D3.3 Feasibility study for the conception of CH focused virtual reality and learning tools to be integrated into the Union Civil Protection Knowledge Network

Protecting Cultural Heritage from the Consequences of Disasters – Network
PROCULTHER -NET PROJECT

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Acronyms and abbreviations

AFAD	Ministry of Interior-Disaster and Emergency Management Authority
AR	Augmented reality
CBRN	Chemical, Biological and Radio-Nuclear
BIM	Building Information Modeling
CEDCHE	European Commission's Expert Group on a common European Data Space for Cultural Heritage
CH	Cultural Heritage
CSO	Civil Society Organization
CNVVF	Italian National Fire and Rescue Service
CP	Civil Protection
C2RMF	Centre de Recherche et de Restauration des Musées de France
DG ECHO	Directorate-General for European Civil Protection and Humanitarian Aid Operations
DGSCGC	Ministère de l'Intérieur- Direction Générale de la Sécurité Civile et de la Gestion de Crises-France
DRM	Disaster Risk Management
EAMENA	Endangered Archaeology in the Middle East and North Africa
ERCC	Emergency Response Coordination Centre
FAR	First Aid and Resilience for Cultural Heritage in Times of Crisis
FCSVM	Fondazione Hallgarten-Franchetti Centro Studi Villa Montesca
GIS	Geographic Information System
HEART	Heritage Emergency and Response Training
ICA	Institute of Contemporary Art
ICOM	International Council of Museums
ICOMOS	International Council on Monuments and Sites
ICORP	International Scientific Committee on Risk Preparedness
ICCROM	International Centre for the Study of the Preservation and Restoration of Cultural Property
ICT	Information and Communication Technologies
IFLA	International Federation of Landscape Architects
INSARAG	International Search and Rescue Advisory Group
JCyL	Consejería de Cultura y Turismo de la Junta de Castilla y León-Spain
LS	Live Simulation
MBLC	Massachusetts Board of Library Commissioners
MDEM	Museum Development East Midlands
MODEX	Module Exercise
MOOC	Massive Open Online Courses
N	Number of respondents (in the graphs)
NEDCC	Northeast Document Conservation Center
NGO	Non-Governmental Organisation
PROCULTHER	Protecting Cultural Heritage from the Consequences of Disasters
PROCULTHER-NET	Protecting Cultural Heritage from the Consequences of Disasters-Network
Q	Question number from questionnaire (in the graphs)
SCRI	Cultural Rescue Initiative
TRACENET	Training Centre Network on 3D and VR
UCPKN	Union Civil Protection Knowledge Network
UCPM	Union Civil Protection Mechanism
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs

1. Introduction

This "Feasibility Study for the conception of CH focused virtual reality and learning tools to be integrated into the Union Civil Protection Knowledge Network", developed by the PROCULTHER-NET management team in collaboration with the project partners, is aimed at facilitating the definition of technical and conceptual elements needed for adequate integration of cultural heritage scenarios within existing or underway virtual reality (VR) tools, as well as for the development of e-learning processes within the Union Civil Protection Knowledge Network (UCPKN).

PROCULTHER-NET – "Protecting Cultural Heritage from the Consequences of Disasters-Network" [1] project, co-funded under the framework of the European Union Civil Protection Mechanism (UCPM) by the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO), has the overall objective of ensuring a sustainable and comprehensive network-based exchange on issues that can increase the efficiency and effectiveness of civil protection and Disaster Risk Management (DRM) actions, as well as to inform decision-makers and advocate for the inclusion of Cultural Heritage (CH) in DRM processes.

Building on the positive results of the previous project, PROCULTHER-NET aims to:
1. Foster the establishment of a European thematic community, within the Union Civil Protection Knowledge Network, focused on the protection and preservation of Cultural Heritage at risk.
2. Increase UCPM interoperability standards and promote the use of a common working method/language by reinforcing the transfer of know-how and learning processes for the inclusion of Cultural Heritage protection in DRM processes within the Union Civil Protection Knowledge Network.

The thematic community fostered by PROCULTHER-NET offers the opportunity to capture a multi-disciplinary perspective about the possibilities enabled by the extended reality technologies applied to the cultural heritage protection. Indeed, thanks to the participation of different stakeholders, there is the chance to capture the point of views, needs, requirements and feedback of different key actors in the process, thus enabling a human-centred design of

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[1] PROCULTHER-NET project is an initiative co-funded by the Directorate-General for European Civil Protection and Humanitarian Aid Operations (DG ECHO) in the context of the Union Civil Protection Mechanism (UCPM). It is implemented under the coordination of the Italian Presidency of the Council of Ministers - Civil Protection Department (Italy) in collaboration with the International Centre for the Study of Preservation and Restoration of Cultural Property- ICCROM, the Ministry of Interior-Disaster and Emergency Management Authority - AFAD (Türkiye), the German Archaeological Institute - DAI (Germany), the Ministère de l'Intérieur - Direction Générale de la Sécurité Civile et de la Gestion des Crises-DGSCGC (France), the Fondazione Hallgarten-Franchetti Centro Studi Villa Montesca-FCSVM, the Ministry of Culture and Tourism of the Region Government of Castilla y León - JCyL (Spain), the Federal Agency for Technical Relief - THW (Germany), the Suor Orsola Benincasa University- UNISOB (Italy) and the University of Porto- UPORTO (Portugal). For more details also see: https://civil-protection-knowledge-network.europa.eu/projects/proculther-net

specific and effective technical systems in support of the shared purpose of disaster and risk management of cultural heritage.

