE-TECH Fire Risk Evaluation to European Cultural Heritage Decision Supporting Procedure Users Guide (5th Framework Programme), 2005.

[150] http://www.fireriskheritage.net/category/building-safety/

2.9 Armed conflicts

Assessment of the impact related to armed conflicts on cultural heritage

The destruction of cultural sites such as temples is already mentioned in the Bible (Jerusalem Temple 586 BC) and in connection with the plundering and artifice in the course of armed conflicts, when Polybius protested in the third chapter of the 9th book of his Historca Generalis (Stachowiak, 2008).

The destruction of cultural property during armed conflicts has recently gained a sad fearfulness, which shattered the world community, especially with the destructions in Syria, Iraq and Jordan by the Daesh.

The intentional destructions in the near East by the IS Terror group since 2015 has affected more than **one hundred of the world's most important cultural sites**. Amongst the most serious losses are the tomb of the prophet Jonah (UNESCO World Heritage site), the museum of Mosul with statues from the UNESCO World Heritage Site Hatra, and the ruins of Hatra with bear witness of Roman, Hellenic, Arabic and Persian influences. The ancient Assyrian city of Nimrud, most of it has not yet been scientifically researched, the temple town of Khorsabad with its unique stone frescoes, the early Christian monastery of Qartatayn and the Baal-Shamin temples as well as the Arcade of Palmyra, which are particularly well-known thanks to the media (Figure 2.15).[151]

Figure 2.15 Propaganda image of the IS of the destruction of the Baal-Shamin temple in Palmyra (Syria) on 25th August 2015. (photo: Social Media / Reuters)

Just a few years ago, the destruction of some of the mausoleums, tombs and mosques in Mali, that were part of UNESCO World Heritage, took place (Figure 2.16). After the military coup in March 2012, the destruction included the mausoleum Sidi Mahmud Ben Amar, and other monuments such as Sidi Mahmud, Sidi Moctar and Alphamoy. 14 of the total 16 mausoleums were destroyed. These losses are very serious, as the oasis-town served in the 15th and 16th century as the intellectual centre of Africa, where numerous historical documents and writings were also stored. **Reconstruction** was carried out after the fighting under the **coordination of UNESCO** and **with the financial aid from abroad**.[152]

[151] SRF news, 5th Oct. 2015

[152] Deutsche UNESCO-Kommission: "Das Welterbe in Timbuktu - Von Extremisten zerstört, von der internationalen Gemeinschaft wiederaufgebaut" (https://www.unesco.de/kultur/2015/welterbe-timbuktu.html, 30th April 2017)

Figure 2.16 Destroyed mausoleum in Timbuktu (Mali)(photo: Keystone /AP/Baba Ahmed)

Also, in collective memories remain the distruction of the **Buddha statues** of Bamiyan in March 2001 by extremist militia forces (Figure 2.17). The statues carved into the sandstone cliff dated to the 6th century. With this act, the rejection of Western cultural understanding and heritage was established. **The rubble has been recovered and a reconstruction is being considered**.

Figure 2.17 The destroyed Buddha-statues of Bamiyan in Afghanistan (photo: UNESCO / Mario Santana).

The most recent destruction of significant amounts of built heritage in Europe took place during the armed conflicts in the territories of the former Yugoslavia in the 1990's. In Croatia, the cities of Dubrovnik, Osijek and Vukovar were severely affected by damage and heavy shelling by the then Yugoslav People's Army (JNA) and Serb forces. In particular, the libraries and the museum were not adequately prepared for the emergency situation they had to deal with. **Their emergency and evacuation plans**

were not functional as they were still based on the old Yugoslavia state system, where a great deal of improvisational capacity was required. Consequently, significant losses occurred. The destruction of the cultural heritage was devastating. 105 of 109 buildings in the historical centre of Osijek were damaged. For a couple of months the city was put under fire. Finally, it was defended, but the scars of war are still visible in the city today.

During the shelling of the port city of Dubrovnik (a UNESCO World Heritage site), 824 buildings were damaged, of which 563 were the most representative, such as churches, palaces and monasteries. For this act of destruction, the International Criminal Tribunal for the former Yugoslavia (ICTY) in The Hague held trials and sentenced two members of the Yugoslav People's Army (JNA). The extent of the destruction in Croatia became apparent only after fighting ended. With 195 libraries partially or completely destroyed. In addition, 44 museum buildings were destroyed and 7 damaged. The most severely affected buildings by the religiously motivated intent to destroy were sacred buildings; 537 churches, 111 parishes and 44 monasteries in Croatia, Bosnia and Herzegovina were totally destroyed (Figure 2.18) (Pribil, 2007 pp.46-48).

Figure 2.18 Harbour town Dubrovnik (Croatia) during the bomb attack in November 1991 (photo: AFP / Peter Northall).

During the war in Bosnia and Herzegovina between 1992 and 1996, the City of Sarajevo experienced serious destruction. Some 35,000 buildings were destroyed and most of the remaining were damaged. The national and university library, which was internationally known due to its diversity of languages, was intensively hit. The library was attacked on 25th August 1992, and 1,500,000 volumes were burned. The National Museum was directly on the front line and suffered heavy losses. **All rescue plans failed because this was designed for flood and not for military attack**. Further losses occurred during the occupation, when books and collections were used as heating material and toilet articles.

The most symbolic acts of destruction happened in Mostar in 1993. After the National Museum and the University had been under attack, the Stari Most Bridge on the Neretva River was intentionally destroyed on 9 November 1993 (Figure 2.19). There was no military necessity for this act of destruction; it was rather the connection between the ethnic groups that was symbolically interrupted. After that, the destroyed World Heritage site was reconstructed by UNESCO and placed as a copy on UNESCO's World Heritage List in 2005 (Pribil, 2007 pp.50-55).

Figure 2.19 The Bridge Stari Most on the river Neretva in Mostar (Bosnia and Herzegovina) after the destruction of 9th November 1993 (photo: AP).

It can be concluded that the intentional destruction of cultured heritage by human beings has become a most demanding challengeod present times. In Europe, the latest notable events are now almost a generation behind, but today's assessment of the security situation in the most European countries does not exclude the possibility of further terrorist-driven destruction of selected, identity-creating monuments. Especially with **regard to the intentional destruction of cultural heritage, the degree of destruction is usually higher than due to natural events** (Table 2.1).

Table 2.1 Selection of incidents with extensive destructions of cultural property (table Christian Hanus).

Year	Country	Destroyed cultural property (selection)
2015	Iraq	Hatra (ruins), Mosul (tomb of Prophet Jonah), Khorsabad, Nimrud
2015	Syria	Palmyra (ruins), Qartatayn (monastery)
2012	Mali	Timbuktu (Mausoleums, tombs and mosques)
2011	Egypt	Cairo (historic centre, museum)
2003	Iraq	Bagdad (museum)
2001	Afghanistan	Bamiyan (Buddha-Statues)
1992-96	Bosnia-Herzegovina	Sarajevo (historic centre, museums), historic centre Mostar (Stari Most bridge)
1991-95	Croatia	Dubrovnik (historic centre), Osijek (historic centre), Vukovar (historic centre)

Monitoring and early warning system related to armed conflicts on cultural heritage

Considering the legal framework, at the end the 16th and start of the 17th century the protection of cultural property became an issue in international law, especially through peace treaties (like the Treaty of Westphalia 1648: the Lieber Code of 1863 (Instructions for the Government of Armies of the United States in the Field) and later multilateral treaties (Hague Conventions II of 1899, IV and IX both of 1907) provided regulations for the protection of cultural property (Figure 2.21a).

The Hague Convention of 1954 and its two additional protocols became the most recognised of legal instruments for the protection of cultural property during armed conflicts. However, compared with the other UNESCO conventions for the protection of cultural heritage and property (especially in relation to the 1970 Illicit Traffic Convention and the 1972 World Heritage Convention), the 1954 Hague Convention with its both additional protocols gained less state parties endorsement (Figure 2.20).

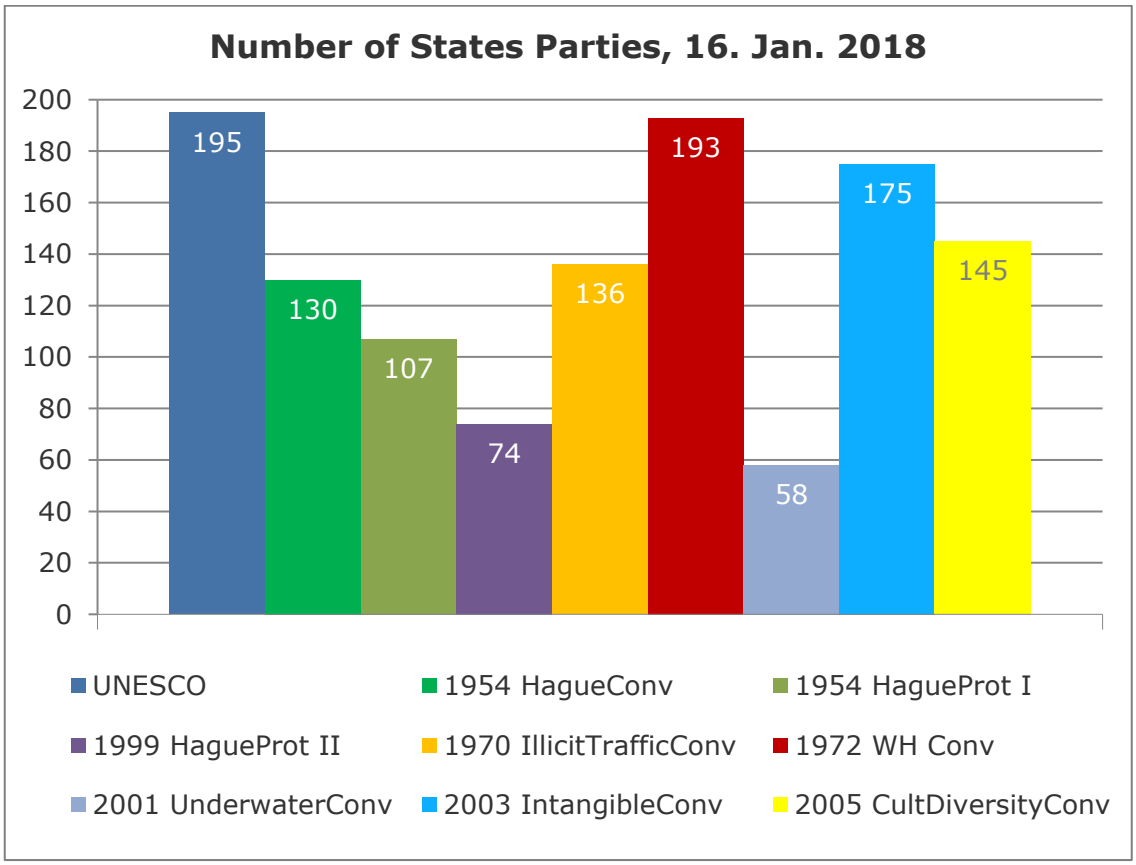


Figure 2.20 Number of State Parties to the different UNESCO-Conventions for the protection of cultural heritage (table: Peter Strasser).

The Treaty on the Protection of Artistic and Scientific Institutions and Historic Monuments (Roerich Pact) represents the **first international legal instrument only dedicated to cultural property**. Initiated by the Russian painter, ethnographer and peace-activist Nicolas Roerich, although the text was drafted by European lawyers, it was adopted by the Pan-American Union in Washington on 15 April 1935 by 21 states. Later it was ratified by ten states[153] in the Americas, amongst others by the United

[153] http://www.unesco.org/eri/la/convention.asp?KO=13637&language=E

States where it is still applicable. Its Article 1 stipulates: "The historic monuments, museums, scientific, artistic, educational and cultural institutions shall be considered as neutral and as such respected and protected by belligerents." It requires that the same respect be paid to the personnel of those institutions, in times of peace as well as in times of war. Article 2 specifies that the neutrality of, and protection and respect due to, monuments and institutions is extended to the entire expanse of territories subject to the sovereignty of each of the Signatory and Acceding States.

The **Peace Banner**, (also called Red Cross of Culture) serves not only as protection-sign for cultural property, but represents also the emblem of the Roerich Societies (Figure 2.21b).

The Convention for the Protection of Cultural Property in the Event of Armed Conflict, signed at The Hague on 14 May 1954 (Hague Convention) represents the first international multilateral treaty applicable on a global level and exclusively focused on the **protection of cultural heritage in the event of armed conflict**. The Convention covers both movable and immovable property, including architectural, artistic or historical monuments, archaeological sites, works of art, manuscripts, books and other objects of artistic, historical or archaeological interest, as well as scientific collections of all types. By end of April 2017, 128 state parties had acceded to the Convention.[154]

The Convention is structured into the following chapters:

- I. General provisions regarding protection
- II. Special Protection
- III. Transport of cultural property
- IV. Personnel
- V. The distinctive emblem
- VI. Scope of application of the Convention
- VII. Execution of the Convention
- Final Provisions

In its Chapter II, paras 8-11, the Convention stipulates the **special protection**. Under certain conditions, cultural property may be placed under this category of protection: being granted either for a limited number of refuges intended to shelter movable cultural property in the event of armed conflict, or for centres containing monuments or for property of very great importance (Art. 8 para 1). However, only a limited number of properties, mostly shelters, were put under special protection (Figure 2.21c).

Chapter V, para 16, introduces the **distinctive emblem**. The emblem, which "take(s) the form of a shield […] per saltire blue and white (a shield consisting of a royal-blue square, one of the angles of which forms the point of the shield, and one of a royal-blue triangle above the square, the space on either side being taken up by a white triangle)" (Art. 16 para 1, Figure 2.21d). This, became the symbol of cultural property and enjoys wide-spread use, even in the context of issues not related to the Hague Convention.

First additional Protocol to the 1954 Hague Convention, a specific Protocol to movable cultural property and the difficult issues of its restitution was adopted with the Convention. The Protocol prohibits the export of such property from an occupied territory and requires its return to the territory of the State from which the property was exported. The Protocol prohibits the retention of cultural property as war reparations, by specifically excluding the inclusion of cultural property in the regime of

[154] http://www.unesco.org/eri/la/convention.asp?KO=13637&language=E

war reparations applicable to "ordinary" property. By end of April 2017 105 state parties have acceded to the 1st Protocol.[155]

Second Protocol to the Hague Convention of 1954 for the Protection of Cultural Property in the Event of Armed Conflict (1999), the **acts of barbarism** committed against cultural heritage during numerous conflicts that took place at the end of the 1980s and the beginning of the 1990s presented new challenges to the international community. Such conflicts and their repercussions were only partially taken into account during the negotiations of the Convention in the 1950s. Contemporary conflicts are often internal, and of an ethnic nature, and thus are not within the scope of the international law applicable to traditional interstate warfare. In addition, this type of conflict is often particularly destructive of cultural heritage. In this type of conflict, an aggressor often directly and deliberately targets a besieged ethnic group's culture and heritage with the intent of humiliating the target group by taking away its past, culture, and heritage.

A process of review of the Convention began in 1991, and led to the negotiation and adoption in The Hague of a Second Protocol to the Convention in March 1999. This Protocol strengthens several provisions of the Convention concerning the safeguarding of and the respect for cultural property and conduct during hostilities.

The Protocol consists of the following chapters:

1. Introduction
2. General provisions regarding protection
3. Enhanced protection
4. Criminal responsibility and jurisdiction
5. The protection of cultural property in armed conflict not of an international character
6. Institutional issues
7. Dissemination of information and international assistance
8. Execution of this Protocol
9. Final clauses

This Protocol also establishes an institutional element: the ***Committee for the Protection of Cultural Property in the Event of Armed Conflict***. The Committee consists of twelve States Parties, and is responsible for ensuring the implementation of the Second Protocol.

By end of April 2017 72 state parties have acceded to the Second Protocol.[156]

This created a new category – **enhanced protection** – for cultural property of the greatest importance for humanity (chapter III, paras 10-14, Figure 2.21e). This category of cultural property is protected by adequate legal provisions at national level and is not used for military purposes. The Second Protocol also increases the effectiveness of the Convention, by directly defining the sanctions triggered by serious violations against cultural property, and the conditions under which individual criminal responsibility apply.

[155] http://www.unesco.org/eri/la/convention.asp?KO=15391&language=E
[156] http://www.unesco.org/eri/la/convention.asp?KO=15207&language=E

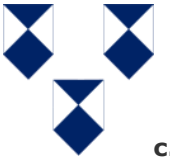
Emblem	Description
 a.	Art. 5 of the Hague Convention no. IX of 1907 contains the first emblem for cultural property.
 b.	The Peace Banner (© Roerich Pact).
 c.	Places and properties defined register under special protection are marked with the emblem repeated three times (Arts. 16 para 2 and 17 para 1).
 d.	The distinctive emblem (Art. 16 para 1) symbol of cultural property.
 e.	The emblem for enhanced protection.

Figure 2.21 Symbols, emblems, logos and their descriptions.

Resilience strengthening and risk management

According to the Hague Convention, the responsibility for implementation of the protection of cultural property in armed conflicts lies primarily with the **military authorities**. An exception to this rule applies to Italy, where responsibility is assigned to the Carabinieri, which is subordinated to the Ministry of Defense; Switzerland and the Principality of Liechtenstein, where the Federal Office for the Protection of the Population is responsible for the protection of the cultural heritage. Most micro-states have also placed the responsibility for the protection of the cultural heritage to civilian authorities.

Most of the European armies have experts for the protection of cultural heritage (liaison officers, sergeants). These officers are usually located in the operational staff of military units. However, it must also be stated that the protection of cultural property in most armies does not receive excessive attention. Amongst the armies, the Austrian Armed Forces has had an excellent international reputation for many years. The cultural property protection officers and specialists (all of them are militia soldiers), are integrated into the military command of the Provinces. The State Defense Academy in Vienna is responsible for professional training. The experts there have an international reputation and also teach at military training centres abroad. Nevertheless, it should be noted that both the training program and the staffing could be largely extended.

The **Carabinieri** are one of the world's most important combat forces specialized in the protection of the cultural heritage (Comando Carabinieri TPC et al., 2016; Rush and Benedettini Millington, 2015). They have combatant status, both in terms of personnel and infrastructure. The Comando Carabinieri del Tutela del Patrimonio Culturale (TPC) encompasses 270 specialists for the protection of the cultural heritage and works very

closely with numerous civilian experts. The unit has the capacity to protect archaeological sites on land, and in the sea, as well as UNESCO World Heritage properties and other culturally valuable sites by utalising aircraft, horseback access, patrol boats and diving units. They are also able to evacuate and restore works of art and cultural objects when conflicts and catastrophes occur. Moreover, the TPC is also in the position to offer specialized support to military contingents in peacekeeping missions abroad.

These broad competences and capacities were a prerequisite for the cooperation between UNESCO and the Republic of Italy in the setting up of a **unite4heritage association**, which laid the foundation for the so-called Blue Helmets for Culture. The massive destruction of UNESCO World Heritage sites in near East by the The destruction of cultural property during armed conflicts has recently gained a sad fearfulness, which shattered the world community, especially with the destructions in Syria, Iraq and Jordan by the Daesh, especially in Palmyra, was a major impetus. This cooperation was signed on 16 February 2016 between the Director-General Irina Bokova and the Italian Foreign Minister Paolo Gentiloni in Rome (Figure 2.22) (UNESCO, 2016). The task force can travel to crisis areas in armed conflicts and natural catastrophes and secure any threatened monuments and cultural objects there. The specialists have the skill and means to take backup measures, to develop reconstruction concepts and to ensure the **preservation of cultural objects from looting**. The unit is 60 person strong, 30 each from the Carabinieri and the Ministry of Culture. It is expected that other states will make staff available for the Blue Helmets to aid the protection of cultural heritage.

Figure 2.22 UNESCO Director-General Irina Bokova and Italian Foreign Minister Paolo Gentiloni sign the cooperation agreement for the unite4heritage mission group in Rome on 16 February 2016. (photo: AP Photo / Domenico Stinellis).

The activities of UNESCO also include the **preparation of a military manual** for the protection of the cultural heritage. This was commissioned in 2016 after the devastating destructions in Mali, Yemen, Libya, Iraq and Syria had occurred. In addition to the basic legal texts, it contains **guidelines for the implementation of the protection** of the cultural heritage in the event of an application and also **exemplary implementation examples** (O'Keefe et al., 2016). The manual is intended to assist the armies in the implementation of cultural heritage protection (Figure 2.23).

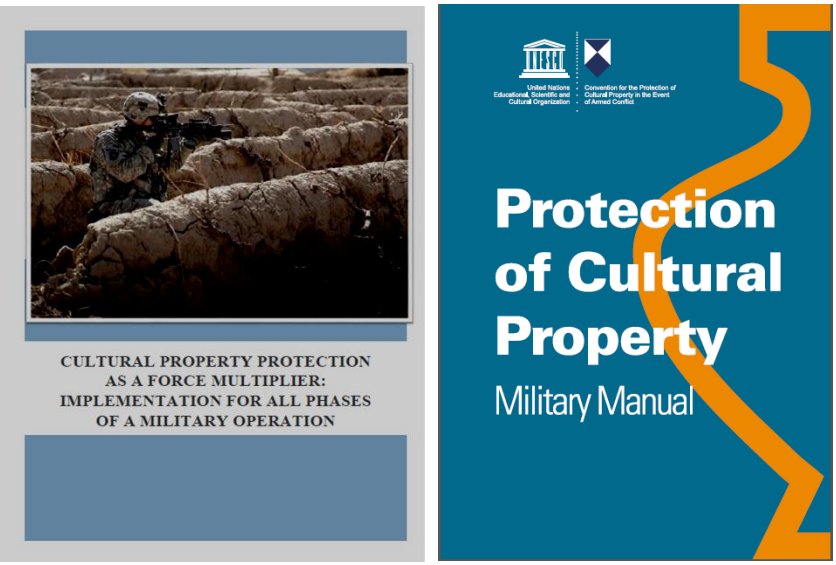


Figure 2.23 The Military Manual of UNESCO (right) and the draft Guidelines for the use of NATO (left) (photos: UNESCO and SPA NATO).

NATO activities in the protection of the cultural heritage are currently particularly relevant. As part of the NATO Science for Peace and Security Programme (SPS)[157] the Emerging Security Challenges Division is coordinating the development of a **Cultural Property Protection as a Force Multiplier**. On the basis of expert conferences held in Sarajevo, Krems and San Remo in 2015 and 2016 involving international experts from military and civilian organizations, a manual designed for the operational implementation is presently (2017) being compiled.

The most important NGO in the area of cultural property protection is the **International Committee of the Blue Shield** (ICBS), headquartered in The Hague. Its official task is to advise UNESCO and its States Parties in the implementation of the Hague Convention (Vgl. 2. Protokoll der Haager Konvention Art. 11 und 27[158]). In addition, the Committee organizes specialist events, supports the development of teaching and practice materials, and advises on the signing and implementation of The Hague Convention and its protocols.[159] Meanwhile, there are 14 national committees of Blue Shield, organized – together with ICBS – in the Association of National Committees of the Blue Shield. The President, Karl Habsburg-Lothringen, is particularly active in matters concerning the protection of the cultural heritage. By traveling frequently to crises regions, he supports the forces involved in the implementation of the Hague Convention. He gained high international recognition during the Libyan civil war in 2011, when he supported the Egyptian military in developing so-called "no-strike-lists" of cultural properties (Figure 2.24)[160]. But, a problem generally lies in the fact that the descriptions in the field of history of art for the cultural property and their civilian-based locations are not suitable for military operations. He often describes his organization as a translation office between academic – military and military – academic.

[157] https://www.nato.int/cps/en/natolive/78209.htm
[158] http://www.unesco.org/culture/laws/pdf/switzerland_germantransl_1954HCP2.pdf
[159] http://www.ancbs.org/cms/index.php/en/about-us/about-icbs
[160] http://www.the-executive.at/at%20Business/page98/page98.html

Figure 2.24 Karl Habsburg-Lorraine with his companion Joris Kila and militia soldiers in 2011 in Cyrene (Libia) (Kila, 2012) (photo: Blue Shield Austria).

In general, it can be said that the most effective measure to prevent the willful destruction of cultural goods, in most cases is in the **diplomatic approach**. The systematic implementation of cultural property protection in military operations plans can at least reduce collateral damage. However, the intentional destruction of identity building monuments can only be prevented, if at all, by using weapons and combat units.

Training and dissemination actions

As indicated above, and with a few exceptions, the responsibility for the execution of the protection of cultural property in armed conflicts according to the Hague Convention lies primarily with the military[161]

Regarding training of the connection officers and experts for the protection of the cultural heritage in the Austrian Armed Forces may be listed. These specialists will receive a one-week basic training at the State Defense Academy in Vienna. Those trained are all militia soldiers who, in their civilian occupation, have a link to cultural properties. After basic training, annual exercises and courses are held. Furthermore, the deepening of knowledge in the protection of the cultural heritage also lies in the military command of the Provinces with specific reference to the cultural heritage in their area (Figure 2.25).

[161] Contrary to the stipulations of The Hague Convention of 1954 in some states the responsibility for the implementation of cultural property protection lies with civil authorities (e.g. Switzerland, Principality of Liechtenstein).

Figure 2.25 Training of the cultural heritage protection officers at the Austrian Army at Carnuntum (photo: Bernhard Hofer).

The educational program for the cultural preservation agencies in Switzerland (and thus also in the Principality of Liechtenstein) organized by the competent authorities of the Swiss Confederation, the cantons and municipalities, can be described as particularly comprehensive and profound. The training documents are compiled by the Federal Office for Population Protection and are considered as some of the most comprehensive in Europe. However, they do not especially refer to armed conflicts. Switzerland is characterized by a particularly comprehensive and interactive inventory, which is also of interest to the general public, such as the hiking trails, cycle paths and nature parks displayed in this way (Figure 2.26)[162]. In addition, the Federal Office for the Protection of Cultural Heritage publishes specialized periodicals linking hiking brochures to visiting cultural objects. As a result, this topic is very popular in Switzerland.

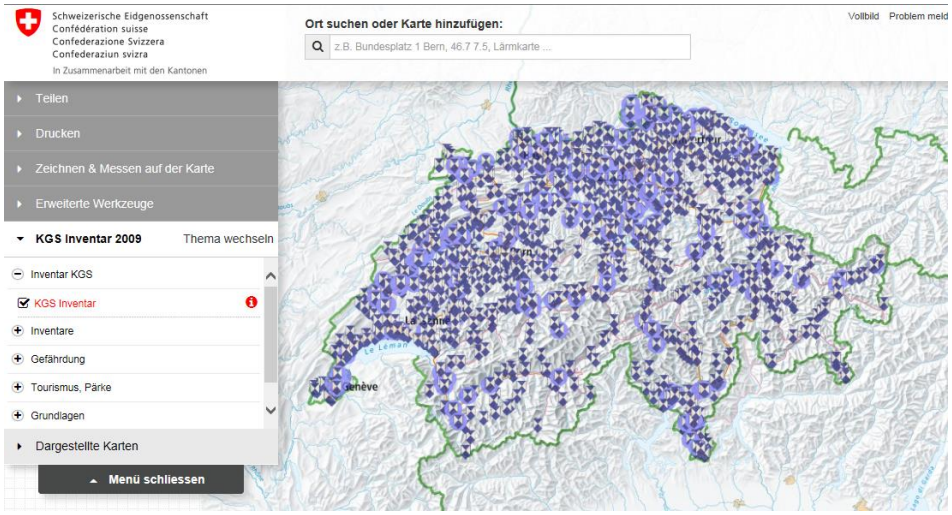


Figure 2.26 The interactive cultural heritage inventory of Switzerland on the pages www.babs.admin.ch (Phot: screen shot).

In the university sector, educational programmes for the protection of cultural heritage are mainly offered to postgraduate students. **A basic study concerning the**

[162] https://map.geo.admin.ch/?topic=kgs&lang=de&bgLayer=ch.swisstopo.pixelkarte-farbe&layers=ch.babs.kulturgueter&layers_opacity=0.75&catalogNodes=363

protection of the cultural heritage does not exist in Europe. The postgraduate courses Protection of European Cultural Property at the Collegium Polonicum in Słubice (PL) and Cultural Heritage at the Danube University Krems (A) should be mentioned here. Both courses are structured in block lessons, and are designed as part-time courses. The content of the curriculum not only focusses on the protection of cultural property during armed conflicts, but also on natural catastrophes. The courses take four to six semesters and conclude with a M.A. with 60 ECTS (Collegium Polonicum) or with an MSc with 120 ECTS (Danube University Krems). At the Danube University Krems, international summer universities are also held on the subject of cultural property protection, and are attended by international experts (Figure 2.27).

Furthermore, it is possible at other universities to complete a doctorate program on the topic of "protection of the cultural heritage". Depending on the focus, the programmes can be enrolled in a faculty of law, philosophy, or a faculty of technology. The doctoral program lasts at least 6 semesters and covers 180 ECTS.

Figure 2.27 International Summer University Cultural Heritage Conservation at the Danube University Krems (Austria) in summer 2017 (photo: Elena Zaunschirm).

Educational programs for experts on the protection of the cultural heritage are carried out by the **International Center for the Study of the Preservation and Restoration of Cultural Property** (**ICCROM**) in Rome. Particularly noteworthy are the programs First Aid to Cultural Heritage in Times of Crisis[163] and Disaster Risk Management of Cultural Heritage. Both programs are about two weeks in duration and are very application-oriented, and are not solely designed for armed conflicts.

The national committees **Blue Shield** as well as Roerich Societies, which are partly held with other cooperation partners (ministries, ICOM, Red Cross, etc.) and are attended by prominent guests, should be mentioned in the organization of public events (such as discussions, symposia or exhibitions) concerning the protection of cultural heritage. All these activities and their public recognition must, under no circumstances, be underestimated. In addition, these organizations regularly contribute to specialist publications and issue informational material on the subject. Since the creation of the "unite4heritage", the national organizations of "Blue Helmet" are also actively involved in the field.

[163] ICCROM: First Aid to Cultural Heritage in Times of Crisis (FAC), http://www.iccrom.org/courses/first-aid/ Disaster Risk Management of Cultural Heritage, http://www.iccrom.org/courses/disaster-risk-management-of-cultural-heritage/

3
Questionnaire

3 Questionnaire

This Chapter includes the questionnaire set up for the online survey aimed at mapping the existing strategies and practices at national level, including support measures and tools (e.g. risk maps, inventories, informative systems), competence and training centres, legislative frameworks and governance models (e.g. chain of command, decision-making), for risk analysis, assessment and management for safeguarding cultural heritage from the effects of natural disasters and threats caused by human action in Europe.

The questionnaire realized through the online Google forms, run from the beginning of June to the middle of October 2017 and is still open. The format utilized along with the outcomes obtained are here presented. It has to be underlined that in specific cases, mainly due to English approach, the questionnaire was submitted also by phone interviews (particularly for Greece, Bulgaria and Republic of Cyprus). The activity as planned in Task 2 – Mapping (surveys and interviews), made use of personal experience, selecting experts and stakeholders according to the criteria represented in Figure 3.1. Finally, the list of experts, which participate in the survey and agreed to be published along with their affiliations is reported in ANNEX B.

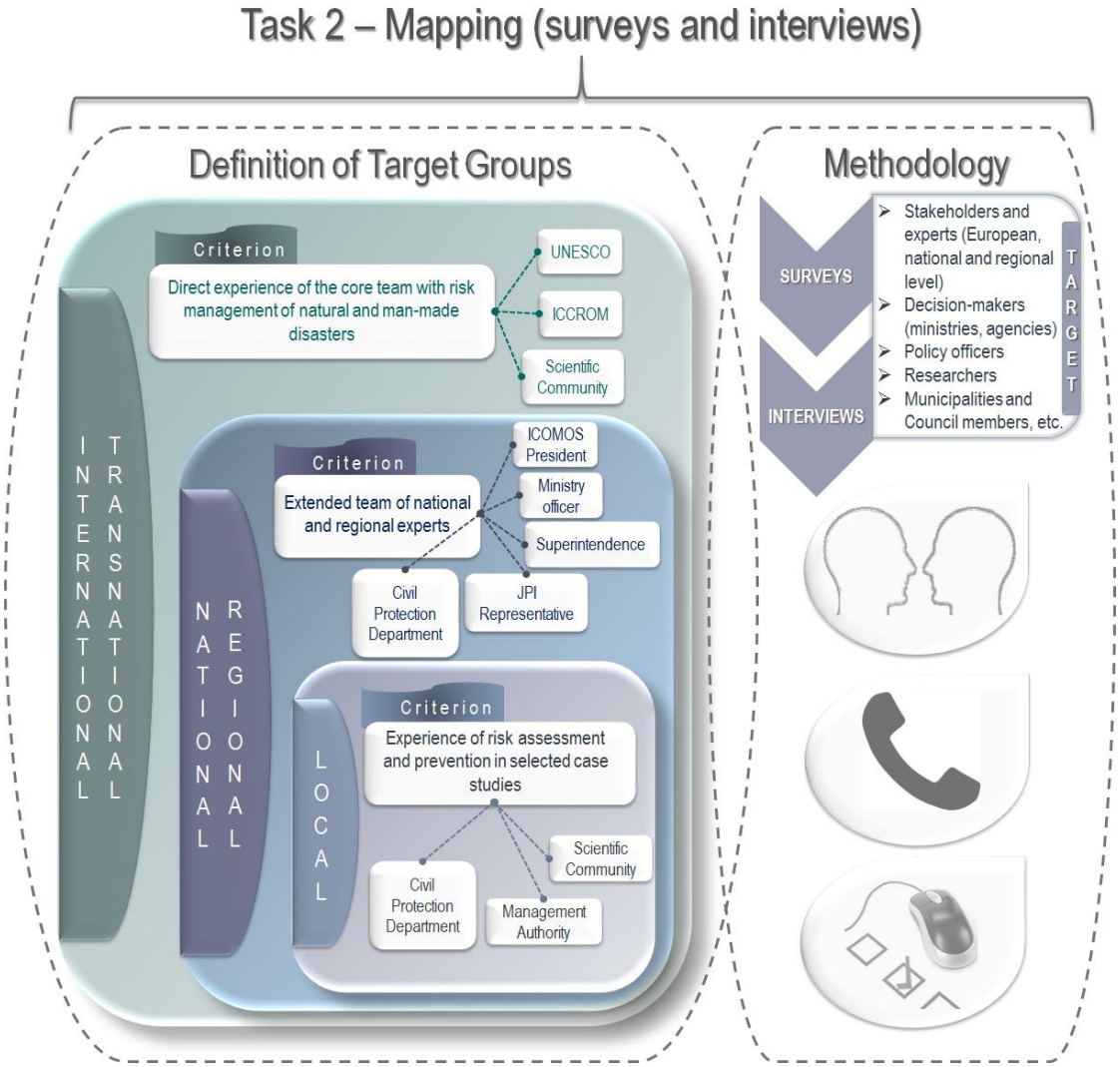


Figure 3.1 Schematisation of Task 2 steps. On the left: main criteria of selection of experts and stakeholders for the different levels. On the right: methodology adopted for carrying out the survey and interviews.

Questionnaire - Disaster Risk Management of Cultural Heritage

Study on Safeguarding Cultural Heritage from Natural and Man-Made Disasters

The following questionnaire is seeking responses to a study being carried for the **European Commission, DIRECTORATE-GENERAL FOR EDUCATION AND CULTURE, Culture and Creativity, Cultural Diversity and Innovation under Contract Number EAC-2016-0248.**

The overall objective of the study is twofold. Firstly, it aims to support European cooperation on Risk Assessment and Prevention for Safeguarding Cultural Heritage from the effects of natural disasters and threats caused by human action. Secondly, it seeks to contribute to the integration of cultural heritage as a new focus area of the Sendai framework to consider the inclusion of disaster risk management.

Introduction

Fields marked with * are mandatory

Please do not skip questions. If there are questions that you do not feel comfortable responding to, please tick the "no opinion / not applicable" option. You can also pause completing the proforma at any time and continue later. Once you have submitted your answers, and uploaded a supporting and concluding written contribution, you will be able to download a copy of the completed questionnaire.

Note that, whatever option is chosen below, your answers may be subject to a request for public access to documents under Regulation EC 1049/2001

In reply please indicate which approval, as below, is acceptable to you:

I agree that the information I provide:

- ☐ **Can be published along with my personal information** (I consent to the publication of any information in my contribution, in whole or in part, including my name or my organisation's name, and I declare that nothing within my response is unlawful or would infringe the rights of any third party in a manner that would prevent publication.)
- ☐ **Can be published provided that I remain anonymous** (I consent to the publication of any information in my contribution, in whole or in part, - which may include quotes or opinions I express - provided that it is done anonymously. I declare that nothing within my response is unlawful or would infringe the rights of any third party in a manner that would prevent the publication.)

About you:

a) **Please provide your full name** (Open)

b) **Are you responding as a representative of a public authority, if so, which?** (Open)

c) **Please indicate your profession or job function in your business / organization** (Open)

d) **Please state what is your role, formal qualifications and entity affiliations are** (Open, *150 characters maximum*)

e) **Please indicate the primary place(s) of your organizations' operations and/or the country(ies) that your organization represents, or works for** (Open)

f) **Date of completing the survey** DD MM YYYY

g) **Gender** F☐ M☐

h) **Age** ☐ <40; ☐ 41-60; ☐ >61

i) **How long have you been employed at your current job**? ☐ <2y; ☐ 3<y<5; ☐ >6y

j) **What is your nationality?** (Choose from the drop down menu: if "Other", please state)

k) **Please give your email address in case we require additional information about your reply and need to seek any further clarifications** _____@_____ (Your e-mail address will not be publicly released)

l) **Please indicate which sector best describes your organisation**:

m) International administration
n) National administration
o) Regional authority
p) Non-governmental organization
q) Large business
r) Small or micro enterprise
s) Medium-sized enterprise
t) Research institute/academia
u) Higher education institution
v) Vocational training organization
w) Public business or innovation support body
x) Private business or innovation support body
y) Financial sector
z) Other

Specific questions

1. Brief introduction

1a. In your opinion, how much is the cultural heritage of your member state/region exposed to each of these risks? (Please rank each topic from: 1 – 'least important' to 5 – 'most important')

NATURAL DISASTER	**1**	**2**	**3**	**4**	**5**
Volcanic eruption	☐	☐	☐	☐	☐
Fire	☐	☐	☐	☐	☐
Earthquake	☐	☐	☐	☐	☐
Landslide/Avalanches	☐	☐	☐	☐	☐
Flood	☐	☐	☐	☐	☐
Tsunamis	☐	☐	☐	☐	☐
Sea Level Rise	☐	☐	☐	☐	☐
Storm	☐	☐	☐	☐	☐
Coastal erosion	☐	☐	☐	☐	☐
Drought	☐	☐	☐	☐	☐
HUMAN ACTION	**1**	**2**	**3**	**4**	**5**
Pollution	☐	☐	☐	☐	☐
Armed conflict / Terrorism	☐	☐	☐	☐	☐
Illicit artefact trafficking	☐	☐	☐	☐	☐
Over-exploitation	☐	☐	☐	☐	☐
Touristic pressure	☐	☐	☐	☐	☐
Unsustainable development	☐	☐	☐	☐	☐
Climate change (fast/sudden)	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐

If you ticked "Other", please specify what you refer to:

200 characters maximum

1b. **Based on the previous answers please select the priority risks, considered SUBJECTIVELY:** (Please rank each topic from: 1 – 'least important' to 5 – 'most important')

	1	2	3	4	5
Volcanic eruptions	☐	☐	☐	☐	☐
Fire	☐	☐	☐	☐	☐
Earthquakes	☐	☐	☐	☐	☐
…..	☐	☐	☐	☐	☐

1c. **How important do you consider the recognition and acceptance by regions (and countries) of risk assessment research and innovation strategy priorities?**

Answer: 1=not at all, 2=to a minor extent, 3=to some extent, 4=to a great extent, 5=no opinion

1	2	3	4	5
☐	☐	☐	☐	☐

1d. **How important, in your opinion, is consultation with business, academic and public stakeholders in advance of deciding on the allocation of funding to achieve the answer to point 1c below?**

Answer: 1=not at all, 2=to a minor extent, 3=to some extent, 4=to a great extent, 5=no opinion

1	2	3	4	5
☐	☐	☐	☐	☐

1e. **Do you know of any existing national strategies or practices (in your country) for safeguarding cultural heritage from the risks listed in 1a (above)?** Yes ☐ No ☐

Please indicate if you answer focuses on:

☐ Your region
☐ Your country
☐ Both, region and country

1f. **If yes, please specify the type of strategy, and indicate which of the risks, listed in 1a above, apply:**

i. Preparedness measures Yes ☐ No ☐ Related to which kinds of risk?
ii. Emergency plans Yes ☐ No ☐ Related to which kinds of risk?
iii. Recovery measures Yes ☐ No ☐ Related to which kinds of risk?
iv. [Other: Please state]…

1g. **Do you know of any similar strategies in other countries? Yes ☐ No ☐**

If so, what are they, and to which countries do they apply?

Which kinds of risk are considered?

1h. **Do you know examples of excellence in risk awareness governance at regional level in your country? (i.e. Regional strategies)**

Yes ☐ No ☐

If yes, please state what governance issues they are and in which Region they apply?

What kinds of risk are considered?

1i. **Are you aware of the existence of any integration of cultural heritage needs in your national legislative platforms for Disaster Risk Reduction in your country**?
Yes ☐ No ☐
If yes, which legislative platforms are they. Please give their formal names and references?

Please state which kind of risks are covered?

1j. **Are you aware of any other good practices/actions to encourage the integration of cultural heritage needs in the national legislative platforms for Disaster Risk Reduction?** Yes ☐ No ☐
If yes, in which country do they apply?

Please state which kind of risks are covered?

1k. **Are you aware of any existing training centres and/or educational tools or facilities that provide the required competencies in dealing with Disaster Risk reduction?**
Yes ☐ No ☐
If yes, what are they, and where are they to be found? Please list:

Please state which kind of risks are addressed?

2. **Effective Risk Management works as a result of a combination of public support and private initiatives. It crucially depends on interaction, openness and cooperation amongst different enterprises, citizens, educational, research, public bodies, etc..**

***Public policy and funding in the right circumstances can create a top-down risk management incentive that* can increase the likelihood of improving the response approach to natural and man-made events.**
Please provide answers to A) and B) in the table below:
☐ A) If you personally implement the management in your enterprise or organization: in the past 3 years did you or your organization work in unison with any of the following listed bodies or enterprises to improve the risk assessment capacity, or implement resilience projects?
☐ B) If you or your organization supported risk assessment in other enterprises or bodies: in the past 3 years did you observe MORE participation of the following type of enterprises or bodies in the risk assessment in your country or region?

	Answer A			Answer B		
*	Yes	No	Not relevant	Yes	No	Not relevant
Consultancy firm						
Multi-national firm						

Private investor (e.g. business angel)						
Public bodies (from your country / region)						
Public bodies (from abroad)						
European body						
Research service provider (from your country / region)						
Research service provider (from abroad)						
Higher Education Institution						
Research Public Entity						
Patent lawyer / advisor						
Civil society organization						
Other						

If you ticked "Other", please specify what you referred to:

400 characters maximum

3**. Which other organizations should be more or better involved in supporting research for Risk Assessment in your country or region?**
(Please choose several options from the table below, as applicable)

*			
Academic Research bodies			
Professional Bodies			
Vocational Craft Trade Bodies			
Suppliers and Manufactures			
Higher Education Institutions and/or vocational training establishments			
Civil Society			
Scientific Research and Technology Organizations			
Funding Enterprises			
SME intermediaries, such as cluster organizations			
Official associations for environment and heritage protection			
Private associations for environment and heritage protection			
Other			

If you ticked "other", please specify what you referred to:

Other

300 characters maximum

4. **Can you identify and describe a significant research and/or specific project on the topic of DISASTER RISK MANAGEMENT OF CULTURAL HERITAGE that was undertaken during the last 3/5 years in your country or region?**

☐ Yes

☐ No

***If yes: Noting the points below, please explain the success the project achieved in creating a link between the disaster risk reduction experience and Cultural Heritage protection, so that the case might inspire others to launch similar projects?**

Please consider mentioning, where relevant:

- The topic or type of research and innovation

- The partners and types of organisations involved

- The project budget and its funding sources

- Any public support received and/or public infrastructure that was used

- The achieved results considered against the original intentions

- Lesson learnt and any crucial issues that led to the project success

- Any web address where further information can be found

600 characters maximum

5. **The EU can provide financial support for public research and innovation. The process works either:**

i) Via Directly Managed Funds through which are apply for directly to the Commission (e.g. Horizon 2020, INTERREG, LIFE, JPI etc.);

ii) The European Investment Fund; or

iii) Via shared managed funds (e.g. European Regional Development Fund, European Social Fund) where the definition of the support conditions and selection of projects is done by national or regional bodies, or intermediaries.