This document is therefore aimed at providing elements for bridging the gap that currently exists in virtual capacity building processes where cultural heritage protection is not yet completely addressed.

For the elaboration of this study, the main elements have been provided by the survey launched by the PROCULTHER-NET project for the *Ex-Ante Feasibility Study on the Establishment of a Thematic Community* (Deliverable D.2.1) submitted to DG ECHO on 17 October 2022. References to the *Ex-Ante feasibility Study* are key to clarifying the context, as well as the needs and capacities available at the European level in the specific field of cultural heritage protection. In addition, an analysis of the existing studies and literature has helped clarify where we stand in terms of technological developments, but also how the protection of cultural heritage is addressed in the adoption of virtual tools. The Training Centre Network on 3D and VR- TRACENET project[2] is the main source to get a clear picture of the state of the art in the use of virtual reality tools within the UCPM framework.

Furthermore, findings that emerged from this document have been reviewed and approved by the PROCULTHER-NET partners, starting from the *Key Elements of a European Methodology to Address the Protection of Cultural Heritage during Emergencies*, the document built on the lessons learnt and best practices capitalised by the members of the PROCULTHER[3] consortium to provide for a set of elements for the inclusion of the protection of cultural heritage at risk of disaster in all disaster risk management processes.

2. Why should cultural heritage be included in virtual tools?

Cultural heritage protection is a key sector of disaster risk management. However, although many virtual and in-presence learning initiatives on cultural heritage protection do exist, only a few include this sector as part of the disaster risk management learning process.

Regardless of the type of presence required (physical or online), cultural heritage protection is still perceived as a non-traditional civil protection sector and many efforts are being made to strengthen the link between civil protection and cultural heritage authorities/stakeholders for the effective inclusion of CH in this field. Due to the interdisciplinary and operational gap between these two worlds, CH and DRM actors involved in emergency activities tend to act separately because of language barriers and/or different working methods. In light of the devastating and increasing impact of natural and man-made hazards on vulnerable communities, this is no longer acceptable. Lack of capacity in this field entails not only the risk of serious loss, but also of damage to the identity, dignity, recovery and development of affected communities, and an impact on humanity as a whole cannot be excluded.

This is particularly significant if we consider that, among the many competence areas addressed by the UCPM, the need to protect cultural heritage at risk is increasingly rising, as

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[2] For more details see: https://civil-protection-knowledge-network.europa.eu/projects/tracenet

[3] The Protecting Cultural Heritage from the Consequences of Disasters-PROCULTHER project was implemented by a consortium led by the DPC, and participated by ICCROM, AFAD, DGSCGC, FCSVM, JCyL. For more details see www.proculther.eu

the interconnection of this sector to the resilience of communities at risk is now widely acknowledged.[4] At the same time, new emerging risks have called for specific interventions to protect cultural heritage, demonstrating the importance of increasing interoperability standards and preparedness capacities to include cultural heritage protection in UCPM operational structures, also in crisis/conflict contexts. Improving knowledge in this field is therefore also motivated by the fact that the UCPM is consistently called upon to support countries struggling to cope not only with the growing impact of climate-related hazards, but also with epidemiological and anthropogenic hazards, such as those caused by the devastating effects of the war in Ukraine.