In the following table:

A) Please indicate which programme you are personally aware of

B) Please indicate which programme you have personally been involved in (last 10 years)

*	Answer A)	Answer B)
Horizon 2020 – collaborative research and innovation project		
Horizon 2020 – SME instrument		
Horizon 2020 – ERC grant		
Horizon 2020 – Marie Skłodowska-Curie		
Horizon 2020 – other		
Other directly managed EU programmes - LIFE (environmental, nature conservation and climate action projects)		
JPI-CH		
Copernicus programme (ex GMES Global Monitoring for Environmental and Security)		

Interreg programme		
URBACT programme		
LEADER programme		
Other directly managed EU programmes		

Please indicate which related EU programme you referred to on indicating "Other"

200 characters maximum

6. **It is recognised that Cultural Heritage still does not occupy a central position in current national and international policy documents on A) 'Climate Change' and B) 'Disaster Risk Reduction'.**

Should be further interregional cooperation and action to include Cultural Heritage in these topics be encouraged?

A) Climate Change		B) Disaster Risk Reduction	
Yes	No	Yes	No

If yes, tick what you consider the <u>three</u> most important benefits in each topic A) and B)

A) B)

☐ ☐ New research partners from abroad

☐ ☐ Exchange of good practices for public administration and business models

☐ ☐ Increase cross-border cooperation with higher education institutions

☐ ☐ Improvement of mutual access to public research and infrastructures

☐ ☐ Use the existing research and facilities of another region/country

7**. Please offer any further suggestions or comments regarding the development and implementation of Risk Management Plans for Cultural Heritage. This might include comment on the wider context of EU-policies on research, innovation, education, etc.**

It would be particularly helpful for the study to have your views on how to reinforce political commitment, dissemination of good practice, and the facilitation of strategic interregional collaboration.

500 characters maximum

THANK YOU for taking the time to complete this questionnaire.

3.1 Data elaboration

302 selected experts have been contacted for submitting the survey and 109 people completed the online questionnaire. Among the reasons of 2/3 of the experts that did not reply, we can mention the impossibility of reaching the person; the declaration of having a different area of expertise; language (English) barrier; no time; not authorized and the feeling uncomfortable in giving personal information (even if there was the possibility of participating in an anonymous way).

The majority of the interviewed people 59%, agreed with the publication of their answers along with their personal information (see Annex B).

Considering the gender, in 102 answers, the 60% were men and the 40% were women (Figure 3.2); while regarding the age, 104 people replied, of which the 64% were between 41 and 60 years old; the 21% were over 61 years old, and the 15% under 40 years old. (Figure 3.3). Figure 3.4 shows the nationality of the interviewed people.

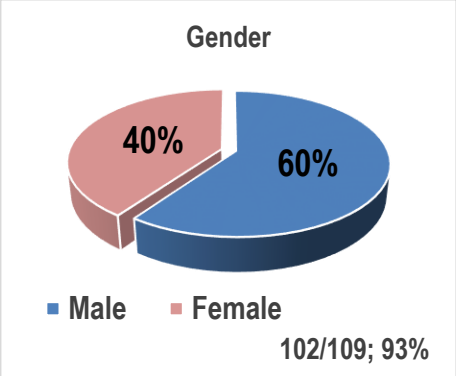


Figure 3.2 Gender.

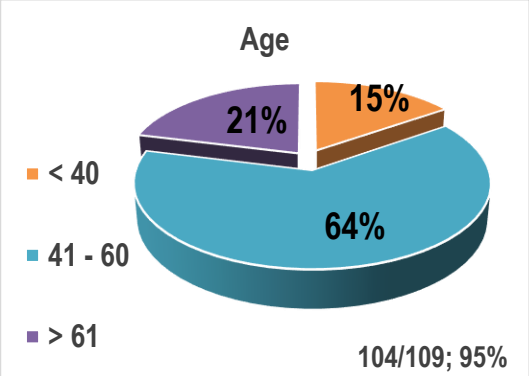


Figure 3.3 Age.

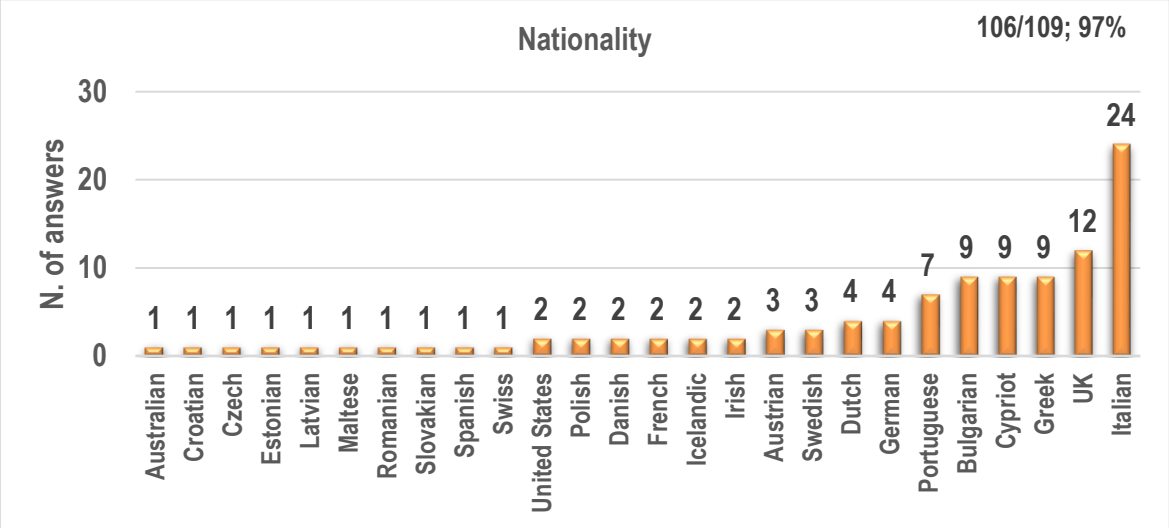


Figure 3.4 Nationality of the stakeholders.

Concerning the working sector 74% have been employed in their current area for more than 6 years (**Question i**, Figure 3.5). Comparing with the typology of represented organizations, 35% were in national administrations, followed by 23% in research institutes/academia, 16% in Higher education institutions, 6% in regional authorities, 5% in medium-sized enterprises, 5% in international administration, 4% in small or

micro enterprises, 4% in non-governmental organizations and 2% in private businesses or innovation support bodies. It has to be underlined that no answers were received from large businesses, vocational training organizations, public business or innovation support bodies, or the financial sector; therefore, they are not present in the following diagram (**Question l**, Figure 3.6).

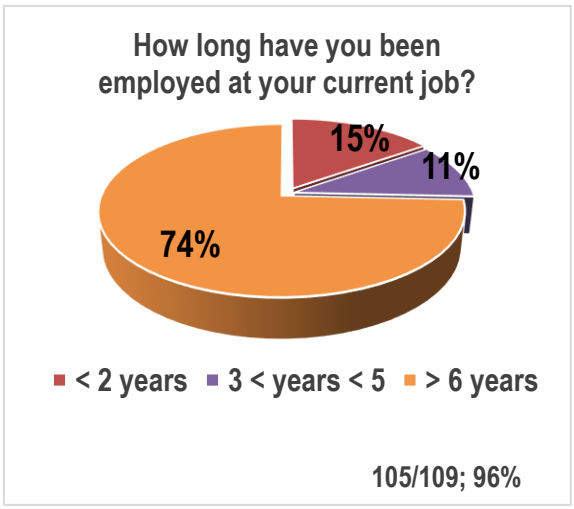


Figure 3.5 Duration of employment in the current job.

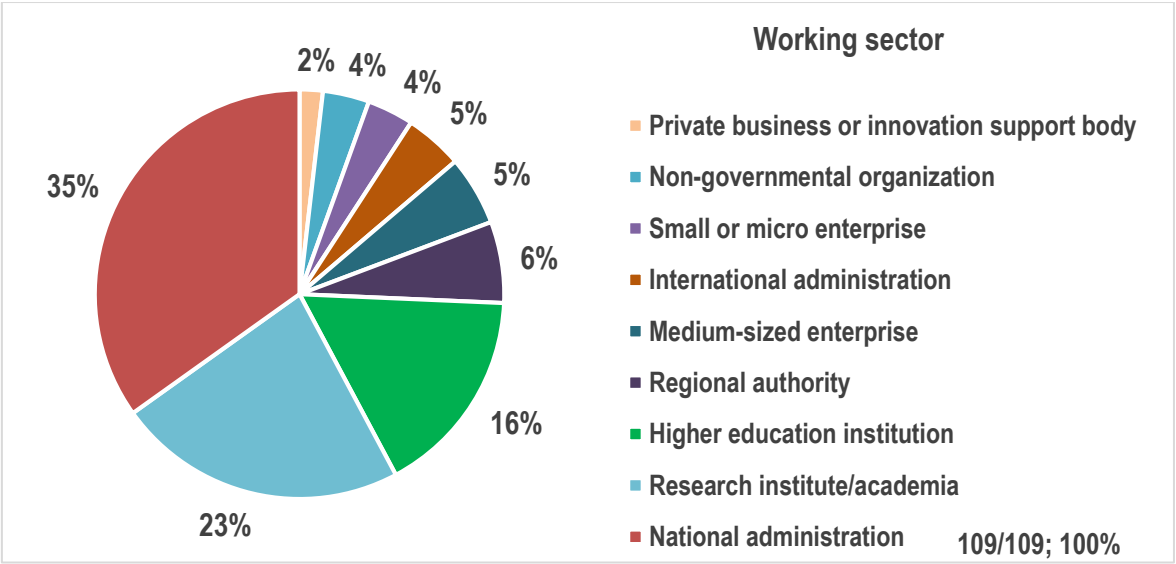


Figure 3.6 Working sector.

The country(ies) that the organizationrepresents, or works in (**Question e**), are listed here in order of abundance: Italy (21), International (12), UK (11), Republic of Cyprus (10), Greece and Bulgaria (9), Portugal (6) and Netherlands (3), followed by Norway, the, USA, Iceland, Germany, Poland and Sweden (2), and Finland, Spain, France, Croatia, Czech Republic, Estonia, Hong Kong, Malta, Denmark, Switzerland, Austria, Latvia, Slovak Republic, Vatican City, Romania and Ireland (1). It should be noted that the International experts also cover the missing nations.

In Table 3.1, the working sectors are subdivided by country of work, and shows the distribution of the contacted experts.

Table 3.1 Working sectors subdivided by country of work of the contacted experts.

	Higher education institution	International administration	Medium-sized enterprise	National administration	Non-governmental organization	Private business or innovation support body	Regional authority	Research institute/ academia	Small or micro enterprise	Total
Austria				2						**2**
Bulgaria	3	1		3			1	1		**9**
Croatia				1						**1**
Czech Republic				1						**1**
Denmark	1									**1**
Estonia				1						**1**
Finland				1						**1**
France								1		**1**
Germany								2		**2**
Greece				5			3	1		**9**
Hong Kong	1									**1**
Iceland				2						**2**
International	2	3						3	2	**10**
Ireland				1						**1**
Italy	2	1	3	7		1	1	6		**21**
Latvia			1							**1**
Malta	1									**1**
Netherlands								3		**3**
Norway								2		**2**
Poland	1			1						**2**
Portugal	3			2				1		**6**
Republic of Cyprus	2			4			2	1	1	**10**
Romania				1						**1**
Slovak Republic				1						**1**
Spain								1		**1**
Sweden				1				1		**2**
Switzerland				1		1				**2**
UK	2		1	2	4			1	1	**11**
USA			1	1						**2**
Vatican City								1		**1**
Total	**18**	**5**	**6**	**38**	**4**	**2**	**7**	**25**	**4**	**109**

The sector of experience (**Question m**) draws quite a similar profile to that previously mentioned in the working sector. Nevertheless, in this case the majority of interviewees belonged to research institutes 32%, whilst 29% had experience in national administrations, followed by 12% in higher education institutions, 6% in regional authorities and in medium-sized enterprises, 5% in non-governmental organizations,

3% in international administrations, 2% in small or micro enterprises, private businesses or innovation support bodies and large businesses, whilst 1% belonged to public businesses or innovation support bodies.

In Table 3.2, in addition to Figure 3.7, opinions are reported concerning the exposure to different kind of risks, both natural and man-made (**Question 1a**). In the first category, the most important was fire and earthquake (more 5 ratings received), followed by flood (more 4 ratings received), storm and coastal erosion (more 3 ratings received), landslide/avalanches and sea level rise (more 2 ratings received), volcanic eruption, tsunamis and drought (more 1 ratings received).

Table 3.2 How much is the cultural heritage of your member state/region exposed to each of these risks? (Please rank each topic from: 1 – 'least important' to 5 – 'most important').

NATURAL DISASTER	1	2	3	4	5	N. of answers	% of answers
Volcanic eruption	83	6	7	4	6	106	97
Fire	3	8	29	34	35	109	100
Earthquake	29	10	12	18	39	108	99
Landslide/Avalanches	19	29	25	19	16	108	99
Flood	8	13	18	41	28	108	99
Tsunamis	72	20	7	7	1	107	98
Sea Level Rise	26	30	19	15	15	105	96
Storm	7	25	29	25	21	107	98
Coastal erosion	20	15	27	23	21	106	97
Drought	29	31	24	15	7	106	97
HUMAN ACTION	**1**	**2**	**3**	**4**	**5**	**N. of answers**	**% of answers**
Pollution	6	22	29	41	10	108	99
Armed conflict / Terrorism	46	32	16	6	7	107	98
Illicit artefact trafficking	26	29	20	15	15	105	96
Over-exploitation	21	23	30	21	10	105	96
Touristic pressure	8	18	36	26	19	107	98
Unsustainable development	7	20	43	21	15	106	97
Climate change (fast/sudden)	12	25	25	33	12	107	98
Other	37%	8%	22%	14%	20%	51	47%

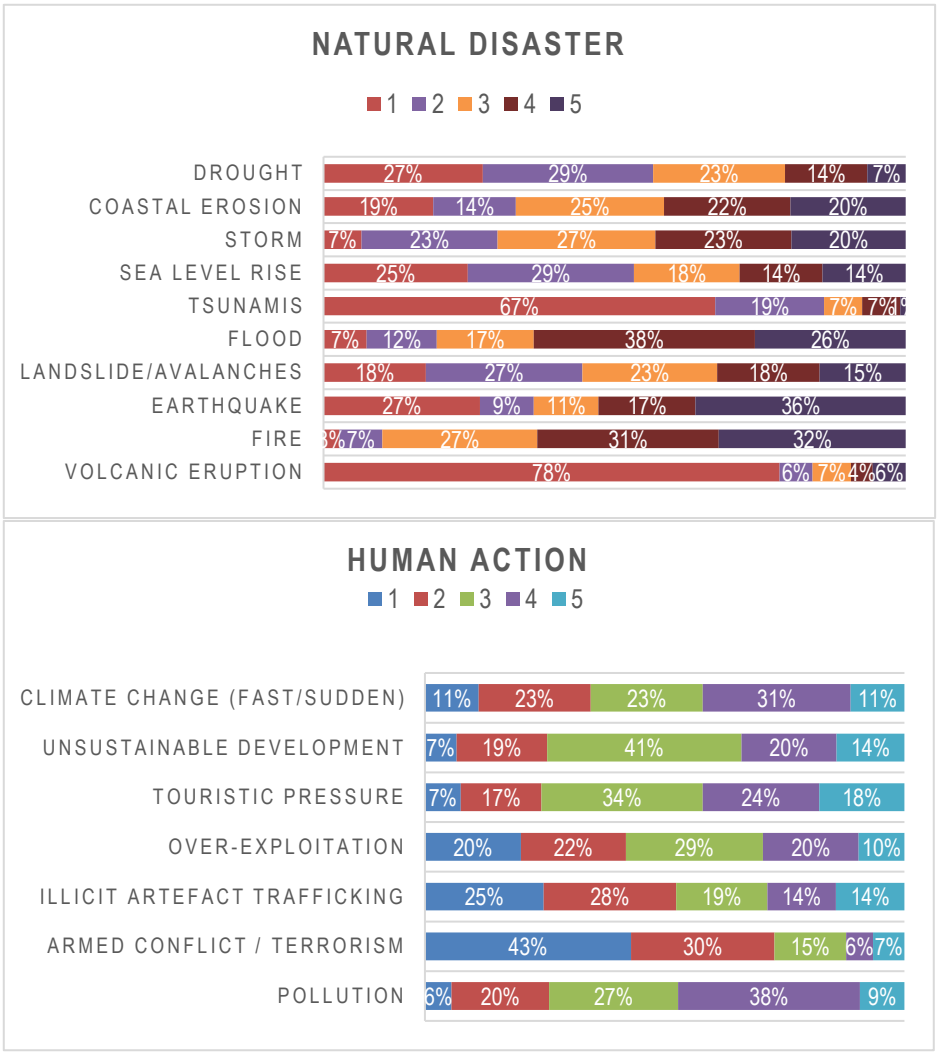


Figure 3.7 Natural and human action disasters ranked by experts from: 1 – 'least important' to 5 – 'most important'.

34 respondents ticked "Other" (37% 1 rating received; 8% 2 rating received; 22% 3 rating received; 14% 4 rating received; 20% 5 rating received). Noticeably, the majority (14/34 answers) referred to negligence and abandonment as the main problems, mostly due to the high cost being un-affordable, especially for private owners, thus weighting the limited quality of restoration and interventions. The item "lack of money" is also mentioned as being related to political will and decisions. Furthermore, additional factors such as land-use changes and connected complications (urbanization, pressure from infrastructure developers, unsustainable development and overexploitation of cultural heritage sites, etc.), terrorism, vandalism, lack of knowledge, illegal migration and cyber-attacks are also cited.

In **Question 1b**, «**Based on the previous answers please select the priority risks, considered SUBJECTIVELY**» opinions are reported concerning the exposure to different kind of risks, both natural and -man-made (Table 3.3 and Figure 3.8). In the first category, the most important was fire and earthquake (more 5 ratings received), followed by flood (more 4 ratings received), coastal erosion (more 3 ratings received), landslide/avalanches, storm and drought (more 2 ratings received), volcanic eruption, tsunamis and sea level rise (more 1 ratings received). Therefore, comparing the

previous results, the first two, 5 and 4 ratings, were the same, whilst storm and sea level rise were evaluated less risky at one rating point, while drought was considered more risky at one rating point.

Table 3.3 Based on the previous answers please select the priority risks, considered SUBJECTIVELY: (Please rank each topic from: 1 – 'least important' to 5 – 'most important').

NATURAL DISASTER	1	2	3	4	5	N. of answers	% of answers
Volcanic eruption	78	4	8	5	5	100	92%
Fire	4	8	19	36	37	104	95%
Earthquake	28	11	12	15	38	104	95%
Landslide/Avalanches	20	30	16	18	13	97	89%
Flood	9	9	19	34	31	102	94%
Tsunamis	69	13	8	6	1	97	89%
Sea Level Rise	27	24	20	20	8	99	91%
Storm	7	28	26	26	14	101	93%
Coastal erosion	21	21	27	20	12	101	93%
Drought	0	14	0	4	4	22	20%
HUMAN ACTION	**1**	**2**	**3**	**4**	**5**	**N. of answers**	**% of answers**
Pollution	9	17	30	29	18	103	94%
Armed conflict / Terrorism	40	23	19	5	11	98	90%
Illicit artefact trafficking	25	19	21	17	14	99	91%
Over-exploitation	16	24	35	14	10	99	91%
Touristic pressure	8	11	32	27	18	96	88%
Unsustainable development	5	18	34	26	16	99	91%
Climate change (fast/sudden)	11	26	21	30	12	100	92%
Others	28%	8%	19%	14%	31%	36	33%

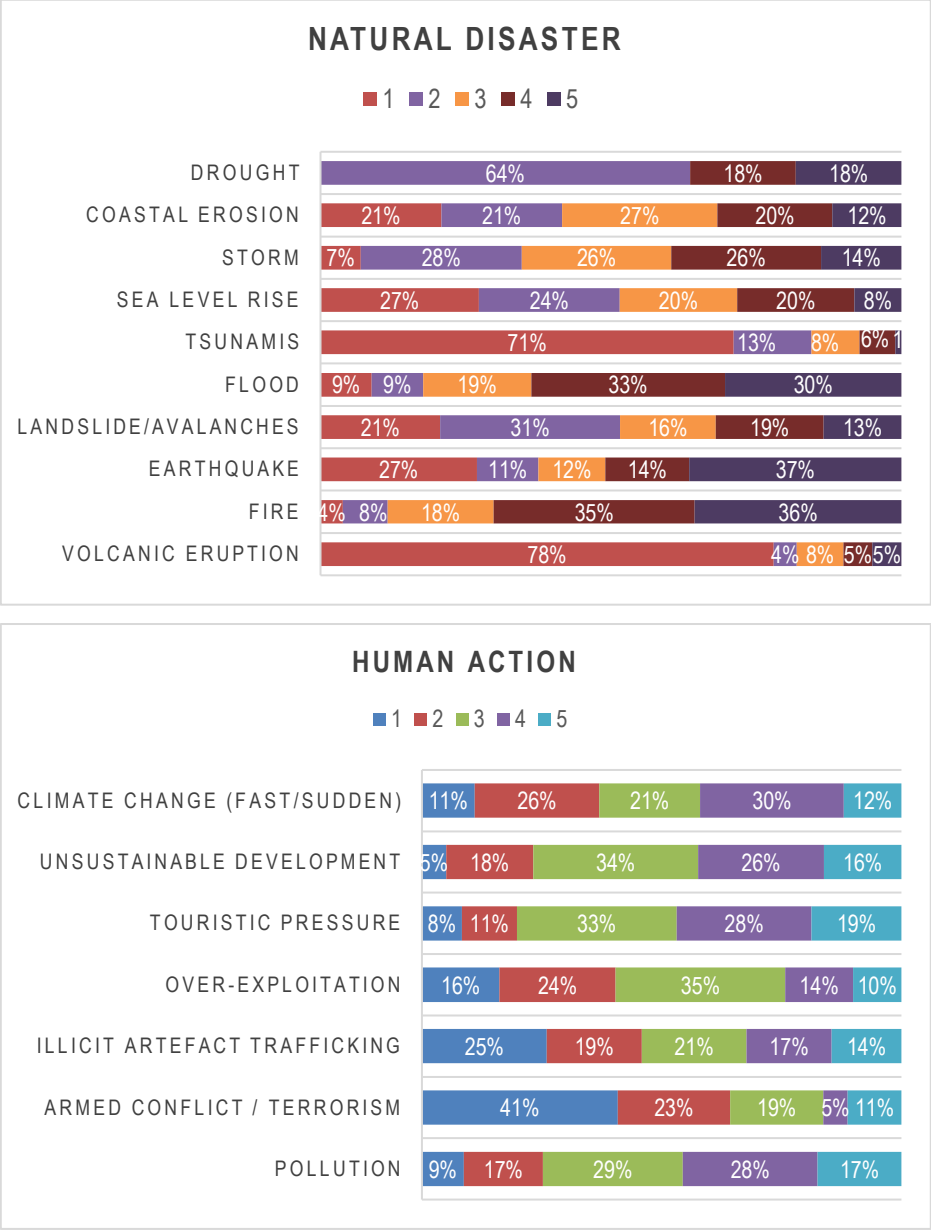


Figure 3.8 Natural and human action disasters ranked by experts from: 1 – 'least important' to 5 – 'most important'.

Considering the awareness of the importance in the recognition and acceptance by regions (and countries) of risk assessment research and innovation strategy priorities (**Question 1c**), the majority (69%) replied "to a great extent" (Figure 3.9). A similar result noted the recognition of the importance to consult with business, academic and public stakeholders in advance of deciding on the allocation of funding to achieve the answer to point 1c below (**Question 1d)**, where 64% answered "to a great extent" (Figure 3.10).

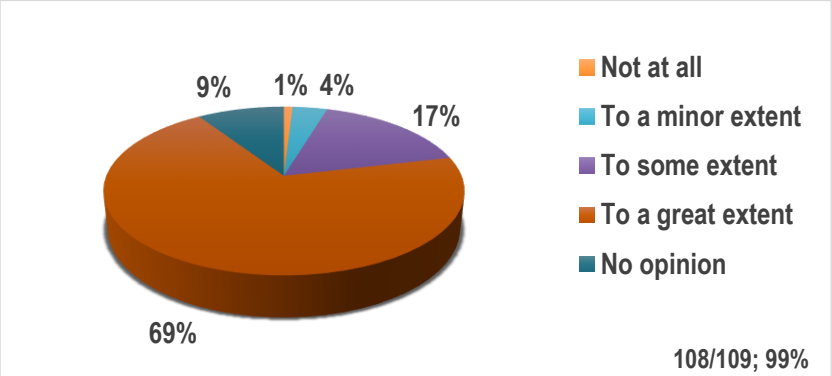


Figure 3.9 Recognition and acceptance by regions (and countries) of risk assessment research and innovation strategy priorities.

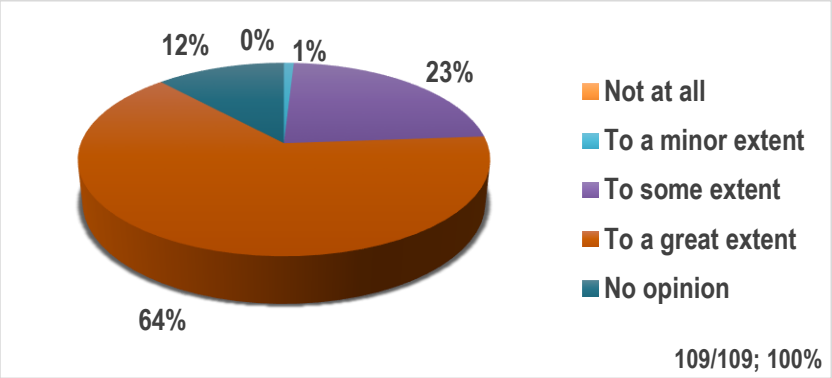


Figure 3.10 Consultation with business, academic and public stakeholders in advance of deciding on the allocation of funding to achieve the answer to point 1c below.

79% of stakeholders declared that they were aware of national strategies or practices (in their country) for safeguarding cultural heritage from the risks listed in 1a (above) (**Question 1e**). 56% affirmed that these strategies or practices focused on their country, 40% both on region and country and 4% only on their region (specifically: Scotland, Greece, Northern Ireland and Emilia-Romagna Region).

Gathering the strategies in: preparedness measures, emergency plans and recovery measures, participants answered the **Question f "If yes, please specify the type of strategy, and indicate which of the risks, listed in 1a above, apply",** as following reported.

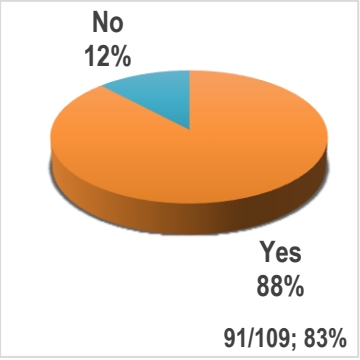
Preparedness measures: 91 experts replied and, in total, 68 answers were obtained. Summing up responses, the majority highlighted the presence of preparedness measures mainly concerning flood, fire, earthquake and seismic risk, climate change, storms and extreme/heavy rain, landslides, sea level rise and tsunami, coastal and environmental erosion, armed conflicts/war, all risks, volcanic risks, drought, atmospheric pollution and terrorism. These are listed in order of the number of answers received, as presented in Table 3.4.

Example of strategies cited are:

- *«The National Disaster Protection Programme 2014-2018: A National Disaster Protection Programme and Plan for the implementation of the National Program for 2017* was adopted in **Bulgaria**, which also defines measures for prevention or reduction of the adverse consequences to the cultural properties when disaster occures»;

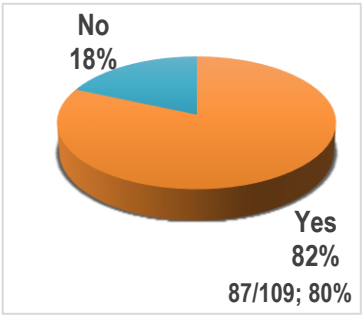
- «Under the ministry of Infrastructure in **Greece** there is a *specialised organisation on the earthquake design and protection in the case of seismic events* (www.oasp.gr). Under the ministry of Culture, the regional Ephorates or Services of Modern Monuments and Technical Works are also responsible for surveillance and security for the monuments against man-maid and natural disasters, suggesting maintenance works; if the necessary measures are simple, such as grouting, frescos restoration etc, the local authority informs in written the Directorate under which the monument is listed and on positive answer, the ID card of the monument is updated with the works that will take place and then permission is granted for the works to be carried out locally».

Table 3.4 Summary of answers on Preparedness Measures.

Preparedness measures	*Related to which kinds of risk?*	N. of answers
	Flood	28
	Fire	25
	Earthquakes (19) & Seismic risk (3)	23
	Climate Change	10
	Storms (5) and extreme/heavy rain (3)	8
	Landslides	7
	Sea Level Rise (6) & Tsunami (1)	7
	Coastal erosion (4) & Environmental erosion (1)	5
	Armed conflicts / War	5
	All risks	3
	Volcanic risks	3
	Drought	2
	(Atmospheric) Pollution	2
	Terrorism	2
		Tot 68

Emergency plans: in total, we obtained 64 answers. Concerning the risks for which emergency plans are prepared for, these are listed in decreasing order of answers: fire, flood, earthquake and seismic risk, all risks, landslides, climate change, sea level rise, tsunami and armed conflicts/war; storms and extreme/heavy rain, volcanic risks, terrorism, drought, atmospheric pollution (Table 3.5). An example of strategies mentioned is in Bulgaria, where "the Council of Ministers adopts an annual plan for the implementation of the disaster protection program. The plan also contain measures related to the prevention of cultural heritage. Measures are taken to protect against floods, fires, earthquakes. A unified table of thresholds for the individual criteria is used in the four main categories of the Directive - human health, business, environment and cultural heritage."

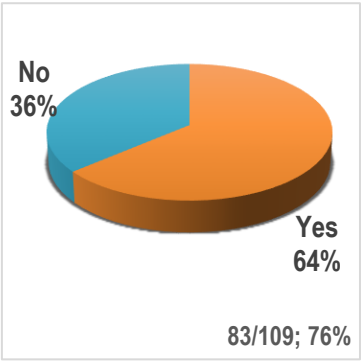
Table 3.5 Summary of answers on Emergency Plans.

Emergency Plans	*Related to which kinds of risk?*	N. of answers
	Fire	30
	Flood	26
	Earthquakes (18) & Seismic risk (2)	20
	All risks	6
	Landslides	5
	Climate Change	4
	Sea Level Rise (2) & Tsunami (2)	4
	Armed conflicts / War	4
	Storms (2) and extreme/heavy rain (1)	3
	Volcanic risks	3
	Terrorism	3
	Drought	2
	Atmospheric Pollution	1
	Coastal erosion & Environmental erosion	0
		Tot 64

Recovery measures: in total, we obtained 46 answers. Considering the risks for which Recovery Measures are prepared, these are mainly focused on earthquakes and seismic hazards, fire and floods, followed by all risks, landslides, climate change, storms and extreme/heavy rain, armed conflicts/war, drought, tsunami, volcanic risks, terrorism and surface erosion.

An example for this case is given by the ISCR (Istituto Superiore per la Conservazione ed il Restauro, Ministero dei Beni e delle Attività Culturali), which reports that "*the Institute recovers, restores and protect artworks (pantings, sculptures, precious objects, etc.) taken from places affected by disasters (for example recent earthquakes in the center of Italy)*".

Table 3.6 Summary of answers on Recovery Measures.

Recovery Measures	*Related to which kinds of risk?*	N. of answers
	Earthquakes (17) & Seismic risk (1)	18
	Fire	17
	Flood	17
	All risks	6
	Landslides	3
	Climate Change	2
	Storms (1) and extreme/heavy rain (1)	2
	Armed conflicts / War	2
	Drought	2
	Sea Level Rise (0) & Tsunami (1)	1
	Volcanic risks	1
	Terrorism	1
	Coastal erosion & Environmental erosion (Surface erosion 1)	1

	Atmospheric Pollution	0
		Tot 47

Other: 10 stakeholders replied to the "Other" field. Citations of answers reported are:

- In Italy the "*National Direction for Archives (DGA-MIBACT) Guide lines for emergency management*";
- "*Norwegian Standards to monitor cultural heritage sites, to enable rescue investigations*".

Considering the question **1g. "if they know any similar strategies in other countries"**, in 102 replies, 43% answered yes and 57% no.

Among the affirmative answers, it was cited the Decision 1313/2013 of the EU ON European Civil Protection Mechanism where all the participating states have to follow article 6 which deals with the Disaster Risk and Management.

Hereafter some examples of strategies for preparing the historic environment, buildings and archaeology for climate change; rising sea levels, more frequent storms, wetter weather during winter and dryer summers etc.; landslides, coastal erosion and floods, both by sea and rivers:

- SCAPE – Scotland's Coastal Archaeology and the Problem of Erosion;
- SCHARP – Scotland's Coastal Heritage at Risk Project;
- Coastal Zone Assessment surveys - In the UK;
- A Climate Change Action Plan for Historic Scotland 2012-2017;
- Klimatanpassning och energieffektivisering – en handlingsplan för kulturhistoriskt värdefull bebyggelse 2015–2017 - In Sweeden;
- Forum for kriseberedskap og restverdiredning for kunst og kulturminner (FORK) - in Norway;
- SiLK guidelines (Sicherheitsleitfaden Kultureinrichtungen/ SiLK guidelines for the protection of cultural property) in Germany.

Or, in case of indoor environment, Barbados Museum and Seattle Art Museum are mentioned as prenting strategies for facing mainly natural disasters. While British Museum (UK) is cited for having a list of priority objects to be removed to safety in the event of an emergency and staff who will deal with the objects.

In relation with question **1h. "Do you know examples of excellence in risk awareness governance at regional level in your country? (i.e. Regional strategies)"**

In 103 replies, 36% answered yes and 64% no.

For instance, in Bulgaria, "district administrations draw up regional disaster risk reduction programs (both for disasters caused by natural or anthropogenic factors). Municipalities set up municipal disaster risk reduction programs 2017-2020, which contain: 1. the operational objectives; 2. the activities for the realization of the operational objectives".

In Croatia is cited the Institute for Restoration of Dubrovnik, Dubrovnik-Neretva County for the eartquakes.

The free state of Saxony in Germany has flood emergency plans.

In Greece is declared "for earthquakes there is excellence in risk awareness governance. Actually, Greece provides aid to other countries too following the earthquake. Likewise, there is excellence in safeguarding antiquities in case of war".

The "Department of Civil Protection and Emergency Management, in all Icelandic regions, for volcanic eruptions, floods and earthquakes."

The National Risk Analysis of Disasters and Emergencies in Switzerland[164] for natural risk, technical risk, cyber.

In Italy, the "Soprintendenza archivistica e bibliotecaria" of the Lombardy region, mainly for natural disasters.

In Netherlands "governance of water management is covered by so called "Waterschappen"; thus for coastal areas, regions near the big rivers, against risks as floods and sea water rise."

The Norwegian city of "Trondheim is building rain gardens to reduce the water load on the sewers and retain water on the site where it falls as rain (risk of heavy rainfall) and they are moving whole neighborhoods in areas more in the inland against the risk of sea level rise".

In Portugal, "at the Algarve there is a specific program for risk awareness of cliff fall, mainly considering the risk of people lying on the beach (with maps and information at every beach)." Always in Portugal, concerning the risk of floods (river and sea): "Flood Risk Management Plans (PGRI) for seven regional areas in Portugal, Municipal Plan for Intervention in the Historic Center of Setúbal, Portugal".

In UK, Climate Change - NI Climate Change Risk Adaption Programme against flooding and climate change.

Always concerning strategies against the climate change impact, it is mentioned the Region of West Sweden.

In question **1i. "Are you aware of the existence of any integration of cultural heritage needs in your national legislative platforms for Disaster Risk Reduction in your country?"**, the majority answered no (70%) and only 30% answered yes (in 105 replies). Examples of answers are reported as follows.

In Bulgaria, against earthquakes, fires, floods, human-induced accidents, armed conflicts, "in 2006 the Disaster Protection Act was adopted, which provides for the protection of life and health of the population, environment and property during disasters. Under this law, a disaster is an event or series of events triggered by natural hazards, incidents, accidents or other emergencies affecting or endangering life or health of the population, property/including cultural properties/or environment to an extent that requires measures to be taken.

Law on the cultural heritage, in force from 10.04.2009 - Art. 49. According to its level of jeopardy, the immovable cultural properties shall be:

1. cultural valuables at risk – which are potentially threatened to be damaged or destroyed, because of:
   a) location on earthquake zones, zones of vast construction projects, close to territories with great risk of flooding or progressive changes of geological, climate and other natural factors;
   b) danger of armed conflict and territorial attacks;
2. threatened cultural valuables – for which there is real danger of damages, vandalism, destruction or serious violation of their entirety, because of:

[164] http://www.babs.admin.ch/de/aufgabenbabs/ski.html

a) fast destruction of their original substance, leading to serious change in the structure;

b) fast worsening of the environment conditions;

c) visible loss of the authentic appearance."

Moreover, a Climate Change adaptation Strategy is under preparation.

In Croatia, there is a "Water Management Plan 2016 - 2021(Official Gazette NN 66/16); Law on Critical Infrastructure (Official Gazette NN 56/13)", for flood and all other risks.

In Finland and Greece, is cited the National Platform for Disaster Risk Reduction.

In France, the 2nd French National Adaptation Plan to Climate Change.

In Switzerland, "Federal Act of PCP, 520.1 Bundesgesetz über den Bevölkerungsschutz und den Zivilschutz (Bevölkerungs- und Zivilschutzgesetz, BZG) vom 4. Oktober 2002 (Stand am 1. Februar 2015)."

In Austria, "Directive for the military protection of Cultural Property and the safeguarding of cultural heritage" against armed conflict.

In Ireland, "Climate Action & Low Carbon Act 2015" covering all the risks associated with climate chang and the "Protection of Cultural Property in the Event of Armed Conflict Bill 2016", covering armed conflicts. In Italy, Management Plans of Civil Protection Department, of Basin Authority and of the MATTM[165], in cooperation with the ISPRA[166] and the "MiBACT[167] Directive of April 23, 2015".

In Netherlands, the "Flood act".

In Portugal, "The Civil Protection Bases Law: "Lei n°80/2015 de 3 de Agosto - Capitulo I artigo 4º 1c) e 1f)" refers to the need to protect cultural heritage and also refers to the need of studies and dissemination of appropriate forms of protection cultural heritage buildings in general."

In Slovak Republic, the "National strategy of the management of the safety risks in the Slovak Republic".

In Sweden, the "National coordination group for natural disasters. Coordinated by MSB, Swedish Civil Contigencies Agency."

In Scotland, "there is a legal requirement for public and private institutions to act to mitigate climate change causes and impacts. See the Climate Change (Scotland) Act 2009 and "Scotland's Climate Change Adaptation Framework". This applies to Historic Environment Scotland, who are responsible for the built cultural heritage and archaeology. This is more about mitigation, but it encourages understanding and adaptation to climate change risks, e.g. flooding, landslides, SLR."

Regarding question **"1j. Are you aware of any other good practices/actions to encourage the integration of cultural heritage needs in the national legislative platforms for Disaster Risk Reduction?",** in 103 replies, 24% answered yes and examples of the answers are here described.

In Bulgaria, for disasters caused by natural or anthropogenic factors, it is mentioned: "The Ordinance on the procedure for setting up and organizing the activity of voluntary units to prevent or contain disasters, fires and extraordinary situations and to remove their consequences (in effect since 03.07.2012) was approved by Decree n°. 123 of 25 June 2012 of the Council of Ministers. Some of the main activities of the voluntary units

[165] Ministero dell'ambiente e della tutela del territorio e del mare
[166] Istituto Superiore per la Protezione e la Ricerca Ambientale
[167] Ministero dei beni e delle attività culturali e del turismo

are immediate emergency and rehabilitation activities and decentralization of cultural properties.

Ordinance on the scope, structure, content and methodology for the elaboration of the plans for conservation and management of single or group immobile cultural properties (in force since 08.03.2011), according to which the existing and potential threats and risks for the protection of the Immovable cultural properties and monitoring of the state of cultural properties and risk prevention are being analyzed.

The state organizes the conservation of cultural heritage in case of natural disasters and armed conflicts. Preservation of cultural property in these cases is carried out in an order determined by regulation act to the Council of Ministers upon proposal of the Minister of Culture, Minister of Defence and Minister of Interior. The regulation act is in process of preparation. It will specify the commitments of public authorities and owners of immovable cultural property in such situations."

In Finland, "Our Common Heritage - For a National World Heritage Strategy 2015–2025 Publications of the Ministry of Education and Culture 2015:15; the Hague Convention was ratified in 1994. Preparations for needed national networks and lists are uncompleted."

In UK, "in terms of fire safety, there is a Historic Buildings Fire Research Coordinating Committee which was set up following the Windsor Castle fire in 1992 and is chaired by Historic England. This body can report to the Secretary of State for Digital, Culture, Media and Sport. In practise, we also lobby directly to industry via the Fire Sector Federation. The problem is, there is no legislative requirement to protect property from fire. Legislation is life safety focused. That said, there are many heritage teams in the various fire services which meet to discuss the issue of fire risk in historic buildings. It is all fairly disjointed. At an international level there is the Association of European Royal Residences (ARRE), this allows us to meet infrequently and share ideas on risk management. In 2015 the focus was fire safety, in 2016 terrorism."

Other general observations and suggestions are:

- Training and readiness activities are provided at a national level only;
- Legislation, recommendation and standards European;
- Plan Climat de Paris. – France;
- Federal Act on the Protection of Nature and Cultural Heritage CC 451 – Switzerland;
- National Monuments Protection Act (Denkmalschutzgesetz 1999) – Austria;
- Codice Beni Culturali (Code of Cultural Heritage) – Italy;
- System of training the fire brigades – Austria.

For the question "**1k. Are you aware of any existing training centres and/or educational tools or facilities that provide the required competencies in dealing with Disaster Risk reduction?**" we obtained 45% of yes, in 107 replies. Here some examples:

- Crisis Management and Disaster Response Centre of Excellence, located in Sofia (Bulgaria), for disaster risk reduction at all;
- European University for the Cultural Heritage (CUEBEC), Ravello, Italy;
- European Centre on Urban Risk, Lisbon, Portugal;
- European Centre on Prevention and Forecasting on Earthquakes, Athens, Greece;

- Training provided by CEP (Citizen Emergency Planning), an independent body within the Ministry of Infrastructure and Transport. Its responsibilities include: civil mobilization, civil defense, civil military cooperation, and civil protection. The latter responds to all types of risks against people, the environment, material and cultural values. Risks, however, related to private properties (i.e. historical buildings) are not addressed;
- Special Secondary School of Fire Protection and High Special School of Fire Protection in Frýdek-Místek, Fire protection and training centres (fire schools) in Borovany, Chomutov, Brno and Frýdek-Místek, Population Protection Institute in Lázně Bohdaneč, CZ;
- The Dutch Instituut Fysieke Veiligheid (institute Physical Security) has been tasked by the government to support the regional security sectors on Cultural Heritage. Threat of cultural heritage through disasters, riots, occupations, attacks or armed conflict;
- EFRU, St John's Rescue Corps, Civil Protection Department (Malta) covers mainly risks to human life;
- First Aid in times of crisis – ICCROM;
- Risk Prevention for World Heritage Sites in the PALOP - African World Heritage Fund, Cape Verde Government and Engeneering faculty of Oporto University, Portugal;
- Donau-Universität Krems (A), Zentrum für Kulturgüterschutz;
- Ritsumeikan-University Kyoto (Japan);
- Universität Heidelberg (D), Heidelberg Center for Cultural Heritage (HCCH);
- Historic England emergency planning and salvage course (UK);
- The National Trust periodically Salvage training course (UK);
- ISCR - Superior Institute for Conservation and Restorer, (I);
- ICOM - International Council of Museums;

Question 2 was related with the effective Risk Management that works as a result of a combination of public support and private initiatives. It crucially depends on interaction, openness and cooperation amongst different enterprises, citizens, educational, research, public bodies, etc..

Public policy and funding in the right circumstances can create a top-down risk management incentive that can increase the likelihood of improving the response approach to natural and man-made events.

In particular, stakeholders have been invited to select if:

A) If you personally implement the management in your enterprise or organization: in the past 3 years did you or your organization work in unison with any of the following listed bodies or enterprises to improve the risk assessment capacity, or implement resilience projects?

B) If you or your organization supported risk assessment in other enterprises or bodies: in the past 3 years did you observe MORE participation of the following type of enterprises or bodies in the risk assessment in your country or region?

Reciprocal answers are represented in the following diagrams (Figure 3.11 – 3.12). It has to be underlined that the following indicated percentages are referred to the answers received and not related to the total 109 replies.