In addition, personnel such as technicians and experts, who combine specific professional skills and competencies with experience in disaster risk management – as provided by training– are often unavailable when disasters strike. Institutions themselves may not be equipped with adequate response capacities in terms of cultural heritage or risk management experts or trainers (PROCULTHER, 2021). This has also been highlighted by the *Ex-ante Feasibility Study*, elaborated by the PROCULTHER-NET project based on a survey circulated among a wide group of stakeholders and public authorities (including contact points of the Member States and Participating States within the UCPM, as well as other relevant actors active in the field of Cultural Heritage) involved in the project.[5] As shown by the graph below, only a third of the covered countries have set up training initiatives to improve the protection of cultural heritage at risk of disaster.
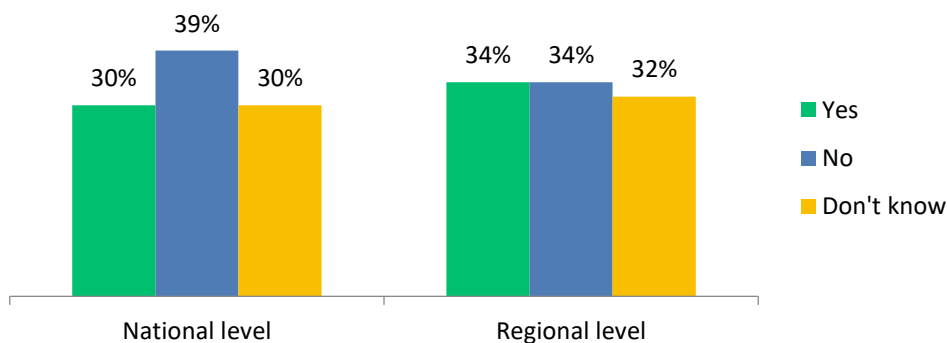
N= 47 Q 48[6]: **Does your country or region have training initiatives in place to improve the protection of Cultural Heritage at risk of disaster?**
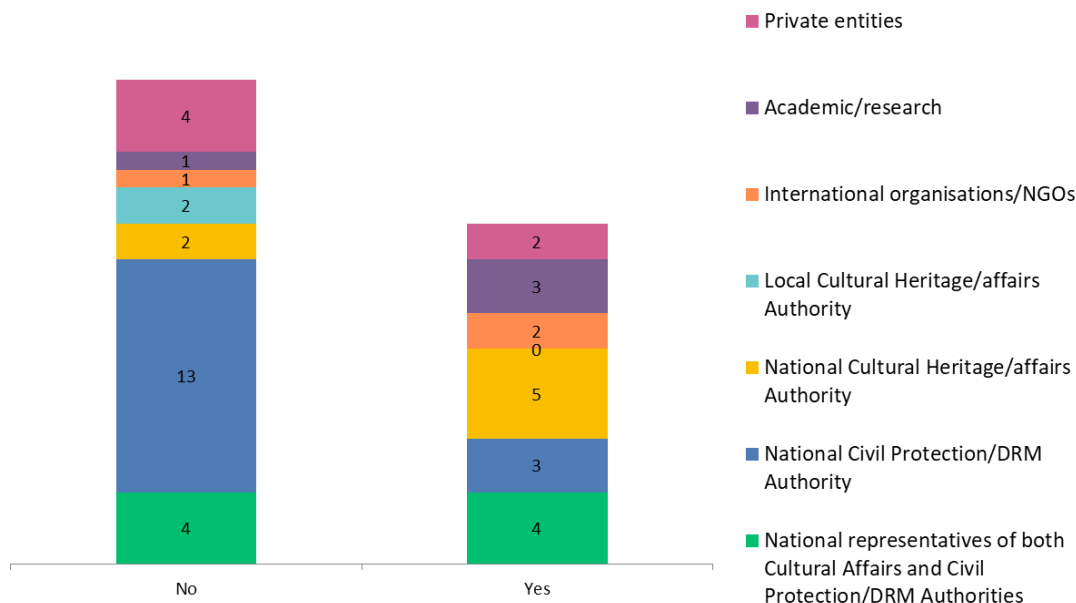*Source: PROCULTHER-NET Questionnaire for Ex-Ante Feasibility Study*

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[4] As specified in the "*Concept on Cultural heritage in conflicts and crises*", released by the Council of the European Union "*Cultural heritage is an important element in the lives and identities of communities and people, a powerful component for the building of resilience that can serve as a basis for sustainable recovery and lasting peace.*" For more details see: https://data.consilium.europa.eu/doc/document/ST-9962-2021-INIT/en/pdf

[5] The survey gathered responses from 28 different Countries: 8 countries contributed to the survey as National representatives of both Cultural Affairs and Civil Protection/DRM Agencies (namely: Bosnia and Herzegovina, France, Germany, Italy, Portugal, Republic of Croatia, Spain and Sweden); 5 Countries participated with a separate contribute from both National Civil Protection/DRM agencies and National Cultural Heritage/affairs Agencies (Finland, Latvia, Luxembourg, Romania, Türkiye); 11 Countries only contributed as National Civil Protection/DRM Agencies (Bulgaria, Cyprus, Czech Republic, Ireland, Kosovo, Malta, Poland, Slovakia, Slovenia, Switzerland, the Netherlands); 3 Countries contributing only as National Cultural Heritage/affairs Agencies (Belgium, Greece, Chile and Mexico).

[6] Graphs from the *Ex-Ante Feasibility Study* bear a label showing the number of respondents who answered the question (N) and the question number corresponding to the one assigned in the questionnaire (Q).

Among the interviewed participants, 60% have not attended any specific training sessions on the safeguarding of cultural heritage in emergencies. The graph below provides the data about attendance by type of respondent category.


N= 46 Q 50: **Have you attended training sessions specifically dedicated to the safeguard of Cultural Heritage in emergencies, which may have also included the Exercise phase?**
Source: PROCULTHER-NET Questionnaire for Ex-Ante Feasibility Study

The number of public institutions stating they never participated in training and exercises dedicated to CH protection is surprisingly high.

At the same time, although the majority of interviewees had no previous training experience in cultural heritage protection, the examples provided by the participants are related to training activities held by projects such as PROMEDHE and PROCULTHER, ICCROM-Disaster Risk Management of Cultural Heritage, simulations of structural stabilization and evacuation of cultural property, workshops on "Managing Disaster Risk in UNESCO Designated Sites".