Four respondents completed the "other field", with the following answers:

- Multiple federal land-managing agencies are becoming more aware of the need to engage with protection of cultural heritage in relation to disasters;
- Chambers for employees or economic Chambers; different Kind of associations;
- Owners of the historic buildings;
- ICMS ICOM.

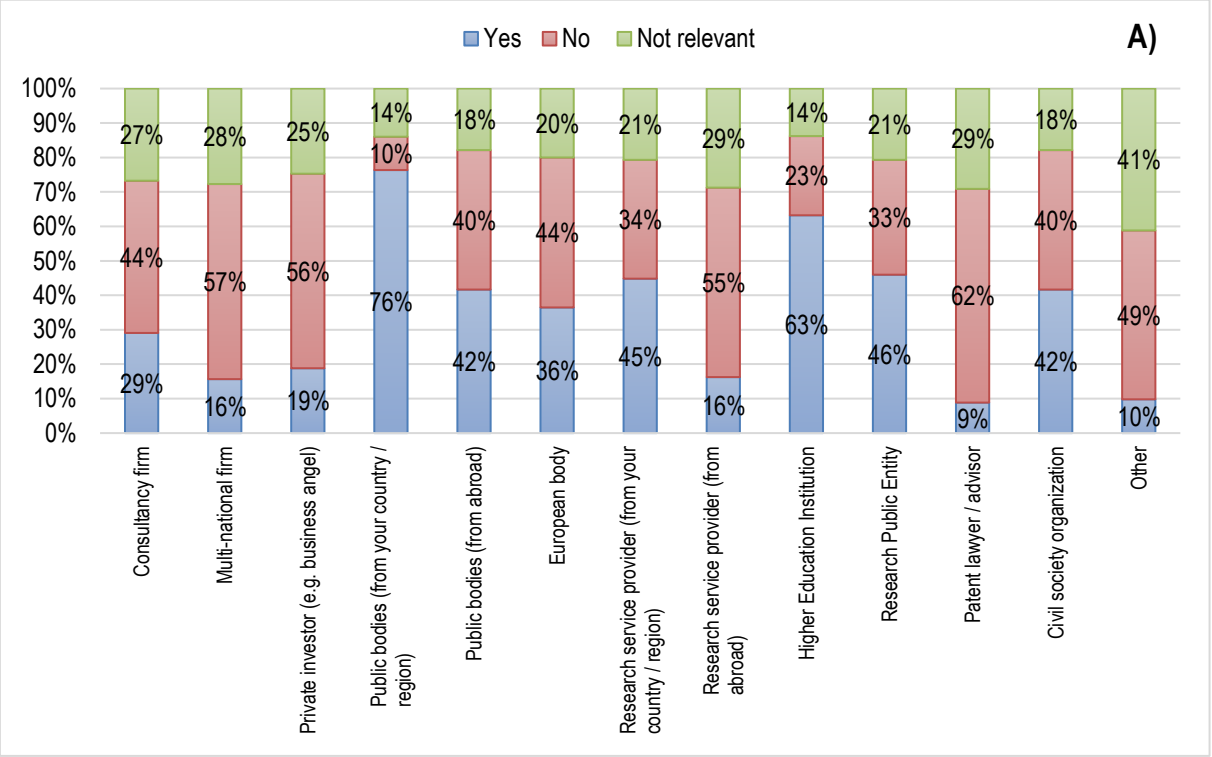


Figure 3.11 Answers for the question: A) If you personally implement the management in your enterprise or organization: in the past 3 years did you or your organization work in unison with any of the following listed bodies or enterprises to improve the risk assessment capacity, or implement resilience projects?

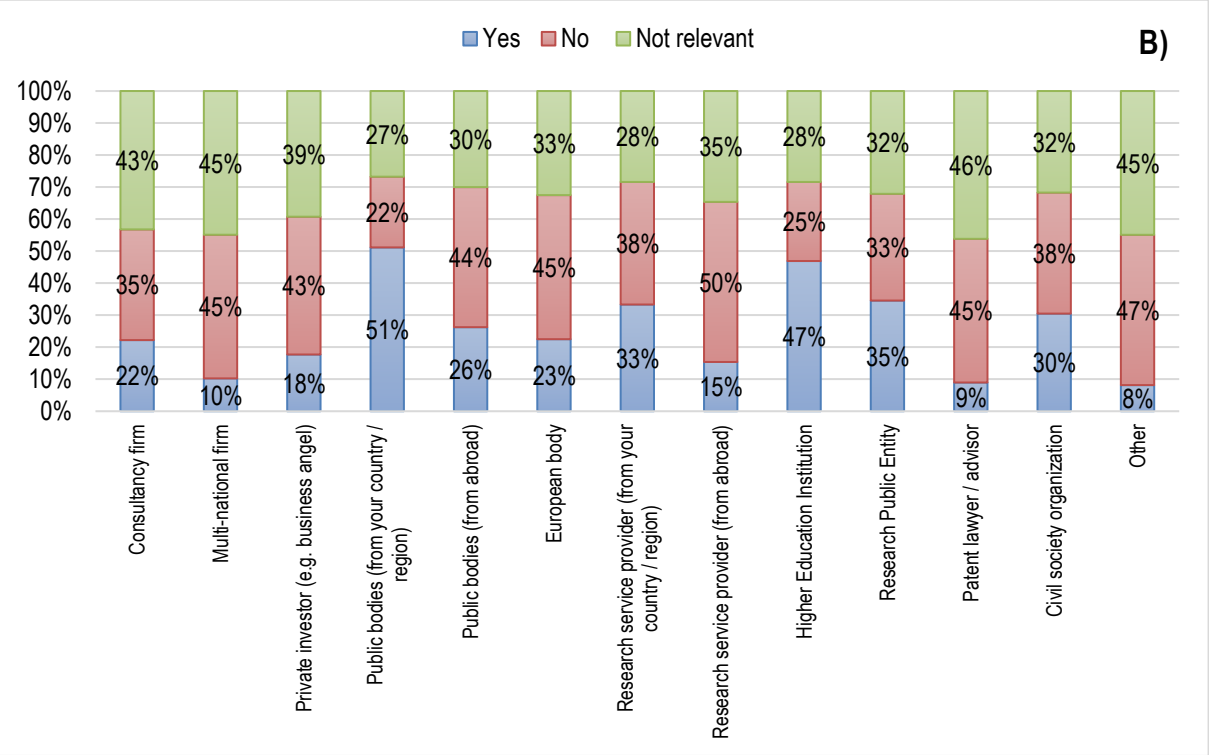


Figure 3.12 Answers for the question: B) If you or your organization supported risk assessment in other enterprises or bodies: in the past 3 years did you observe MORE participation of the following type of enterprises or bodies in the risk assessment in your country or region?

Concerning the **question 3: "Which other organizations should be more or better involved in supporting research for Risk Assessment in your country or region?**", 105 respondents answered. As set out in Figure 3.13, the majority highlighted the following organizations as "more" or "better" involved, listed in their order of abundance: Academic Research bodies, Official associations for environment and heritage protection, Scientific Research and Technology organizations, Professional Bodies, Higher Education and/or Vocational training establishments, Private associations for environment and heritage protection, Civil Society, Funding Enterprises, Suppliers and Manufactures, Vocational Craft Trade Bodies, and SME intermediaries - such as cluster organizations.

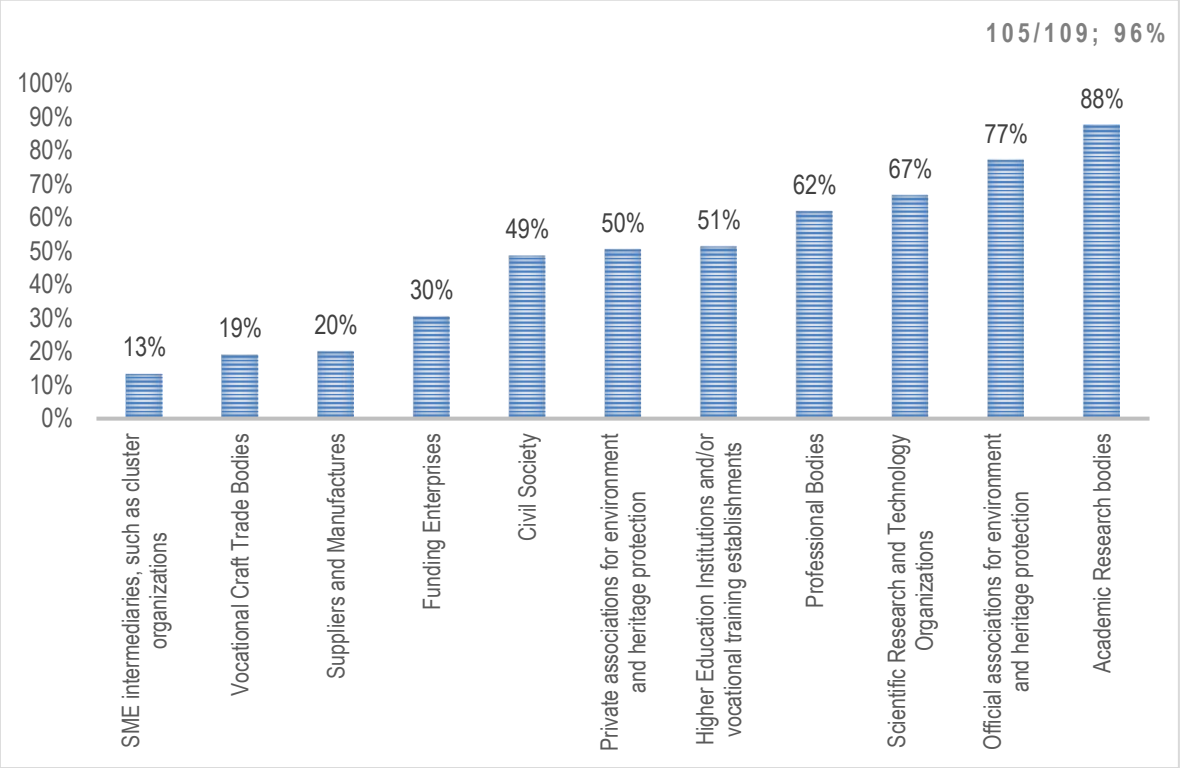


Figure 3.13 Stakeholders opinion in relation with the organizations that should be more or better involved in supporting research for Risk Assessment in their country or region.

Moreover 5 replies were obtained as "other", specifically being: 1. Associations, 2. Government, 3. ICOMOS could educate their members on DRM to be able to help their national sites, 4. Insurance Companies, 5. Other National Authorities.

In **Question 4. Can you identify and describe a significant research and/or specific project on the topic of DISASTER RISK MANAGEMENT OF CULTURAL HERITAGE that was undertaken during the last 3/5 years in your country or region?**, 39% answered yes, on 104 replies.

If yes stakeholders have been asked to explain the success that the project achieved in creating a link between the disaster risk reduction experience and cultural heritage protection, so that the case might inspire others to launch similar projects. Examples of answers are reported below.

- CARISMAND project aims to deal with the issues of preparedness, response to disasters and after-crisis recovery which is inevitably influenced by cultural background of individuals and the society they live in. In this context culture is understood as the characteristics of a particular group of people defined by everything from a set of values, history, literature, language, religion to cuisine, social habits or music and arts. The project is funded by the European Commission under the Horizon 2020 Framework Programme, coordinated by the "Security, Technology and e-Privacy Research Group (STeP)" team from the Faculty of Law of the Rijksuniversiteit Groningen (RUG) led by Professor Joseph Cannataci. Partners - University of Groningen (RUG), The Netherlands; Law and Internet Foundation (LIF), Bulgaria; LIBRe Foundation (LIBRe), Bulgaria; European-Mediterranean Seismological Centre (EMSC), France and 15 other partner organizations.
- Institute for restoration of Dubrovnik was established after the strong earthquake in 1979. The aim of the Institute was to continue the revitalization of the city's

functions, the renewal of infrastructure, through the structural rehabilitation of the damaged buildings, to re-evaluate the most important monuments and certain urban areas (Croatia).

- Fire and Rescue Service has a cooperation agreement with National Heritage Institute. We collaborate on projects whose goal is audit of fire protection of historical monuments (castles, palaces, cathedrals, monasteries etc.). The project was implemented since 2010 to 2014. In the framework of this project we have visited and realized fire risk audit of 90 cultural heritage buildings. Project is continuing since 2015 to 2019 (Czech Republic).
- Discussions of fire safety with several partners (Evangelical Lutheran Church of Finland, Heritage Authorities, The Finnish National Rescue Association, Finance Finland etc), updating the current guidebook (Finland).
- UNESCO, ICOMOS, ICCROM and ICOM several years ago started organizing special workshops on such issues. The Olympia Workshop in 2008 produced a series of recommendations known as the Olympia Protocol for International Cooperation, which are still worth considering.

  The main points of the protocol are:

  - Conservation:

    1. Establishment of a Clearing House on Disaster Risk Reduction;
    2. International Workshops to introduce the Protocol, identify pilot sites, and facilitate the establishment of twinning arrangements;
    3. Workshops to build capacities of concerned stakeholders and launch the development of appropriate disaster risk reduction strategies at selected sites;
    4. Risk Assessment at selected pilot properties;
    5. Socio-economic analysis and research on traditional skills and local knowledge systems relevant to disaster risk reduction;
    6. Inter-institution Workshops on Disaster Risk Reduction at site level;
    7. Seminars with local communities;
    8. Mid - term International Workshop to review progress of the activities and validate methodologies for developing an appropriate risk management strategy at site level;
    9. Development of disaster risk reduction strategies at selected World Heritage properties;
    10. Follow up at Pilot Properties.

  - Capacity building and Communication:

    1. Publications and dissemination of materials on the web;
    2. Distribution of information to each region;
    3. Development of a curriculum for a training course on disaster risk reduction;
    4. Development of a component on disaster risk reduction within the World Heritage in Young Hands School Kit and activities;
    5. International Day of Disaster Reduction at World Heritage Properties.

- EU-funded Project STORM168.
- Climate Change facing Cultural Heritage: Evaluation of the Training Course Programme; Recommendation addressed to Council of Europe member States on that topic.
- NPS, Historic England, Historic Environment Scotland strategies.
- Two unpublished (as yet) reports/guidance commissioned by Dep. of Culture, Heritage & the Gaeltacht (Ireland):
    1. "Archaeological & Built Heritage Climate Adaptation Study" 2017 - to inform forthcoming sectoral plan;
    2. "Disaster Management in Historic Built Environment - Guidance for owners of Historic Buildings". To be published in 2018.
- Guidelines for the Prevention of Risks And Reaction to Emergency in The Archives - DGA, MIBACT, State Archives, Private Companies - Publication on the MIBACT website of a complete document - Cooperation between public Institutions and specialized private companies with years of experience and high technologies (Italy)169.
- Prothego EU Project170.
- H2020 Project HEritage Resilience Against CLimate Events on Site, HERACLES171.
- The SIMIT (Integrated Civil Protection System for the Italo-Maltese Cross-Border Area) project is achieving notable success in producing original base-line data on seismic vulnerability of different building typologies, which will also prove invaluable to model the vulnerability of the historic building fabric, which makes up a significant proportion of the residential building fabric in the study region172.
- The InSituFarms research project; interdisciplinary cooperation between researchers and heritage management bodies on managing climate change effects on cultural heritage sites, developing mitigation measures. NIKU, NIBIO, MVH Consult, National Museum of Denmark, Tromsø museum UiT, Archaeological museum UiS, Troms County Council. Funded by the RCN, 4.5 million NOK[173].
- Monitoring Climate Change effect on Historic Buildings - Pilot Project (Norway).
- Four projects, funded by FCT in recent years, are worth mentioned in this context: "Improved and innovative techniques for the diagnosis and monitoring of historical masonry"; "FRURB - Managing Flood Risk in Urban areas in a global change context"; "SEISMIC-V: Vernacular Seismic Culture in Portugal", "Development and optimization of a higro-adjustable system for drying out buildings after a flood". Although I'm not in conditions to comment on the achieved results, lessons learn, partners and organizations involved and project budget and funding sources, the topic and the type of research indicated are completely in line with the indications.

[168] http://www.storm-project.eu
[169] http://www.archivi.beniculturali.it/index.php/cosa-facciamo/tutela/item/1091-prevenzione-dei-rischi-e-reazione-alle-emergenze
[170] http://www.prothego.eu/
[171] http://www.heracles-project.eu/
[172] http://www.um.edu.mt/newsoncampus/researchinitiatives/archive/simit_-_new_project_funded_by_the_italia-malta_programme
[173] https://www.researchgate.net/publication/309391613_Preserving_Rural_Settlement_Sites_in_Norway_Investigations_of_Archaeological_Deposits_in_a_Changing_Climate

- The NPS released its Cultural Resources Climate Change Strategy in early 2017, product of 5 years of research, planning, and writing[174]. The Strategy is a major document establishing the importance of cultural heritage and climate change as a field unto itself for the US and directions government and its partners should go in developing appropriate responses. More detailed research is now getting underway, per "Directions for Action" provided in the Strategy (USA).
- The Society for California Archaeology is currently surveying the California coastline on a volunteer basis, to record sites ahead of sea level rise. The study includes local agency partners, Native American tribes, universities, and vocational groups (USA)[175].

Question 5. Asked to indicate: **«which programme you: have been personally involved in the last 10 years, and/or are personally aware of**.» Figure 3.14 describes the answers obtained.

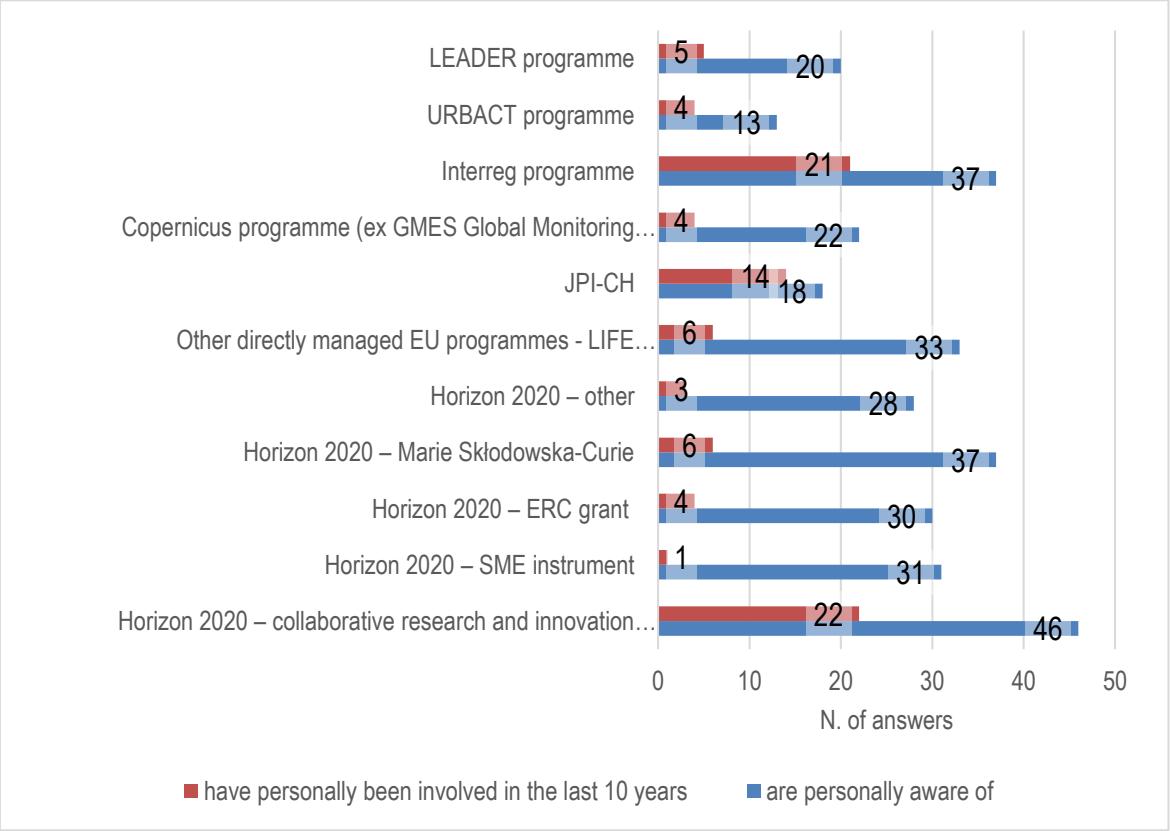


Figure 3.14 Stakeholders' answers in relation to the programmes in which they have been personally involved in the last 10 years, and/or are personally aware of.

Considering 21 "other" answers, the following contributions are noteworthy:

- COST Action C17;
- HEREIN[176] - HEREIN is a European Cultural Heritage Information Network which brings European public administrations in charge of national cultural heritage policies and strategies together. At present, 44 Council of Europe Member States lend impetus to this project and form a unique co-operation network;

[174] https://www.nps.gov/subjects/climatechange/culturalresourcesstrategy.htm.
[175] https://scahome.org/sca-climate-change-and-california-archaeology-studies/
[176] http://www.herein-system.eu

- HEREIN was established by the Council of Europe at the request of the Member States to take stock of the changes in legislation and practices in the participating countries and provide a forum for pooling and sharing information on cultural heritage.
- ARTES 20 IAP programme of the European Space Agency (ESA).

Question «6. It is recognised that Cultural Heritage still does not occupy a central position in current national and international policy documents on A) 'Climate Change' and B) 'Disaster Risk Reduction'. Should further interregional cooperation and action to include Cultural Heritage in these topics be encouraged?»

In considering Climate Change, the majority of respondents voted the topic "new research partners from abroad", whilst in the DRR, 68% highlighted the importance of the exchange of good practises for public administration and business models (Figure 3.15).