Moreover, the participation of the surveyed Countries and institutions in Exercises related to cultural heritage protection was also quite low, with only 41% of positive answers.
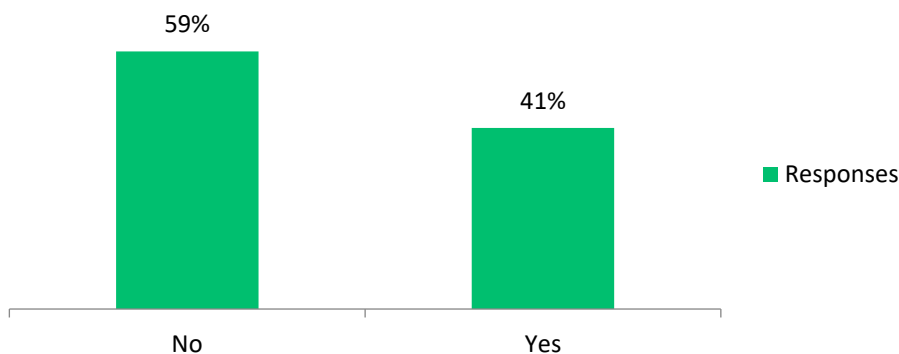
N= 46 Q 52: **Has your country/institution participated/organized exercises related to the protection of Cultural Heritage at risk of disaster?**
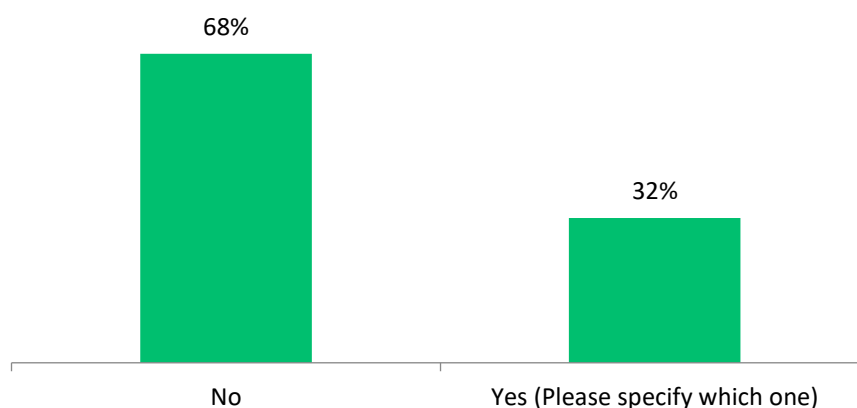*Source: PROCULTHER-NET Questionnaire for Ex-Ante Feasibility Study*

The examples of Exercises provided are: simulations of stabilization of structures and evacuation of cultural property, annual exercises, exercises organized by military emergency unit/civil protection in which a specific scenario focused on cultural heritage safeguarding, exercises in museums, castles or cathedrals with different actors.

Therefore, the results of this survey show that the learning processes in this field are not organized on a consistent and sustained basis, and that capacities, poorly systematized, are not regularly tested. This could lead to poor coordination and ineffectiveness of aid, but also to contrasts during emergency or risk management operations.

The urgency of building further capacities is also evident in the number of countries (70% of UCPM MS/PS)[7] that have agreed to enrol their DRM and CH experts in the training activity proposed by the PROCULTHER-NET project in March 2023. In particular, the results of this initiative stressed the fact that comprehensive disaster risk management is inconceivable without an appropriate focus on the protection of tangible and intangible cultural heritage.

In this panorama, although virtual technologies, computer game technologies, virtual simulation-based training tools and applications that provide new learning environments have multiplied in recent years, the inclusion of cultural heritage has occurred in only a few limited cases.
In this regard, as shown in the graph below, the availability of online training resources and e-learning tools in this domain is currently low in the Countries covered by the survey of the *Ex-Ante Feasibility Study* developed by PROCULTHER-NET.