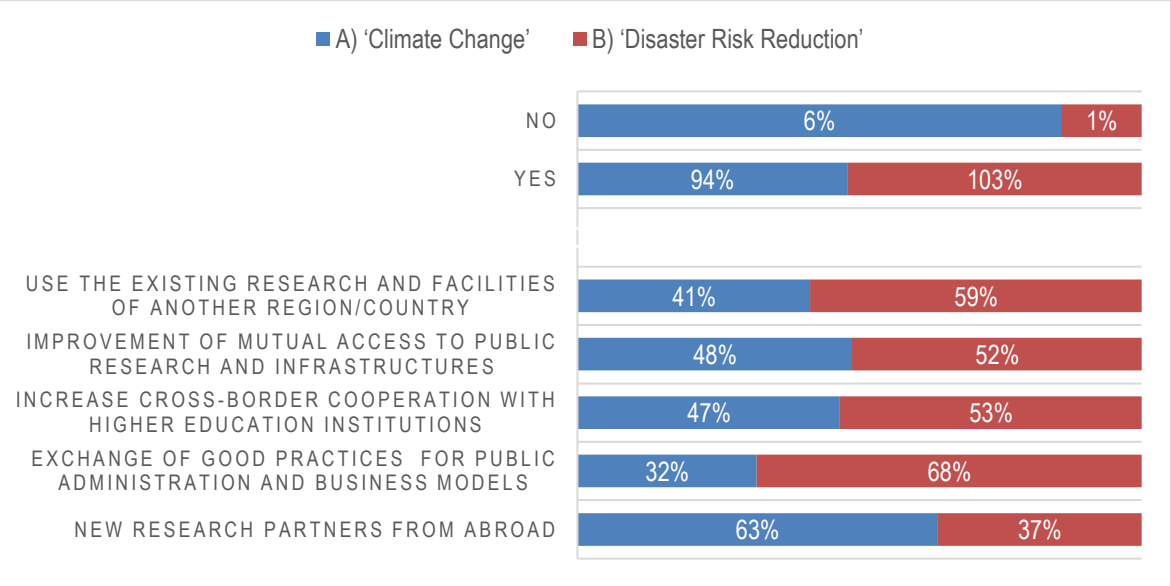


Figure 3.15 Replies to question 6, further interregional cooperation and action should include Cultural Heritage in Climate Change and Disaster Risk Reduction topic.

Question 7. «Please, offer any further suggestions or comments regarding the development and implementation of Risk Management Plans for Cultural Heritage. This might include comment on the wider context of EU-policies on research, innovation, education, etc. It would be particularly helpful for the study to have your views on how to reinforce political commitment, dissemination of good practice, and the facilitation of strategic interregional collaboration.»

52 stakeholders answered and hereafter are reported some examples of contributions given.

Risk management plans should be a mandatory part of the conservation and management plans of cultural properties, specifying in each plan the specific organizations and institutions responsible for preserving the cultural heritage at risk. The reports on the implementation of the annual plans of the National Program for Disaster Protection provide the opportunity to follow the results and to plan effective measures for the next periods of implementation. Scientific

research is an important part of risk prevention policy and should be expanded. The Ministry of Culture annually finances seismic monitoring of the Ivanovo Rock Churches and the Rila holy cloister (World Heritage sites), as well as instrumental monitoring of dangerous cracks affecting the stability of the Madara Rider, the Madara Archaeological Reserve, Shumen Municipality and the territory of the Archeological Reserve "Kaliakra". (Bulgaria).

There is already a lot of work on these issues by EU, UNESCO, ICOMOS and other organizations[177]. More effort to disseminate and enforce new policies and strategies to the member states is needed.

Need of:

- Evaluation of the importance of the monuments in EU depending on their age, value for the public or European Heritage, the damages they have suffered in the past, and their state of preservation. This is a very difficult and time-consuming work, needing the study of the historical and archaeological data for the damages the monuments have suffered in the past, in the base of a appropriate interdisciplinary cooperation.
- Assessment of the disasters that threaten the monuments in their current condition.
- Research on the facing the disasters threatening them under public support and with cooperation of public bodies, research organizations.
- Determination of strategics by the European Union for the Safeguarding of the European Heritage.
- Education of the involved stakeholders in the heritage on the application of good practices for the safeguarding of the Cultural Heritage.
- Continuous monitoring and evaluation of the applied measures.

Inventory on european level, access to the inventory for partners (fire brigade, army, civil protection (intervention forces), research institutions, cultural institutions, engineers (prevention)).

It is fundamental to have the possibility, both in climate change and disaster risk reduction to have the possibility to partecipate to mid and long-term project as an effective result can be achieved only making research and implementing results on a long term scale. However further research needs to be developed to understand what is the methodological approach that can work effectively on such time scale (i.e. on a future time scale larger than 10 years).

Enhance European programmes for funds to be distributed to each member state for research, innovation, education of DRR on CH, and the results obtained, shared on a common platform.

Promote exchange of experiences between europe and other countries with more expertise in DRM and climate change.

Develop a common legal basis for multiple hazard assesment and management to be adopted in all member states.

Create more funds for the implementation of DRR strategies.

Create job opportunities for cultural heritage professionals in risk managment.

[177] http://ec.europa.eu/assets/eac/culture/library/reports/2014-heritage-mapping_en.pdf

Include the integration of DRM for cultural heritage in degree programmes (undergraduate courses, masters, Phd).

Integrate cultural heritage in climate change adaptation policies.

Foster cooperation between universities, public administration, mainly for cultural heritage protection and civil protection.

Losses to tangible and intangible cultural heritage are difficult to quantify and the impact of such losses is not fully grasped immediately after a disaster. Mechanisms should be developed to establish an equivalent socioeconomic value able to partially reflect those losses (e.g. indirect losses in different sectors such tourism), to create awareness about these impacts among stakeholders and engage society in the protection of cultural heritage.

A European wide exchange of information and best practise would help to harness the awareness there is to these issues and encourage governments to legislate to improve political commitment to address these real issues. Only by considering the impact of these changes on a multi national approach can a sufficient body of evidence be compiled to identify the risks which exist.

4
Final remarks and gaps

4 Final remarks and gaps to be covered

Safeguarding cultural heritage from natural and man-made disasters still suffers from the fact that **it is not considered a priority in risk management planning for emergency situations**. Protecting cultural heritage does not in itself save lives, but it has an irreplaceable role in preserving the long-standing spirit and individual identities of communities and the resilience of their historic settlements, cities and villages. Cultural heritage assets are substantial elements of the urban and rural landscape that are complex and adaptive. They possess a considerable capacity for establishing a uniqueness of place that society can embrace as handed down through time into our temporary care in this, the second decade of the 21st century.

However, such resilience remains unrecognised by authorities despite this considerable responsibility. Consequently and collectively, we will be severely judged in the future if we continue to fail in accepting that obligation. To prevent us from lacking in this duty, any ameliorating progress must be underpinned by a critical well-focused research approach that combines economic, social and physical themes of resilience with judicious conservation necessities. Combined, this approach should generate a "resilience friendly" conservation approach, but, sadly, the fact remains that there is a **serious gap in the collective approach to creating and promoting fully effective resilience policies**. Cultural heritage is persistently omitted, and this need must be addressed.

Present knowledge concerning safeguarding cultural heritage offers numerous ideas and contributions for the improvement of disaster preparedness. Unfortunately, this wealth of material and information is largely ignored in the development of related policies. To date policies are generally created on a reactive basis usually and specifically in response to emergency situations occurring. There is scant attention paid to non-structural measures that could incorporate a wide variety of relevant instruments including guidelines, mobile applications, training and awareness-raising, and insurance incentives.

In addition, **research results are inadequately transferred into risk management practices and guidelines, and the transfer of knowledge to improve public awareness in cultural heritage protection is still insufficient.**

It has to be underlined that, at a political and policy making level, **existing strategies and procedures on Disaster Risk Reduction for safeguarding cultural heritage are not exhaustively integrated in National Plans.**

Across European member States, only Italy, France, Bulgaria, UK and Spain, have developed National Adaptation Plans for Climate Change that take into account the cultural heritage sector, but a further established deficiency is **the lack of alignment in the involved processes from policy making to practical application**.

Specifically, the Study found key identifiable gaps where issues concerning natural and man-made disasters affecting cultural heritage are not taken into consideration. **Many such gaps were consistently and repeatedly identified in each of the detailed study areas**. Divided into Policy Making/Managerial Implementation, Governace and Knowledge-Related/Research these are collectively illustrated below:

PoliticyMaking and Managerial Implementation

In political and managerial terms there is a need for:

- General advancements in a trans-national understanding that cultural heritage requires protection from a wide range of potentially damaging multi-risks scenarios;
- Ratification of the relevant international legal instruments of the Council of Europe and of UNESCO for the protection of the cultural heritage;
- Greater universal integration of cultural heritage requirements into existing funded research, information and mapping development programmes;
- Common legal developments to emerge and be implemented in preparing and promoting long-term cultural heritage measures and strategies to address the impact of both natural and man-made consequences;
- Improvements in collaboratively unifying the accessibility of National and Regional/Local strategic, guideline, and regulatory documentation that also overcomes the "linguistic obstacle" where texts are only available in the local language, not in English;
- The implementation of amendments to Eurocodes and other relevant standards to take into account the physical features, and the cultural and socio-economic value of traditional and historic assets, when addressing disaster scenarios;
- The recognition that the lack of maintenance and remedial work leading to consequential negligence and/or abandonment, can be due to the absence of financial incentives, including tax relief;
- An understanding that all forms of physical damage create considerable economic loss;
- Funding mandatory and periodic pan-professional disaster training for experts in the built heritage field should cover the full range of possible risks relevant to the circumstances;
- Monitoring to inform and resolve a general lack of pre-paredness measures and to assist in recovery procedures in emergency situations.

Governance

In governmental terms there is a need for:

- Piloting, creating and promoting an effective co-ordinating methodology for all potential disaster related incidents that could also transcend operational boundaries;
- Significant improvements in public awareness of disaster risk management issues through informed educational programmes;
- Focusing the training of responsible employees on the intention of emergency disaster plans and how to respond accordingly;
- The digitalization of heritage asset documentation and the creation and ready availability of electronic archival reference material;
- Creating informed criteria and techniques for the prioritising and securing of valuable items and assets in the event of an emergency occurring.

Practical Applications and Knowledge-Related/Research

Regarding practical requirements and knowledge related research there is a need for:

- The creation of a comprehensive inventory of cultural heritage assets that have been pre-assessed to be disaster endangered;
- The development of an effective risk management of cultural assets strategy that fully takes into account the true cost of loss and damage, along with an assessment of the non-market nature of related cultural heritage values;
- Collating and improving inspection and diagnostic observational data to establish an integrated methodology for the comprehensive modelling of the impact of disasters;
- Prioritising an understanding of multi-risk complex system scenarios in urban historic centres, archaeological sites, and cultural landscapes regarding climate change impacts and other jeopardising factors;
- Creating and developing an effective early warning system to specifically address safeguarding cultural heritage from multi-risk and disaster situations;
- Developing appropriate quantitative design data, codes and procedures to ameliorate induced damage and establish funding action priorities;
- Overcoming the absence and promotion of pre-planned analysis and preventative measures required for the development of efficient plans to protect cultural heritage against disasters;
- Developing and promoting pre- and post-event informative documentation, based on soundly researched findings, to enhance awareness raising in all levels of interested parties.

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ANNEX A - Funded Projects at European, National and Regional level on natural and man-made disasters effects on cultural heritage

Funded Projects at European, National and Regional level on natural and man-made disasters effects on cultural heritage reported in Chapter 2 are listed with a brief description of objectives and outputs in Table 1 and 3. Projects on disaster adaptation and risk reduction, which do not include cultural heritage, but whose results can be capitalized for its safeguard are also reported (Table 2).

Table 1 List of European funded projects on the following issues (International level), listed in chronological order (from the most recent to the oldest ones) and highlighted according to the typology of events with different colours as follows.

Climate Change and cultural heritage (CH)
Air Pollution and cultural heritage (CH)
Flood and cultural heritage (CH)
Wind and cultural heritage (CH)
Geological Hazards: Landslides, Volcanic Eruptions, Earthquakes and cultural heritage (CH)
Fire and cultural heritage (CH)
Armed Conflicts and cultural heritage (CH)
More than one event and cultural heritage (CH)

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
European level				
INTERREG Central Europe project, Risk assessment and sustainable protection of Cultural Heritage in changing environment – ProteCHt2Save (2017-2020)	Climate Change-Geohazardand CH	Development of feasible and tailored solutions for building resilience of CH to floods and events of heavy rain. Outputs of the project will strengthen the risk management and protection of CH in central Europe, delivering ICT solutions and tools, also in order to support regional and local authorities to prepare measures and evacuation plans in case of emergencies[178].	X	X
			Finalized to the strengthening of Adaptation and DRR.	
H2020 Heritage Resilience Against CLimate Events on Site - HERACLES (2016-2019)	Climate Change-Geohazardand CH	Aim at designing, validating and promoting responsive systems/solutions for effective resilience of CH against climate change effects[179,180].	X	X
			Finalized to the strengthening of Adaptation and DRR.	
H2020 Safeguarding cultural heritage through Technical and Organisational Resources Management – STORM (2016-2019)	Climate Change-Geohazard and CH	Novel predictive models and improved non-invasive and non-destructive methods of surveying and diagnosis, respectively for effective prediction of environmental changes and for revealing threats and conditions that could damage cultural heritage[181,182].	X	X
			Finalized to the strengthening of Adaptation and DRR.	

[178] http://www.interreg-central.eu/Content.Node/ProteCHt2save.html
[179] http://www.heracles-project.eu
[180] http://cordis.europa.eu/project/rcn/203438_en.html
[181] http://www.storm-project.eu/
[182] http://cordis.europa.eu/project/rcn/202681_en.html

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
		European level		
UNDERWATER EXPLORER FOR FLOODED MINES - UNEXMIN[183] (2016-2019)	Flood and specific CH	It develops a novel robotic system for the autonomous exploration and mapping of Europe's flooded mines. The Robotic Explorer (UX-1) will use non-invasive methods for autonomous 3D mine mapping for gathering valuable geological and mineralogical information. This will open new exploration scenarios so that strategic decisions on the re-opening of Europe's abandoned mines could be supported by actualised data that cannot be obtained by any other ways.		
JPI-CH PROTection of European Cultural HEritage from GeO-hazards - Prothego[184] (2015-2018)	Geohazard and CH	It aims to make an innovative contribution towards the analysis of geohazards in areas of CH in Europe, but it does not consider directly volcanic activity. PROTHEGO's goals are enhancing CH management practices at national level; reinforcing institutional support and governance through knowledge and innovation; identifying, assessing and monitoring risks strengthen disaster preparedness at heritage properties in the future.	X	X
H2020 Flood Risk Assessment and mitigation for Masonry Arch Bridges - i[185] (2015-2017)	Flood and specific CH	Development of novel modelling strategies for masonry arch bridges and a comprehensive framework for the flood risk evaluation for these heritage structures (risk assessment framework). The project outcomes will contribute to the preservation of CH and to the development of innovative solutions for reducing the flood risk of infrastructural systems by promoting the unbiased allocation of the economic resources for flood risk mitigation.	X	?
IRSES - Marie Curie Action "International Research Staff Exchange Scheme", FP7 Cultural and Natural Heritage in Arctic and Sub-Antarctic Regions	Partially on Climate Change and CH	The project aims at studying these extreme regions, which have common features as regards their natural and cultural heritage, training professionals working in public administrations in facing changes due to the global warming and globalisation processes[186].	X	

[183] http://www.unexmin.eu/
[184] http://www.prothego.eu/
[185] http://cordis.europa.eu/project/rcn/195375_en.html
[186] http://cordis.europa.eu/project/rcn/106872_en.html

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
European level				
for a Cross-Cultural and Sustainable Valorisation Process and Tourism Development: Siberia, Lapland and Patagonia – POLARIS (2013-2017)				
FP7 Building Capacity for a Centre of Excellence for EO based monitoring of Natural Disasters – BEYOND (2013-2016) [187,188]	Partially on Climate Change and CH Flood	BEYOND Floods Observatory and the FloodHub service contribute to the implementation of the EU Floods Directive (2007/60/EC), to reduce and manage the risks that floods pose to human health, the environment, CH and economic activity.		X
FP7 Economics of climate change adaptation in Europe – ECONADAPT [189] **(2013-2016)**	Partially on Climate Change and CH	Within the "WP6. Case Study: Economic Project Appraisal", aimed at assessing adaptation costs and their uncertainties. In particular, it used a Real Option Analysis to appraise the potential investment in flood reduction, utilizing detailed climate model projections and hydrological modelling, assessing the full economic costs of climate change (including on cultural heritage).		
FP7 STrengthening And Redesigning European FLOOD risk practices Towards appropriate and resilient flood risk governance arrangements - STARFLOOD[190] **(2012-2016)**	Partially on Flood and CH	In some of the generated reports and documents, CH issues are mentioned, however, no focused measures are suggested. (For example, in comparison of approaches in six EU countries: Prevention has become the most articulated in discourse in both the Flanders and Walloon regions, and in Flanders it has also been given new regulation, i.e. art. 136 Walloon code of spatial planning, urbanization and cultural heritage, CWATUP). This project elaborated very detailed and useful analyses of various approach to flood risk management[191].	X	
FP7 WeSenseIt: Citizen Observatory of Water[192]	Flood	Good use of the power of human observation as an essential part of an early warning system. People contribute by taking		X

[187] http://www.beyond-eocenter.eu/
[188] http://cordis.europa.eu/project/rcn/108747_en.html
[189] http://cordis.europa.eu/result/rcn/195491_en.html
[190] http://www.starflood.eu/
[191] http://www.starflood.eu/documents/2016/04/comparison-of-countries.pdf
[192] http://cordis.europa.eu/project/rcn/106532_en.html

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
		European level		
(2012-2016)		measurements using new apps currently being developed by the project and sending information and images by mobile phone. The new technologies and approaches are being tested in Italy, the Netherlands and the UK.		
FP7 SYstem for Digitization and Diagnosis in ART Applications - SYDDARTA[193] (2011-2014)	Partially on Air pollution and specific CH	Methodological approach, producing a new portable type of equipment to use in the preventive conservation and monitoring of movable cultural assets, by the acquisition of 3D-hyperspectral imaging through scanning non-destructive techniques, providing enormous data sets by non-destructive characterisation techniques.		X
FP7 Nano-systems for the conservation of immoveable and moveable polymaterial Cultural Heritage in a changing environment - NANOMATCH[194] (2011-2014)	Partially on Air pollution and specific CH	Government authorities, restoration architects and conservation scientists have always had to face the problem of deterioration of historic building materials, in particular stone, wood and glass; an issue that has become more and more urgent since climate change has worsened natural decay and the impact of atmospheric pollution. In addition, in recent years socio-economic requirements have claimed for a more sustainable use of existing building heritage. On these premises, the NANOMATCH project addressed this issue through the development of a class of innovative consolidants to be specifically designed to meet the requirements of the historic substrates and to identify high performance products to renovate the market dedicated to the conservation of the built heritage.	X	
LIFE Programme - Adapting to Climate Change in Time (ACT) [195] (2010-2012)	Climate Change and CH	Involving the Italian Institute ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale (Servizio Monitoraggio e Prevenzione degli impatti sull'Atmosfera, Settore Impatti e Piani di Risanamento) and the FAIC - Forum delle Città dell'Adriatico e dello Ionio, the study has been addressed on the	X	

[193] http://cordis.europa.eu/project/rcn/100977_en.html
[194] http://cordis.europa.eu/project/rcn/101243_en.html
[195] http://www.actlife.eu/EN/index.xhtml

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
		European level		
		climate changes impacts on the CH of the city of Ancona[196].		
FP7 Performance-based approach to the earthquake protection of cultural heritage in European and Mediterranean countries – PERPETUATE[197] (2010-2012)	Seismic risk and CH	A methodology for evaluation and mitigation of seismic risk to CH assets was proposed. The final aim of PERPETUATE was the development of European Guidelines for the achievement of a homogenous and reasonably low seismic risk to CH in European and Mediterranean countries. In particular, the Italian "Guidelines for the evaluation and mitigation of seismic risk to cultural heritage" was the framework for the drawing up of this document. Focusing the attention on masonry structures, the project has faced the problem for both architectonic assets (historic buildings or parts of them) and artistic assets (frescos, stucco-works, statues, pinnacles, etc…).		
FP7 NEW INTEGRATED KNOWLEDGE BASED APPROACHES TO THE PROTECTION OF CULTURAL HERITAGE FROM EARTHQUAKE-INDUCED RISK – NIKER[198] (2010-2012)	Earthquake and CH	Earthquake-impact on CH assets started from the basic assumption that efficient protection, with substantial guarantee of compatibility and low-intrusiveness, can only be achieved on the basis of the "minimum intervention" approach. This requires that the potential of existing (authentic) materials and components be as much as possible exploited in terms of strength and energy dissipation, and that candidate interventions are validated and optimized under specific, real life conditions.	X	
Collaborative Project in the Cooperation programme of the FP7 - SHARE	Seismic Hazard and CH?	SHARE's main objective is to provide a community-based seismic hazard model for the Euro-Mediterranean region with update mechanisms. The project aims to establish new standards in Probabilistic Seismic Hazard Assessment (PSHA) practice by a close cooperation of leading European geologists, seismologists and engineers.	X	
FP7 Climate for Culture Project - CfC	Climate Change and CH	Hazard and damage high resolution projections to assess the impact of the slow ongoing	X	

[196] C. Cacace, R. Gaddi, A. Giovagnoli, M. Cusano, P. Bonanni, Gli impatti dei cambiamenti climatici sui beni culturali di Ancona

[197] http://cordis.europa.eu/project/rcn/93579_en.html

[198] http://cordis.europa.eu/project/rcn/93572_en.html

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
European level				
(2009-2014)		climate change rather than extreme events effects on indoor and outdoor CH buildings, creating more than 55000 maps for the assessment of vulnerability[199,200,201,202,203,204].		
FP 7 Fire Detection and Management through a Multi-Sensor Network for the Protection of Cultural Heritage Areas from the Risk of Fire and Extreme Weather Conditions - FIRESENSE[205] (2009-2013)	Fire + Extreme weather conditions (such as storms and floods)	It aimed to develop an automatic early warning system to remotely monitor areas of archaeological and cultural interest from the risk of fire and extreme weather conditions: - Providing real-time information about the evolution of fire using wireless sensor network data. - Estimating the propagation of the fire based on the fuel model of the area and other important parameters such as wind speed, slope, and aspect of the ground surface. - Providing visualisation of the predicted fire propagation by a 3-D Geographic Information System (GIS) environment. Demonstrator deployments has been operated in selected sites in Greece, Turkey, Tunisia and Italy.		X
FP7 IMproving Preparedness and RIsk maNagemenT for flash floods and debriS flow events – IMPRINTS[206] (2009-2012)	Flood	Early warning platform to cut responses to flash floods down to about two hours. The platform is based on better rainfall predictions and uses meteorological models and weather radar networks. The software is able to predict water flows on the ground and provide		X

[199] Hujibregts, Z., Kramer, R.P., Martens, M.H.J., van Schijndel, A.W.M., and H.L.Schellen 2012. A proposed method to assess the damage risk of future climate change to museum objects in historic buildings, Building and Environment, Vol. 55, Pages 43–56

[200] Martens, M.H.J. 2012. Climate risk assessment in museums: degradation risks determined from temperature and relative humidity data. Eindhoven: Technische Universiteit Eindhoven. ((Co)promot.: prof.dr.ir. M.H. de Wit, dr.ir. H.L. Schellen & H.A. Ankersmit).

[201] Antretter, F., Kosmann, S., Kilian, R., Holm, A., Ritter, F., Wehle B. 2013. Controlled ventilation of historic buildings: Assessment of impact on the indoor environment via hygrothermal building simulation, in Freitas, V. Peixoto (Ed.): Hygrothermal Behavior, Building Pathology and Durability. Berlin: Springer, 2013.ISBN: 978-3-642-31157-4

[202] Kramer, R., van Schijndel, J., and H. Schellen. 2013 Inverse modeling of simplified hygrothermal building models to predict and characterize indoor climates. Building and Environment, 68, p. 87-99

[203] Leissner, J., Kaiser, U. and R. Killian (Ed.s), 2014.Climate for Culture – Built Cultural Heritage in times of Climate Change, Fraunhofer MOEZ, Leipzig, Germany, pp.51. ISBN 978-3-00-048328-8

[204] Leissner, J., Kilian, R., Kotova, L., Jacob, D., Mikolajewicz, U., Broström, T., Ashley-Smith, J., Schellen, H.L., Martens, M., van Schijndel, J., Antretter, F., Winkler, M., Bertolin, C., Camuffo, D., Simeunovic, G., Vyhlídal, T., 2015. Climate for culture: assessing the impact of climate change on the future indoor climate in historic buildings using simulations. Herit. Sci. 3, 38 DOI:10.1186/s40494-015-0067-9

[205] http://cordis.europa.eu/project/rcn/93948_en.html

[206] http://cordis.europa.eu/project/rcn/91253_en.html

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
European level				
		a full early warning system for flash floods, the amount of debris they might carry and any potential damage to local infrastructure.		
FP7 European Cultural Heritage Identity Card - EU CHIC[207] (2009-2012)	Climate Change and CH	The primary objective of the EU-CHIC project was to propose a strategy and systems, for the most efficient methods and tools of harmonising criteria and indicators to track changes, caused by human interventions and environmental impacts, on the tangible CH across Europe and its neighbouring countries. The project worked on efficient compilation and storage of data for each asset and structure to support its maintenance, conservation and rehabilitation. In addition, the project team produced accurate criteria and indicators for resilience assessment.	X	X
FP7 UrbanFlood[208] (2009-2012)	Flood	Development of sensors and related technology to monitor flood embankments and provide early warning of their risk of failing. The underground sensors monitor the state of embankments, changes to water levels, and other factors such as temperature, moisture and Earth movements. The information is then assessed by the project's modelling software, which can trigger an alert if there is a problem. The software calculates how fast the site will be flooded if the dam fails and even suggests the best ways to move citizens to safer areas.		X
FP7 Strategies for the protection of shipwrecks in the Baltic Sea against forthcoming attack by wood degrading marine borers. A synthesis and information project based on the effects of climatic changes – WRECKPROTECT[209] (2009-2011)	Climate change and specific CH	The Baltic sea is a brackish marine environment, enclosing a unique well preserved historical collection of wooden shipwrecks and settlements. The WreckProtect project will develop guidelines synthesised on currently available information: 1. The prediction of marine borer attack in marine waters 2. The protection of wrecks in situ. These guidelines will be applicable to other European marine waters outside the Baltic.		X

[207] http://cordis.europa.eu/project/rcn/92042_en.html
[208] http://cordis.europa.eu/project/rcn/93800_en.html
[209] http://cordis.europa.eu/project/rcn/92243_en.html

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
European level				
FP7 Technologies and Tools to prioritize assessment and diagnosis of air pollution impact on immovable and movable Cultural Heritage – TeACH [210,211,212,213] **(2008-2012)**	Air pollution and CH	Identifications of the multi-pollutants and the prioritization of the principal ones; identification of ways of improving the more reliable and efficient among existing technologies and tools, developing new devices and tools, particularly a new a compact and economical kit of instruments; production of guidelines for the future prioritization of air pollution and disseminate the results.	X	X
Identity and Conflict. Cultural Heritage and the re-construction of identities after conflict – CRIC[214] **(2008-2012)**	Conflicts and CH	To investigate the ways the destruction and subsequent selective reconstruction of the CH impact identity formation. Through five regional case studies, this project seeks to illuminate both the empircal and theoretical relationship between cultural heritage, conflict and identity. In particular, it will examine how destruction as well as reconstruction affect notions of belonging and identies at different scales ranging from the individual to the pan-national. The project enhances insights into the crucial relationship between heritage and identity, and on this basis it will provide much needed knowledge of use to policy-makers.		
INTERREG IIIC Sud, Patrimoine et prévention des risques naturels - NOÉ Project [215] **(2007-2013)**	Climate Change and CH	Aimed at preventing in facing natural risks (floods, earthquakes, fires) for the cultural heritage, considering cross-actions among the experts of cultural heritage, specialists of intervention and local authorities; enhancing the transfer of knowledge among the Mediterranean Regions.		X
FP7 Cultural Heritage	Flood and CH	Detailed analyses of flood impacts on architectural heritage,	X	

[210] http://cordis.europa.eu/project/rcn/89329_en.html

[211] Ozga I., Bonazza A., Lyazidi S.A., Haddad M., Ben-Ncer A., Ghedini, N., Sabbioni C., 2013. Pollution impact on the ancient ramparts of the Moroccan city Sale, ELSEVIER FRANCE-EDITIONS SCIENTIFIQUES MEDICALES ELSEVIER 2013, DOI:10.1016/j.culher.2012.10.018

[212] Ozga I., Bonazza A., Bernardi E., Tittarelli F., Favoni O., Ghedini N., Morselli L., Sabbioni C., 2011. Diagnosis of surface damage induced by air pollution on 20th-century concrete buildings, PERGAMON-ELSEVIER SCIENCE LTD 2011, DOI:10.1016/j.atmosenv.2011.05.072.

[213] Strlic M., Cigic I. K., Mozir A., de Bruin G., Kolar J., Cassar M., 2011. The effect of volatile organic compounds and hypoxia on paper degradation, ELSEVIER SCI LTD 2011, DOI:10.1016/j.polymdegradstab.2010.12.017

[214] http://cordis.europa.eu/project/rcn/88572_en.html

[215] http://www.interreg4c.eu/uploads/media/pdf/NOE_2S0066R.pdf

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
European level				
Protection against flood - CHEF project (2007-2010)		landscape and moveable heritage and generated results focused on all aspects of CH damage[216],[217]..		
FP6 Integrated Flood Risk Analysis and Management Methodologies – DISFLOOD [218] (2004-2009)	Partially on Flood and CH	Which had some sections that take into account CH issues in relation to socio-economic evaluations of flood damage.	X	
FP6 Seismic Protection of Historical Buildings by Reversible Mixed Technologies- PROHITECH[219] (2004-2008)	Earthquakes and CH	The objective was to develop sustainable methodologies for the use of reversible mixed technologies in the seismic protection of existing constructions, with particular emphasis to buildings of historical and artistic interest. This project delivered several useful outputs in both the nonstructural measures (guidelines and assessment tools) and proposals for structural strengthening.		
Under the JRC Enlargement action within the FP6 "Management of Natural and Technological Risks"	Hazards and CH	Investigation risk mapping practices and policy for priority hazards in several Central European countries. With the help of a questionnaire, the survey focused on several hazards. The respondents assigned a lower level of importance of CH exposed to landslide risk than of infrastructure or private property objects.		
FP6 Noah's Ark Project[220,221,222] (2004-2007)	Climate Change and CH Air pollution	Produced Vulnerability Atlas and Guidelines for CH protection towards climate change. The Noah's Ark coupled climatology with conservation science expertise, acquired a unique know-how in delivering future forecast of CH vulnerabilities induced by outdoor climate	X	

[216] Drdácký, M.: Impact of Floods on Heritage Structures. *J. Perf. Constr. Fac.* Volume 24, Issue 5, pp. 430-431, 2010, http://dx.doi.org/10.1061/(ASCE)CF.1943-5509.0000152.
[217] Drdácký, M.: Flood Damage to Historic Buildings and Structures. *J. Perf. Constr. Fac.* Volume 24, Issue 5, pp. 439-445, 2010, http://dx.doi.org/10.1061/(ASCE)CF.1943-5509.0000065.
[218] http://cordis.europa.eu/project/rcn/74268_en.html
[219] http://cordis.europa.eu/project/rcn/75643_en.html
[220] C. Sabbioni, P. Brimblecombe, M. Cassar. 2010. Atlas of climate change impact on European Cultural Heritage, Anthem Press, ISBN 978927909800-0, 2010.
[221] Bonazza, A., Messina, P., Sabbioni, C., Grossi, C.M., Brimblecombe, P., 2009a. Mapping the impact of climate change on surface recession of carbonate buildings in Europe. Science of the Total Environment 407, 2039-2050.
[222] Bonazza, A., Sabbioni, C., Messina, P., Guaraldi, C., De Nuntiis, P., 2009b. Climate change impact: mapping thermal stress on Carrara marble in Europe. Science of the Total Environment 407, 4506-4512.

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
		European level		
		changes, including extreme weather related events		
FP6 Risk Mitigation for Earthquakes and Landslides – LESSLOSS[223] (2004-2007)	Landslides and multi-risk situations and CH	It is an integrated project dealing with landslides and multi-risk situations (together with earthquakes), which studies CH vulnerability and protection strategies and assesses historic bridges in accordance with European standards.		
FP6:Specific Support to Policy (2003–07)	Air pollution and CH	• Assessment of air pollution effects on CH – CULT-STRAT[224] • Sensor system for detection of harmful environments for pipe organs – SENSORGAN[225]		
COST Action C17: Built Heritage: Fire Loss to Historic Buildings[226] (2002–06)	Fire and CH	As a European research initiative, directly involved 20 participating countries and included corresponding links with contacts in the Baltic States, Russia and the USA. Through mutual collaboration the aim was to reduce the significant physical and cultural loss of Europe's built heritage to the damaging effects of fire. It involved a wide range of experts in a multidisciplinary manner through the collaboration and integration of a variety of related research and practical projects.		
FP5 Fire risk evaluation to european cultural heritage: quantification of priorities and optimisation of fire protection strategies – FIRE-TECH[227] (2002–2005)	Fire and CH	A quantitative decision method has been developed, able to prioritise between series of projects, on the basis of parameters such as value of cultural heritage, fire risk, the protection methods available - their cost and efficiency. As input to this decision method, a valuation method and risk analysis method based on statistical data on fire damage in CH will be developed. Fire protection methods has been examined on their efficiency, cost and applicability on cultural heritage.	X	X
The potential benefits of fire safety engineering in the European union – BeneFEU - EC contract EDT/01/503480 (2001-2002)	Fire and CH	Following a brief given by the EC, the areas studied were "Current Regulations in Member States", with 18 countries responding; the "State of the art in Fire Safety Engineering", noting the general move away from a prescriptive approach to one that is performance-based;		

[223] http://cordis.europa.eu/project/rcn/74272_en.html
[224] http://cordis.europa.eu/project/rcn/73914_en.html
[225] http://cordis.europa.eu/project/rcn/81427_en.html
[226] http://cordis.europa.eu/project/rcn/69426_en.html
[227] http://cordis.europa.eu/project/rcn/61199_en.html

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
		European level		
		and "Possible initiatives and cost benefit analysis', where there was a call for further European initiatives including a comprehensive legal framework, greater technical support, training and education, and further progress in associated research and standardisation.		
FP5 Advanced Research Centre for CH Interdisciplinary Projects – ARCCHIP[228] (2000-2004)	Natural disasters and Air pollution and CH	The vulnerability of CH to natural disasters and similar threats was discussed within the ARCCHIP project workshops which revealed a number of examples of good and ill practice; they have also revealed gaps in scientific knowledge. The effect of climate change on the frequency of occurrence of some natural hazards, like windstorms, floods and landslides was identified.	X	X
Environment and Sustainable Development FP5: Key action City of tomorrow and cultural heritage (1999–2002)	Air pollution and CH	• Carbon content and origin of damage layers in European monuments – CARAMEL[229] • Innovative modelling of museum pollution and conservation thresholds – IMPACT[230] • Model for multi-pollutant impact and assessment of threshold levels for CH – MULTI-ASSESS[231] • On-site investigation techniques for the structural evaluation of historic masonry buildings – ONSITEFORMASONRY[232] • Determination of conditions to prevent weathering due to condensation, particle deposition and micro-organism growth on ancient stained glass windows with protective glazing – VIDRIO[233]		
IGCP-425 Landslide Assessment and Mitigation for Cultural Heritage Sites and other Locations of High	Landslides and CH	The structure of the UNESCO–IUGS joint project, International Geological Correlation Programme (IGCP), is based on the results of national projects involving over 50 national and regional institutions and universities. It contributed to the development of a public access landslide database in Japan,	X	

[228] http://cordis.europa.eu/project/rcn/52609_en.html
[229] http://cordis.europa.eu/project/rcn/54203_en.html
[230] http://cordis.europa.eu/project/rcn/52973_en.html
[231] http://cordis.europa.eu/project/rcn/60386_en.html
[232] http://cordis.europa.eu/project/rcn/58620_en.html
[233] http://cordis.europa.eu/project/rcn/61198_en.html

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
European level				
Societal Value [234, 235] **(since 1998)**		which enables data sharing between various interest groups (SLIDELinks). IGCP-425 also initiated the creation of the International Consortium on Landslides in 2002.		
Environment and climate programme FP4 - 1st phase Technologies to protect and rehabilitate the European cultural heritage (1994–1998)	Air pollution and CH	• Archaeometric study to reconstruct the pollution and the climate of the past and their effects on CH - ARCHEO • Environmental deterioration of ancient and modern hydraulic mortars - EDAMM • Development of new non-destructive method for analysis of the atmospheric corrosion and corrosion protection of copper and copper alloys – CONTACTLESS CORROSION ANALYSIS • Baroque artificial marble: environmental impacts, degradation and protection – ENVIART • System and methods for assessing the conservation state and environmental risks for outer wooden parts of cultural buildings - WOOD-ASSESS		
Environmental programme FP3 – 1st and 2nd phases Environmental protection and conservation of the European cultural heritage (1991–1994)	Air pollution and CH	• Marine spray and polluted atmosphere as factors of damage to monuments in the Mediterranean coastal environment • Rôles des apports atmosphériques solides et gazeux, et de la nature du substrat dans les altérations superficielles des monuments – approche expérimentale et modélisation • Particulate pollution and stone damage • Deposition of gases and particles and their corrosive effect on surfaces of cultural and artistic value inside museums • Environmental research for art conservation – ERA • Atmospheric eutrophication and secular organic pollution (biological and mineralogical reactions of Mediterranean monuments)		
STEP programme FP2: Protection	Air pollution and CH	• Effects of airborne particulate matter on building surfaces		

[234] Sassa, K., Fukuoka, H. and Shuzui, H. (2000a): Field investigation of the slope instability at Inca's World Heritage in Machupicchu, Peru. Landslide News, (13):37-41.
[235] Sassa, K., Fukuoka, H., Wang, F. and Furuya, G. (2000b): Landslide hazard assessment in lishan, xian, China. In Earthquake-resisting technologies for geo-hazards, pages 25-96, Manila.

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
European level				
and conservation of the European cultural heritage (1989–1992)		• The effects of air pollutants on the accelerated ageing of cellulose containing materials • Granitic materials and historical monuments: study of weathering and application conservation • Physicochemical parameters, including pollutants interaction, affecting the rates of dry deposition on stone surfaces		
FP1: EU Funded Projects on the Effects of air pollution on historic buildings (1986–1990)	Air pollution and CH	All projects of this programme.		

Table 2. List of European funded projects on the following issues (International level), listed in chronological order (from the most recent to the oldest ones) and highlighted according to the typology of events with different colours as follows:

Climate Change **capitalized for** cultural heritage (CH)
Air Pollution **capitalized for** cultural heritage (CH)
Flood **capitalized for** cultural heritage (CH)
Wind **capitalized for** cultural heritage (CH)
Geological Hazards: Landslides, Volcanic Eruptions, Earthquakes **capitalized for** cultural heritage (CH)
Fire **capitalized for** cultural heritage (CH)
Armed Conflicts **capitalized for** cultural heritage (CH)
More than one event **capitalized for** cultural heritage (CH)

Project Name	Sector	Brief description	Adaptation	Disaster Risk Reduction
European level				
Oasis Innovation Hub for Catastrophe and Climate Extremes Risk Assessment - H2020_Insurance[236] (2017-2020)	Climate Change	This project intends to operationalize a system, called the Oasis Loss Modelling Framework, that combines climate services with damage and loss information and provides a standardised risk assessment process that can assess potential losses, areas at most risk and quantify financial losses of modelled scenarios.	X	X
H2020 BRIdges the GAp for Innovations in Disaster resilience – BRIGAID[237] (2016-2020)	Climate Change		X	
Public FLOOD Emergency and Awareness SERVice - FLOOD-serv[238] (2016-2019)	Flood	To develop and provide a pro-active and personalised citizen-centric public service application that will enhance the involvement of the citizen and will harness the collaborative power of ICT networks (networks of people, of knowledge, of sensors) to raise awareness on flood risks and to enable collective risk mitigation solutions and response actions.		
H2020 Improving Resilience to Emergencies through Advanced Cyber Technologies -I-REACT (2016-2019)	Flood	The proposed system targets public administration authorities, private companies, as well as citizens in order to provide increased resilience to natural disasters though better analysis and anticipation, effective and fast emergency response, increased awareness and citizen engagement. It integrates existing services, both local and European, into a platform that supports the entire emergency management cycle.		X

[236] http://cordis.europa.eu/project/rcn/210519_en.html
[237] http://cordis.europa.eu/project/rcn/202708_en.html
[238] http://cordis.europa.eu/project/rcn/204804_en.html

Project Name	Sector	Brief description	Adaptation	Disaster Risk Reduction
European level				
H2020 Enhancing Synergies for disaster PRevention in the EurOpean Union – ESPREssO[239] (2016-2017)	Climate Change	ESPRESSO will engage an interdisciplinary network of cities, industries, organizations and academic partners in the definition of this framework with the final goal of helping cities to implement it, enabling the scaling up of solutions and preventing the vendor lock-in with real economic benefits.	X	X
Flood CBA 2[240] (2016-2017)	Flood	Knowledge exchange project, designed to introduce some member states (UK, Greece, Portugal and Spain) to a more rigorous assessment of flood protection and flood risk management schemes, with an emphasis on both economic efficiency and the maximisation of public safety. The method of working is to select case studies in each country and analyse the costs and benefits of flood risk management measures there, as a vehicle for training programmes for stakeholders and users of project appraisal techniques and methods.	X	X
The European Flood Database - INUNDO[241] (2016)	Flood	It provides accurate, current and historical flood spatial information for risk modelling to help (re-)insurance companies improving their existing risk assessment processes. INUNDO fills the geospatial information gap missing in today's risk models and facilitates the impact assessment during and after large flood events. The objective of INUNDO is to create, validate, update, organise, license, and provide access to geospatial flood disaster information based on Earth Observations, meteorological data, and social media for the insurance industry to enhance their risk modelling and reduce their expenses.		
H2020 PLAtform for Climate Adaptation and Risk reDuction – PLACARD[242] (2015-2020)	Climate Change	PLACARD seeks to support the coordination of the Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) communities for coherent, mutually reinforcing and pragmatic planning and action.	X	X

[239] http://cordis.europa.eu/project/rcn/202690_en.html
[240] https://www.mdx.ac.uk/our-research/centres/flood-hazard/projects/flood-cba-2
[241] http://cordis.europa.eu/project/rcn/207424_en.html
[242] http://cordis.europa.eu/project/rcn/198647_en.html

Project Name	Sector	Brief description	Adaptation	Disaster Risk Reduction
European level				
H2020 EU-CIRCLE[243] (2015-2018)	Climate Change	Pan European framework for strengthening Critical Infrastructure Resilience to Climate Change. It is to move towards infrastructure network(s) that is resilient to today's natural hazards and prepared for the future changing climate. Furthermore, modern infrastructures are inherently interconnected and interdependent systems; thus extreme events are liable to lead to "cascade failures".		
H2020 IMPROVER[244] (2015-2018)	Climate Change	Improving European critical infrastructure resilience to crises and disasters through the implementation of resilience concepts to real life examples of pan-European significance, including cross-border examples. The improvement will arise through the development of a methodology for implementing combinations of societal, organisational and technological resilience concepts to critical infrastructure based on risk evaluation techniques and informed by a review of the positive impact of different resilience concepts on critical infrastructure.		X
FP7 Preparing for Extreme And Rare events in coastaL regions – PEARL[245] (2014-2017)	Coastal risks	PEARL brings together world leading expertise in both the domain of hydro-engineering and risk reduction and management services to pool knowledge and practical experience in order to develop more sustainable risk management solutions for coastal communities focusing on present and projected extreme hydro-meteorological events.		X
FP7 Resilience-Increasing Strategies for Coasts – toolkit - RISC-KIT[246] (2013-2017)	Coastal risk due to multi-hazards	It will deliver ready-to-use methods, tools and management approaches to reduce risk and increase resilience to low-frequency, high-impact hydro-meteorological events. The open-source and free-ware RISC-KIT tool kit will consist of a Coastal Risk Assessment Framework (CRAF) which - at the regional scale (100's km) - can quickly assess present and future hot spot areas of coastal		X

[243] http://www.eu-circle.eu/eu-funded-projects/
[244] http://improverproject.eu/discover/
[245] http://cordis.europa.eu/project/rcn/111109_en.html
[246] http://cordis.europa.eu/project/rcn/110483_en.html

Project Name	Sector	Brief description	Adaptation	Disaster Risk Reduction
		European level		
		risk due to multi-hazards a quantitative, high-resolution Early Warning and Decision Support System (EWS/DSS) for use on these hot spots (with a scale of 10's of km) and a web-based management guide offering innovative, cost-effective, ecosystem-based DRR measures; and a Coastal Risk Database of present and historic socio-economic and physical data. These tools will enable Europe's coastal managers, decision-makers and stakeholders to identify hot spot areas; produce timely forecasts and early warnings; evaluate the effect of climate-related, socio-economic and cultural changes on coastal risk; and choose the best prevention, mitigation and preparedness measures for their coast. The RISC-KIT products will help to achieve rapid attainment of UNISDR Disaster Reduction Goals and promote EU-consistent methods through innovative e-learning and open access publication.		
FP7 Assessment, STrategy And Risk Reduction for Tsunamis in Europe – ASTARTE[247] (2013-2017)	Tsunami hazards	It aims to develop a comprehensive strategy to mitigate tsunami impact in The NEAM (North East Atlantic, Mediterranean and Adjacent Seas) region of IOC/UNESCO. To achieve this goal, an interdisciplinary consortium has been assembled.		X
FP7 Advance Model Development and Validation for the Improved Analysis of Costs and Impacts of Mitigation Policies – ADVANCE[248] (2013-2016)	Climate Change	ADVANCE developed a new generation of advanced Integrated Assessment Models and applied the improved models to explore different climate mitigation policy options in the post-Paris framework.	X	
FP7 MED-SUV (2013-2016)	Volcanic Hazard	Project addressed on the expositions to potential volcanic hazards in the Mediterranean Area[249].		
FP7 Integrating GMES Emergency Services with satellite navigation and communication for establishing a flood	Flood	3 kind of map products: (i) flood delineation maps that are automatically fetched from Copernicus EMS and dynamically visualized on a map; (ii) flood nowcast maps that are created from		X