N= 47 Q 48: **Are there e-learning tools available in your country for training in Cultural Heritage protection?**
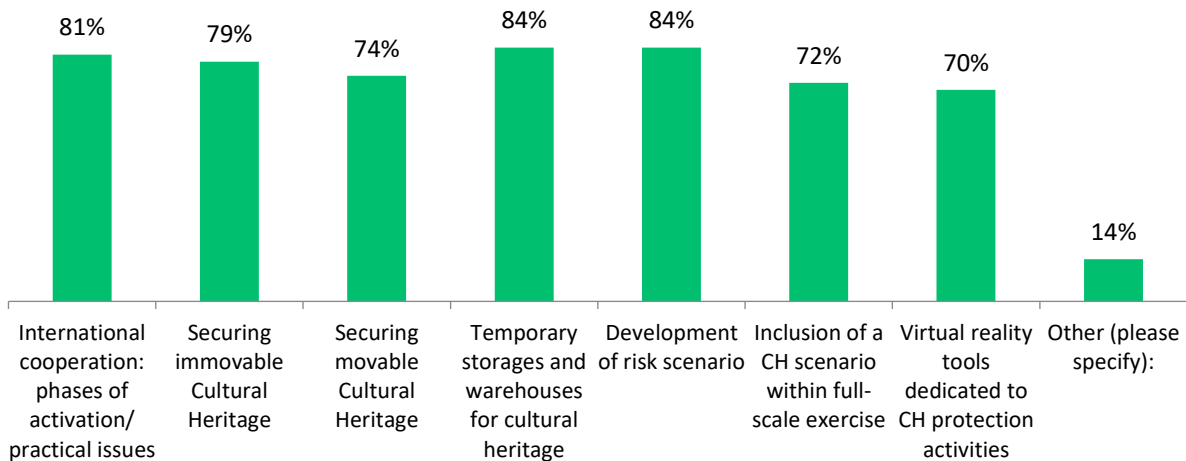*Source: PROCULTHER-NET Questionnaire for Ex-Ante Feasibility Study*

When asked to specify which e-learning tools were available, responders mostly referred to online manuals or virtual training activities, such as "*Manual on Heritage in risk*", "*Toolkit First Aid to Cultural Heritage in Times of Crises*", "*Endangered heritage: emergency evacuation of*

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[7] Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Malta, Netherlands, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden and Türkiye.

heritage collections". Some specific experiences are also mentioned such as the *E-patrimoine* platform[8], managed by the Loire Valley, which since 2011 offers online courses (MOOCs) in the fields of conservation and restoration of tangible and intangible heritage.

Therefore, as shown by the *Ex-ante Feasibility Study* in the graph below, there is a strong interest, quantified at 70%, in improving virtual reality tools dedicated to the protection of cultural heritage.

N= 43 Q 49: **Which area(s) of the Training and Exercise program could be improved? (Multiple choice question)**
Source: PROCULTHER-NET Questionnaire for Ex-Ante Feasibility Study

This shows that it is strongly recommended to ensure adequate training and exercise programs focused on this sector, benefitting from the knowledge-sharing potential of the UCPKN, not only in terms of curricula and scenario-based training, but also in terms of technological improvement, while ensuring consistency with the technical and operational procedures required by the UCPM. In simple terms, this can be translated into the opportunity for the UCPM and its Participating States:
- to add, under the UCPKN umbrella, training and exercises dedicated to the protection of cultural heritage
- to promote the use of virtual reality tools specifically dedicated to this topic
- to include cultural heritage protection in other specific or more general training and exercise activities.

To better clarify how to make the best use of virtual reality tools, it is necessary to know what already exists or is in the pipeline in this field, so as to base technical and conceptual requirements on existing good practices.

However, as discussed in the next chapter, it is not yet clear how technological developments are supporting the world of civil protection and, at the same time, the

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[8] For more details see: https://loirevalley-worldheritage.org/News/Articles/All/The-e-patrimoine.org-platform-is-offering-a-MOOC-on-gardens

technological potential already in use in the world of culture has not yet been fully exploited for emergency management.

3. Virtual tools: what's in store?

The importance of developing virtual tools in the cultural heritage sector is so relevant that the European Commission Directorate General for Communications Networks, Content & Technology has conducted extensive policy coordination and funding actions to supplement Member States' cultural policies. In particular, to fuel the policy debate and bring stakeholders together to improve the framework conditions for the digitalization process and digital preservation, the European Commission has published the "*Recommendation on a common European data space for cultural heritage*".[9] Since 2021, the European Commission's Expert Group on a common European Data Space for Cultural Heritage (CEDCHE)[10] monitors progress toward the implementation of the Commission's Recommendation. The CEDCHE reviews and discusses policies for digital cultural heritage and the upcoming initiative for a common European data space. It also facilitates the exchange of information and good practices, working closely with cultural institutions. Specific funding is also dedicated to the development of these technologies.[11]

Needs connected to the development of virtual tools and virtual simulation-based training tools and applications that provide new learning environments has increased in recent years, not least because of the limitations experienced during the COVID 2019 pandemic. Indeed, during the pandemic, all on-site training came to a halt to avoid the gathering of people and prevent the spread of the virus.

VR technology is an effective cognitive tool and a crucial medium for interacting with virtual history and heritage material in a virtual world. Its use is generally intended for preservation, documentation, research studies, teaching, reconstruction, and exploration but also to allow virtual visits for educational purposes. In the field of cultural heritage, VR technology has mostly been used to exchange and display information. Augmented Reality (AR) is also a useful feature since it may provide not just visual, but also olfactory, tactile, and, in the future, taste stimuli. At the same time, and because many CH places are under threat of destruction, the use of VR recreations has become critical in preserving public memory. One major source of worry for preservationists is the devastation caused by conflict in nations such as Ukraine, Iraq, and Syria.

In particular, the application of VR technology in the field of cultural heritage risk management has several advantages. For starters, it allows people to connect, share vital information, as well as plan *ad hoc* stabilization and restoration works, while limiting losses

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[9] For more details: https://digital-strategy.ec.europa.eu/en/news/commission-proposes-common-european-data-space-cultural-heritage

[10] This has been set up by the COMMISSION *DECISION C(2021) 4647 of 29.6.2021 setting up the Commission Expert Group on the common European Data Space for Cultural Heritage and repealing Decision C(2017) 1444* for more details see: https://ec.europa.eu/transparency/expert-groups-register/core/api/front/expertGroupAddtitionalInfo/42330/download

[11] For more details see: https://digital-strategy.ec.europa.eu/en/policies/cultural-heritage

and risks for operators. Second, it allows numerous experts to collaborate in a virtual setting. Third, it helps preserving the public memory of intangible heritage – such as practices and rituals – and of cultural objects and assets that could be involuntarily or voluntarily damaged or even destroyed during natural and man-made events.

Some of the available experiences offer a perspective on how the protection of cultural heritage must be understood in a broader sense, both in terms of material and physical protection of the asset (tangible assets) and in the sense of preservation of the memory of the asset (intangible cultural heritage).[12] In 2019, the United Nations Educational, Scientific and Cultural Organization (UNESCO) partnered with Google Arts & Culture to create a VR experience of the ancient city of Palmyra, Syria. The experience was created using 360-degree photos and videos taken before the city was destroyed by ISIS. The experience allows users to explore the city in a way that would not be possible in the real world. ICCROM is using VR to create digital records of cultural heritage sites that are located in conflict zones. ICCROM has partnered with a number of organizations to create VR records of cultural heritage sites in Syria, Iraq, and Yemen.

In terms of preservation and recovery purposes, another noteworthy example is provided by the CyArk project, which uses laser scanning technology and virtual reality to digitally document historical and cultural sites around the world. For example, VR technology was used to create a 3D model of the interior and exterior of the Notre-Dame de Paris cathedral, after the fire in 2019. This digital reconstruction is a valuable resource for the ongoing restoration process.[13]

For documentation purposes, a remarkable experience worthy of mention is the Mosul Museum in Iraq. After its partial destruction by ISIS in 2015, experts used virtual reality to document the remaining artifacts and reconstruct a digital model of the museum. This digital archive serves as a basis for restoration and education.[14] Also, the National Museum of the Philippines is using VR to create virtual copies of cultural heritage artifacts that have been damaged or destroyed. The museum has created VR copies of several artifacts, including a 16th-century painting and a 10th-century bronze sculpture.

In some cases, the recovery of memory has also contributed to the inclusion of emergency-related features. As an example, in 2020, the Italian Ministry of Culture partnered with the University of Bologna to create a VR experience of the ancient city of Pompei, using 3D scans of the ruins. The experience allows users to walk through the city and explore it before the volcanic eruption, in a way that would not be possible in the real world. VR has also been used for planning preventive measures against risks, such as the implementation of evacuation and emergency plans for cultural heritage in case of volcanic eruptions.

In addition, research has recently begun to concentrate on producing assessments for estimating future scenarios of severe events such as heavy rains, storms, floods, extended droughts, and heat waves. Some experimentations and practices developed in the last years in

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[12] An interesting overview on best practices related to the digitalization of cultural heritage is provided by the SOS Heritage project. For more details see: https://www.sos-heritage.eu/wp-content/uploads/2023/05/D3.1-Handbook-of-good-practices-for-digitalisation-and-promotion-of-cultural-heritage.pdf
[13] For more details see: https://www.cyark.org/projects/
[14] For more details see: https://www.wmf.org/project/mosul-cultural-museum

the field of virtual reality applied to the protection of cultural heritage are noteworthy. The Italian National Fire and Rescue Service (CNVVF), for example, adopted a software application suite to reassess in quantitative terms the stability of structures subject to the stress of aftershocks, facilitating the rapid comparison of damages on two 3D point clouds of the same structure acquired at different times. By using this technology, it is possible for example to measure the increase of protrusion of wall portions, and length of cracks or to ignore the previous unaltered damages

Among the different virtual tools available and in response to the needs that emerged during the COVID-19 pandemic, a remarkable example is the trial launched in 2021 by ICCROM, the PREVENT – Mitigating Fire Risk for Heritage initiative, under the FAR programme in partnership with the Estonian National Heritage Board, Estonian Rescue Board, Estonian Police and Border Guard Board, CNVVF and the Swedish National Heritage Board.[15] The workshop included presentations, interactive group activities, and an online simulation for planning fire risk mitigation. The course concluded with a virtual exercise simulating a fire in a virtual museum, created with the help of a 3D video.

In the field of e-learning platforms, there are also very few examples of significant capacity-building experiences connected with the management of cultural heritage in emergencies or at risk. ICCROM dedicates its official YouTube channel[16] and website[17] to a wide array of webinars, lecture series and group discussions focused on the protection of cultural heritage worldwide.

In addition, there is an e-learning platform, partially free of charge, sponsored by ALIPH[18] that has compiled a reference repository of e-learning resources available from the web. These include online courses (MOOCs), tutorials, webinars, lectures and more.