[247] http://cordis.europa.eu/project/rcn/111481_en.html
[248] http://cordis.europa.eu/project/rcn/104887_en.html
[249] MED-SUV project, http://www.med-suv.eu/

Project Name	Sector	Brief description	Adaptation	Disaster Risk Reduction
European level				
information service - FLOODIS (2013-2015)		crowdsourced reports; (iii) and flood forecast maps that are based on a 2-D flood model (LISFLOOP-FP) taking into account EFAS sensor forecasts and the Corine Land Cover.		
Flood CBA[250] **(2013-2014)**		Aimed at establishing a sustainable Knowledge Platform for the use of stakeholders dealing with the cost-benefit analysis of flood prevention measures in the context of different socio-economic environments within the EU.		
FP7 Reconciling Adaptation, Mitigation and Sustainable Development for Cities – RAMSES[251] **(2012-2017)**	Climate Change	The project is employing generic principles that are transferable across cities. As such, eight case studies will be conducted in cities in Europe, India, and North and South America. RAMSES will ultimately improve understanding of urban systems and determine the impact of climate change and the costs and benefits of adaptation and mitigation in cities.	X	
FP7 Bottom-up Climate Adaptation Strategies towards a Sustainable Europe – BASE (2012-2016)[252]	Climate Change	It supports action for sustainable climate change adaptation in Europe. BASE makes experiential and scientific information on adaptation meaningful, transferable and easily accessible to decision-makers at all levels.	X	
FP7 Enhancing risk management partnerships for catastrophic natural disasters in Europe – ENHANCE[253] **(2012-2016)**	Catastrophic natural hazards	The main goal of the ENHANCE project was to develop and analyse new ways to enhance society's resilience to catastrophic natural hazard impacts, by providing new scenarios and information in selected hazard cases in close collaboration with stakeholders, and by contributing to the development of new multi-sector partnerships (MSPs) to reduce or redistribute risk. The ENHANCE proposal is unique as it studies the potential for new MSPs for managing different catastrophic hazards, related to heat waves, forest fires, flood, drought, storm surge, and volcanic eruptions.		
FP7 A European volcanological supersite in Iceland: a monitoring system	Volcanic Hazard	It established an integrated volcanological monitoring system through European collaboration.		X (Monitoring and early

[250] http://www.floodcba.eu/main/
[251] http://cordis.europa.eu/project/rcn/105326_it.html
[252] http://cordis.europa.eu/project/rcn/105324_en.html
[253] http://cordis.europa.eu/project/rcn/106592_en.html

Project Name	Sector	Brief description	Adaptation	Disaster Risk Reduction
European level				
and network for the future - FUTUREVOLC[254] (2012-2016)				warning system)
FP7 Volcanic unrest in Europe and Latin America: Phenomenology, eruption precursors, hazard forecast, and risk mitigation - VUELCO[255] (2011-2015)	Volcanic Hazard	To create global strategies for 1) enhanced monitoring capacity and value, 2) mechanistic data interpretation and 3) identification of reliable eruption precursors. The project consortium objective was to generate guidance in the definition and implementation of strategic options for effective risk mitigation, management and governance during unrest episodes.		X (Monitoring and early warning system)
Atmospheric Composition Change: the European Network-Policy Support and Science - ACCENT-PLUS[256] (2010-2014)	Climate change and Air pollution	ACCENT-Plus aims at extending the breath of the previous ACCENT phase to reach out to the policy community, facilitating the transfer of research results into policy/decision making.		
FP7 Climate change integrated assessment methodology for cross-sectoral adaptation and vulnerability in Europe – CLIMSAVE[257] (2010-2013)	Climate Change	CLIMSAVE has developed the CLIMSAVE IA Platform, a unique, interactive, exploratory web-based tool to allow European stakeholders to assess for themselves climate change impacts and vulnerabilities for a range of sectors. It provides rapid user-friendly interactivity through www.climsave.eu and the European Climate Adaptation Platform (CLIMATE-ADAPT - http://climate-adapt.eea.europa.eu/), helping to broaden accessibility and participation and increase impact in research communities.	X	
FP7 Costs of Natural Hazards – CONHAZ[258] (2010-2012)	Climate Change	The project sought to assemble data on cost evaluation methods in order to refine natural hazard management and planning. It aimed to analyse the different methods and produce recommendations on dealing with disasters, in addition to defining further research needed.	X	X
Interreg IVC, Adapting to Climate Change through	Climate Change	F:ACTS! is focused on risk prone areas that lack resilience to respond to and recover from extreme weather conditions,	X	X

[254] http://cordis.europa.eu/project/rcn/105557_it.html
[255] http://cordis.europa.eu/project/rcn/100132_it.html
[256] http://cordis.europa.eu/project/rcn/96700_en.html
[257] http://cordis.europa.eu/project/rcn/93957_en.html
[258] http://cordis.europa.eu/project/rcn/93525_en.html

Project Name	Sector	Brief description	Adaptation	Disaster Risk Reduction
		European level		
Territorial Strategies! - F:ACTS![259] (2010-2012)		due to climate change. The project also works with 5 pilot projects. These pilots are all areas facing droughts, floods or forest fires. The F:ACTS! handbook[260] gathers all the knowledge, experience and good practices.		
FP 7 Innovative coastal technologies for safer European coasts in a changing climate – THESEUS[261] (2009-2013)	Coastal risk due to multiple change factors	THESEUS will develop a systematic approach to delivering both a low-risk coast for human use and healthy habitats for evolving coastal zones subject to multiple change factors. The innovative combined mitigation and adaptation technologies to be considered will include ecologically-based mitigation measures, hydro-morphodynamic techniques, actions to reduce the impact on society and economy and GIS-based software to support defence planning. THESEUS guidelines consider the environmental, social and economic issues raised in any coastal area.	X	X
FP7 Social Capacity building for Natural hazards: Towards more resilient societies - CAPHAZ-NET[262] (2009-2012)	Climate Change	The main objectives of CapHaz-Net are to identify and assess existing practices and policies for social capacity building in the field of natural hazards and to elaborate strategies and recommendations for activities to enhance the resilience of European societies to the impacts of natural hazards. This will be achieved by bringing together different scientific disciplines and by enhancing and fostering communication between researchers, policy-makers and practitioners from across Europe, realizing a guidance tool for the assessment of existing social capacities as well as for highlighting those that might need to be developed by organisations and local communities.	X	
Local Climate Change Response – CHAMP[263] (2009-2012)	Climate Change	The CHAMP project supports and trains cities and subregional authorities in responding to climate change effects through implementing integrated	X	

[259] http://www.factsproject.eu/aboutfacts/Pages/default.aspx
[260] http://www.factsproject.eu/SiteCollectionDocuments/Handbook/HandbookDEF.pdf
[261] http://cordis.europa.eu/project/rcn/92871_en.html
[262] Social Capacity building for Natural hazards: Towards more resilient societies
[263] http://climate-adapt.eea.europa.eu/metadata/projects/local-climate-change-response

Project Name	Sector	Brief description	Adaptation	Disaster Risk Reduction
		European level		
		management systems for climate change mitigation and adaptation, promoting the method and the model Europe-wide, and improving of effective planning. The main output of the project is the Capacity Development Package supporting local authorities in implementing the IMS for climate change mitigation and adaptation.		
Action on Climate Change through Engagement, Networks and Tools – ACCENT[264] (2009-2011)	Climate Change	15 relevant organisations among science centres, science museums and aquariums have been engaged by this proposal. ACCENT proposes to contribute to a global effort to move the campaign on climate change from "informative" to the "active" phase, through the exchange and dissemination of practices, with specific actions that encourage the involvement of citizens in actions and dialogue.	X	X
FP7 Mitigate and assess risk from volcanic impact on terrain and human activities – MIA-VITA[265] (2008-2012)	Volcanic Hazard	MIA-VITA project aims at developing tools and integrated cost effective methodologies to mitigate risks from various hazards on active volcanoes (prevention, crisis management and recovering) Mainly addressed to the early warning system, policy and economic impact.		X
FP7 Morphological Impacts and COastal Risks induced by Extreme storm events – MICORE[266] (2008-2011)	Coastal risks and storms	Specifically targeted to contribute to the development of a probabilistic mapping of the morphological impact of marine storms and to the production of early warning and information systems to support long-term disaster reduction.		X (Monitoring and early warning system)
Network for Observation of Volcanic and Atmospheric Change – NOVAC[267] (2005-2010)	Gases and areosols emitted by Volcanoes	It established a network for measurements of the emissions of gases (in particular SO_2 and BrO) and aerosols by volcanoes, and to use the data from this network for risk assessment and volcanological research, both locally and on a regional and global scale.		
FP5 Multi-disciplinary monitoring, modelling and	Volcanic Hazard	Modelling and forecasting volcanic hazard.		X (Monitoring and early

[264] http://cordis.europa.eu/project/rcn/91021_en.html
[265] http://cordis.europa.eu/project/rcn/89305_en.html
[266] http://cordis.europa.eu/project/rcn/88552_en.html
[267] http://cordis.europa.eu/project/rcn/75513_en.html

Project Name	Sector	Brief description	Adaptation	Disaster Risk Reduction
European level				
forecasting of volcanic hazard - MULTIMO[268] (2001-2004)				warning system)

[268] MULTIMO Project, http://www.see.leeds.ac.uk/Multimo/

Table 3. List of European funded projects on the following issues (National/Local Level), listed in chronological order (from the most recent to the oldest ones) and highlighted according to the typology of events with different colours as follows:

Climate Change and cultural heritage (CH)
Air Pollution and cultural heritage (CH)
Flood and cultural heritage (CH)
Wind and cultural heritage (CH)
Geological Hazards: Landslides, Volcanic Eruptions, Earthquakes and cultural heritage (CH)
Fire and cultural heritage (CH)
Armed Conflicts and cultural heritage (CH)
More than one event and cultural heritage (CH)

Project Name	Sector	Brief description	Assessment of the impact	Monitoring and early warning system
National/Local level				
ITALY				
Environmental impact on the UNESCO heritage sites located in Panama (2014-2016)	Climate Change and CH	A research work realized in collaboration among the CNR-ISAC, the Department of Physics and Earth Sciences of the University of Ferrara (Italy) and the Patronages of Panama Viejo and of Portobelo and San Lorenzo (Panama).Taking into account the slow changes, the work realized evaluation and predictions of possible future damages through the use of damage functions[269].	X	X
POR CALABRIA FESR - SIstemi e tecnologie per il MONitoraggio di Aree culturali in ambiente subacqueo e terrestre (SIMONA) (2007-2013)	Climate Change and CH	The possible risks related to the man-made and natural disasters have been evaluated and predicted realizing damages maps in considerations for the possible deterioration phenomena linked to slow changes[270].	X	X
Carta del Rischio	Climate Change and CH	The ISCR-MiBACT realized a territorial information system of risk maps for CH by adopting a holistic multi-risk approach, including the impact of volcanic and storm hazard that have not been previously assessed[271].	X	X
CZECH REPUBLIC				
Methodology and instruments for protection and safeguarding cultural heritage	Flood and CH	Those projects were specifically designed to study complex problems of floods impacting cultural heritage. Limited historical data are available from another	X	

[269] Ciantelli C. PhD. Thesis, A.Y. 2014-2016, ENVIRONMENTAL IMPACT ON UNESCO HERITAGE SITES IN PANAMA.

[270] http://www.laboratorisilpa.com/laboratori/index.php?option=com_content&view=article&id=34&Itemid=180

[271] CARTA DEL RISCHIO Project, www.cartadelrischio.it/

threatened by floods		project supported from the Grant Agency of the Czech Republic[272]		
Identification of important territories with cultural heritage values endangered by natural and anthropogenic influences	Flood and CH	Those projects were specifically designed to study complex problems of floods impacting cultural heritage. Limited historical data are available from another project supported from the Grant Agency of the Czech Republic[273]	X	
GERMANY				
Disaster Information System for Large-scale Flood Events using Earth Observation - DISFLOOD[274] (2005-2008)	Partially on Flood and CH	Contained elements which supported the CH stock at risk inventory in flooded areas. This project focused on urban territories and involved many historic cities.	X	
URBAS - urban flash floods (2005-2008)	Partially on Flood and CH	It was concentrating on the urban occurrence of flash floods and was supported by the German Ministry of Research in the framework of the RIMAX project cluster. RIMAX grouped together more than 30 projects which were all investigating aspects of extreme floods in Germany. Case studies involved several historic cities and thus indirectly contributed to the cultural heritage protection. [275]	X	
GREECE				
THALES Program on Reinforcement of the interdisciplinary and/or inter-institutional research and innovation- SEISMIC PROTECTION OF MONUMENTS AND HISTORICAL STRUCTURES[276] (2012-2015)	Earthquakes and CH	The project aimed at developing an integrated, interdisciplinary and innovative methodology to evaluate the seismic behaviour of monuments and historic structures. The implementation of the methodology on selected real case-study historic structures included (a) documentation of the existing state (b) recording of damage (c) identification of the construction materials (d) investigation of parameters that affect their seismic response, such as regional seismicity and soil conditions.	X	
Upgrading Infrastructure for Earthquake Protection in Greece and	Earthquakes and CH	The main objectives of the project include the development of models for active faults, the implementation of software for the estimation of ground shaking and the creation of modern scenarios	X	X

[272] Brázdil, R., Dobrovolný, P., Kakos, V., Kotyza, O.: Historical and Recent Floods in the Czech Republic: Causes, Seasonality, Trends, Impacts. In Flood Risk Management: Hazards, Vulnerability and Mitigation Measures, Springer, 2006, pp 247-259,

[273] Brázdil, R., Dobrovolný, P., Kakos, V., Kotyza, O.: Historical and Recent Floods in the Czech Republic: Causes, Seasonality, Trends, Impacts. In Flood Risk Management: Hazards, Vulnerability and Mitigation Measures, Springer, 2006, pp 247-259,

[274] http://www.umweltbundesamt.de/en/topics/climate-energy/climate-change-adaptation/adaptation-tools/project-catalog/disflood-disaster-information-system-for-large

[275] www.urbanesturzfluten.de/project/index_html/view?set_language=en

[276] http://excellence.minedu.gov.gr/thales/en/thalesprojects/380152

Enhancing Services through Actions of Excellence - The project ASPIDA[277] (2007-2013)		evaluating the damage to the built environment of major Greek cities. In particular, the individual goals include: (a) Assessment of large earthquake effects on the urban environment of Greek cities, (b) Rating the effect of tsunami in coastal cities in Greece–Adapting an early warning system, and (c) specific measures for CH protection against strong earthquakes.		
Draft Framework regulatory document for structural interventions and seismic protection of monuments[278] (2010-2011)	Earthquakes and CH	This study has been an initiative of the Earthquake Planning and Protection Organization[279] and its purpose is threefold: (a) the description of the contents of structural documentation (b) the presentation of structural analysis methods for masonry structures (c) the description of the criteria for appropriate schemes of structural interventions.	X	
Evaluation of the mechanical behavior of Byzantine masonry with or without mosaics and intervention methods: Application in Dafni Monastery (2005-2007)	Earthquakes and CH	The aim of this research project is: (a) the estimation of the mechanical characteristics of walls of the Katholikon before the earthquake (b) the optimization of high-penetration hydraulic grouts application in the Katholikon walls (c) the determination of the mechanical characteristics of the Katholikon walls after their repair with hydraulic grouts. (d) the comparison of two types of high-penetration hydraulic grouts in terms of repair effectiveness.	X	
Assessment and recommendations for the interventions on buildings of Lefkada's historical settlement[280] (2003-2004)	Earthquakes and CH	Driven by the earthquake that occured in 2003 in the greek island of Lefkada, the Earthquake Planning and Protection Organization and the National Technical University of Athens[281] cooperated for this study. The publication aims at presenting (a) all the data obtained from the field observations, (b) a constructional analysis of the local structural system and (c) specific recommendations for structural interventions.	X	

[277] http://aspida.gein.noa.gr/?page_id=2360
[278] http://ecpfe.oasp.gr/sites/default/files/files/ENGLISH%20VERSION.pdf
[279] http://www.oasp.gr/
[280] http://www.sciencedirect.com/science/article/pii/S0950061805001911v
[281] http://www.civil.ntua.gr/

ANNEX B - List of experts, which participated in the survey and agreed to be published along with their affiliations

Name	Affiliation	Country
Hans Sanderson	Aarhus University	Denmark
Dorota Folga-Januszewska	Academy of Fine Arts	Poland
Luca Maria Cristini	Academy of Fine Arts of Macerata - Restoration Institute of Marche Region	Italy
Maria Ioannidou	Acropolis Restoration Service (YSMA)	Greece
Hubert Speckner	Austrian Armed Forces/National Defence Academy	Austria
Heinrich Speich	Civil Defence Forces in Cultural Heritage Protection	Switzerland
Wouter van Koeveringe	Civil-military cooperation centre of excellence (CCOE)	Netherlands
Despina Pilides	Department of Antiquities	Cyprus
Filipa Neto	Department of Cultural Goods - Archaeological Information Unity	Portugal
Irene Hadjisavva	Department of Town Planning and Housing	Cyprus
Alessandro Zucchini	Emilia-Romagna Region	Italy
Markus Leitner	Environment Agency Austria, Department Environmental Impact Assessment and Climate Change	Austria
Michael Newland	Environmental Science Associates (ESA) - Northern California Cultural Resources Group	USA
Evangelia Pelli	European Center on Prevention and Forecasting of Earthquakes (ECPFE) Earthquake Planning and Protection Organization (EPPO)	Greece
Rino Büchel	Federal Office of the Protection of the Population/Protection of Cultural Property	Switzerland
Pietro Livi	Frati e Livi srl	Italy
Styliani Papatzani	Hellenic Ministry of Culture and Sports	Greece
Manus Deery	Historic Environment Division Department for Communities	UK
Terry Crowdy	Historic Royal Palaces	UK
Valentina Varbanova	History Museum of Sofia	Bulgaria
Nikos Grammalidis	Information Technologies Institute - Centre of Research and Technology Hellas	Greece
Patrizia Bonanni	Italian National Institute for Environmental Protection and Research (ISPRA)	Italy
Dario Camuffo	Italian National Research Council - Institute of Atmospheric Sciences and Climate (CNR-ISAC)	Italy
Cathy Daly	Lecturer in conservation	UK
Konstantinos Drakodaidis	Lefkada Municipality	Greece
Stewart Kidd	Loss Prevention Consultant Ltd	UK
Christopher Marrion	Marrion Fire & Risk Consulting PE, LLC	USA
Andrea D'Agostino	MEDIASS S.p.A.	Italy
Carlo Cacace	Ministry of Cultural Heritage and Activities and Tourism (MIBACT), Central Institute for Restoration (ISCR)	Italy
Maria Elena Corrado	Ministry of Cultural Heritage and Activities and Tourism (MIBACT), Central Institute for Restoration (ISCR)	Italy
Tiziana Biganti	Ministry of Cultural Heritage and Activities and Tourism (MIBACT) Polo Museale dell'Umbria	Italy
Massimo Osanna	Ministry of Cultural Heritage and Activities and Tourism (MIBACT) - Parco Archeologico di Pompei	Italy
Biancaneve Codacci Pisanelli	Ministry of Cultural Heritage and Activities and Tourism (MIBACT)	Italy
Amalia Androulidaki	Ministry of Culture	Greece
Uliana Maleeva	Ministry of Culture - Cultural Heritage, Museums and Fine arts	Bulgaria
Dominik Horn	Ministry of Defence and Sports	Austria
Priit Laaniste	Ministry of the Interior	Estonia
Rudolf Kaiser	Ministry of the Interior, Fire and Rescue Service	Czech Republic
Pavol Ižvolt	Monuments Board	Slovak Republic
Marcy Rockman	National Park Service	USA
Froso Antoniou	Nicosia Municipality	Cyprus

Name	Affiliation	Country
Athina Papadopoulou	Nicosia Municipality	Cyprus
Vibeke Vandrup Martens	Norwegian Institute for Cultural Heritage Research (NIKU)	Norway
Roberto Cela	Opera Primaziale Pisana	Italy
Umberto Maggio	Professional in the field of restoration	Italy
Óscar Manuel Fernandes Cerveira Ferreira	Professor on Marine Sciences, University of Algarve	Portugal
Johanna Leissner	Researcher at Fraunhofer-Gesellschaft	Germany
Christopher Catling	Royal Commission on Ancient and Historical Monuments of Wales	UK
Juan Carlos Prieto Vielba	Santa María la Real Foundation	Spain
Erika Hedhammar	Swedish National Heritage Board	Sweden
Alexandros Panteleios	Technical Chamber of Greece Kefalonia and Ithaca Prefectural Committee	Greece
Guðmundur Stefán Sigurðarson	The Cultural Heritage Agency of Iceland	Iceland
Agnes Stefansdottir	The Cultural Heritage Agency of Iceland	Iceland
Gregory Quenet	Université de Versailles Saint-Quentin-en-Yvelines (UVSQ) French government	French
Lefèvre Roger-Alexandre	Université Paris Est-Créteil Laboratoire Interuniversitaire des Systèmes Atmosphériques (LISA)	French
Milena Tasheva - Petrova	University of Architecture, Civil Engineering and Geodesy (UACEG)	Bulgaria
Peter F Biehl	University of Buffalo Society for American Archaeology (SAA), Climate Change Strategies and Archaeological Resources Committee (CCSAR), European Association of Archaeologists (EAA)	USA
Maria Philokyprou	University of Cyprus	Cyprus
Sergio Lagomarsino	University of Genoa (DICCA)	Italy
Maria João Baptista Neto	University of Lisbon	Portugal
Reuben Grima	University of Malta	Malta
Steve Emery	University of Oxford	England
Esmeralda Paupério	University of Porto	Portugal
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