Among online experiences, the PROCULTHER initiative is also worth mentioning. In 2021, the PROCULTHER project proposed an advanced training program for disaster risk management and cultural heritage experts dealing with the protection of both tangible and intangible cultural heritage during an emergency. The course aimed at reinforcing knowledge, skills, and procedures for the creation of UCPM-driven modules dedicated to the protection of cultural heritage at the European level, as well as strengthening resilience capacities at the national level. In particular, the course addressed issues that can increase the capacity of the UCPM to support, upon request, countries overwhelmed by disasters that also affect the cultural heritage protection sector. Although the training was conducted in virtual mode due to the travel restrictions related to the COVID-19 health crisis, participant evaluations showed that the course was a valuable opportunity for lecturers and trainees alike, to increase their understanding of the topics proposed and to enhance networking among disaster risk managers and cultural heritage experts, confirming the opportunities and advantages offered

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[15] For more details see: https://www.iccrom.org/news/preventing-fires-save-lives-and-heritage
[16] https://www.youtube.com/user/ICCROM07/featured
[17] https://www.iccrom.org/resources/iccrom-lecture-series/past
[18] https://elearning.aliph-foundation.org/resource-topic/museum

by the e-learning tools.[19] As another example during COVID-19, the Smithsonian Cultural Rescue Initiative (SCRI), organized the Heritage Emergency and Response Training (HEART) in a virtual format to train emergency responders in how to respond to cultural heritage disasters. This is still available on SCRI's YouTube Channel.[20] Also the American Institute for Conservation provides a space for e-learning in particular in terms of "Organizing of a Salvage operation", "Drying Methods", "Salvage Methods Overview, Book and Paper Salvage, Photo and Electronic Media Salvage".[21]

Even the Fondazione Hallgarten-Franchetti Centro Studi Villa Montesca (FCSVM) has worked extensively over the years on the definition of learning tools capable of providing virtual and thus constant support to operators interested in capacity building in the field of civil protection. In particular, FCSVM has developed *the CP Model Civil Protection Massive Open Developed E-Learning*, taking into consideration both e-learning and virtual reality tools. It focused in particular on: 1) a Resilience Critical Map to analyze and verify the reasons that make it difficult to adopt strategies aimed at increasing the self-organization level of community response in case of natural and anthropogenic crises. 2) a MOOC (online courses) platform, addressed to experts and volunteers, which contains courses, guidelines and operational information to put into practice the learning of the procedures to be adopted. 3) an online game (the game of resilient cities) to help complete the learning offer, with the main objective of spreading the concept of resilience to a wider audience, not just specialists and professionals.[22] Another interesting practice was developed by the FCSVM in 2011 in the framework of the EU-funded project PATCH-Prevention Analysis and Tools for Cultural Heritage. A scenario in 3D has been created to allow DRM operators as fire-fighters, restorers, actors working in the CH protection to be trained and test their competences through virtual simulation.[23]

In terms of risk analysis, prevention, prioritization and preparedness there are also examples that facilitate the realization of Cultural Heritage Safeguarding Plans, with special attention to Museums, Archives, etc. An interesting example is provided by the Centre de Recherche et de Restauration des Musées de France- C2RMF that organized in 2023 a series of webinar on Gathering information, Prioritising collections, Recovery and treatment areas, Equipment, Human resources, Setting up an exercise. These are still accessible online.[24]

Another interesting tool guiding interested institutions to carry out all the necessary actions to design and draft plan is dPlan|ArtsReady.[25] Developed by the Northeast Document

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[19] For more details also see: https://www.proculther.eu/follow-up-and-outcomes-from-the-proculther-pilot-international-training-module-on-the-protection-of-tangible-and-intangible-cultural-heritage-during-emergency-november-2021/

[20] For more details see: https://www.youtube.com/playlist?list=PLQ59x86gKVvJYmh45nTKXH7_eBM8vIHC_

[21] For more details see: https://learning.culturalheritage.org/products/nhr-collections-emergency-response-training

[22] For more details see: https://www.montesca.eu/2.0/cpmodel/?lang=en

[23] For more details see: https://www.montesca.eu/2.0/patch-prevention-analysis-and-tools-for-cultural-heritage/?lang=it and https://www.youtube.com/watch?v=_SeQE_nMVyY

[24] For more details see: https://c2rmf.fr/webinaire-plan-de-sauvegarde-des-biens-culturels

[25] For more details see: https://www.dplan.org/about

Conservation Center (NEDCC) and the Massachusetts Board of Library Commissioners (MBLC), is an online "template" guiding planning for risk assessment and preparedness actions, as well as response and recovery in various type of disasters. Also the Historic England[26], the public body in charge of England's historic environment, Museum Development East Midlands (MDEM)[27], part of a national network of Museum Development providers across England, the Museum of London[28], provide e-learning tool for drafting emergency plan for museums.

There are also some relevant experiences in the field of remote sensing, such as the one proposed by the Endangered Archaeology in the Middle East and North Africa (EAMENA), an e-learning tool to teach how to identify and monitor threats to heritage sites and landscapes by using satellite imagery to find new sites, monitor site destruction, and organise heritage management across several countries.[29]

Apart from these interesting and very promising virtual experiences, few VR apps have addressed the use of these technologies to include virtual CH environments for scenario-based training activities. Some examples in which CH elements are addressed are the Belice project[30], reproducing the scenario of the Sicilian earthquake that occurred in Poggioreale in 1968, and the virtual EU module exercise (MODEX)[31] Passo del Tonale, simulating a devastating avalanche that occurred in Italy in 2017.

Concerning the use of virtual tools for scenario-based training/exercises for the organization of MODEX, some very interesting insights are provided by the EU-funded project TRACENET.[32] This project aims to develop a civil protection training center network to offer technologies and innovations for prevention, preparedness and response, to support policy and decision-making, to encourage scientific excellence and to disseminate and exchange state-of-the-art knowledge and expertise.

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[26] For more details see: https://historicengland.org.uk/advice/technical-advice/emergency-and-fire/response-plans/

[27] For more details see: https://mdem.org.uk/resources/emergency-plan-template/

[28] For more details see: https://www.museumoflondon.org.uk/Resources/e-learning/emergency-planning-tool/index.html

[29] For more details see: https://www.futurelearn.com/courses/endangered-archaeology-remote-sensing/2 and https://www.youtube.com/playlist?list=PLKHFxabu_5SFjiuZgHqnir1QiFCqijhzH

[30] For more details see: https://www.beliceproject.eu/download-area/

[31] Module Exercises foreseen by the UCPM to prepare modules/capacities/civil protection authorities and experts for international deployments to ensure a faster, coordinated and efficient response to emergencies and enhance the coordination during UCPM interventions by ensuring improved interoperability and cooperation between intervention teams, national authorities and other stakeholders.

[32] Some other examples of studies related to VR are: VR platform for training for CBRN first responders: Lamberti, F., De Lorenzis, F., Pratticò, F. G., & Migliorini, M. (2021, July). An immersive virtual reality platform for training CBRN operators. In 2021 IEEE 45th Annual Computers, Software, and Applications Conference (COMPSAC) (pp. 133-137). IEEE.https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9529711 ;VR platform for flood disasetr management: De Lorenzis, F., Pratticò, F. G., & Lamberti, F. (2022). HCP-VR: training first responders through a virtual reality application for hydrogeological risk management. In Proc. 6th International Conference on Human Computer Interaction Theory and Applications (HUCAPP 2022) (pp. 273-280). SCITEPRESS. https://www.scitepress.org/Papers/2022/110078/110078.pdf ; VR platform for training for fire first responders: Calandra, D., De Lorenzis, F., Cannavò, A., & Lamberti, F. (2023). Immersive virtual reality and passive haptic interfaces to improve procedural learning in a formal training course for first responders. Virtual Reality, 27(2), 985-1012. https://link.springer.com/article/10.1007/s10055-022-00704-9

In 2023, the TRACENET project launched a *Survey analysis and status-quo of ICT solutions for civil protection needs* to understand the status quo in AR-3D-VR and simulation environments for Civil Protection needs. A study related to *Best practices and guidelines* was produced to present best practices of other exercises, similar to EU MODEX [33], which use virtual or augmented reality in this field. According to this study, on June 29, 2023, only the organizers of a MODEX exercise dedicated to Forest fires replied to the survey.

In consideration of the still lack of systematized information, the study concluded that:

"there is still work to be done before defining a best practice of VR/AR in training and exercises in the context of civil protection. Both overarching and specific goals have to be more systematically described and matched against various ways of using VR/AR to be able to understand the achievable effect on and value from its implementation."[34]

In addition, both studies elaborated by TRACENET do not refer to technical and conceptual elements or to any new sector, such as the protection of cultural heritage, to be included. The only possible conclusion on the current use of VR and AR in this area is that this is *"still fragmented, very context-specific and often on an experimental or proof-of-concept level"*.[35]

However, looking at the opportunities that technology can offer in this field, a strong interest emerges from the information gathered by the TRACENET project, even if a framework for developing and/or proposing a certain type of approach is still lacking. For this reason, the next chapter will clarify what is desirable from a cultural heritage point of view and what advantages virtual reality tools could offer for the optimal inclusion of CH protection in virtual training and exercises.

4. Advantages of using virtual reality tools for the learning process

From the analysis of the state of the art and the gaps still existing in the knowledge of the sector, it is clear that such innovative technologies can offer simulation scenarios and countless opportunities to build expertise, share knowledge and establish remote but real contacts among participants, all the while reducing costs and the environmental impact of training activities and facilitating the widest access and attendance of single individuals and communities.

As is well known, the UCPKN currently offers within the UCPM only one course dedicated to the protection of cultural heritage at risk, through the PROCULTHER-NET project. Based on the *Key Elements of a European Methodology to Address the Protection of Cultural Heritage during*

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[33] For more details see: https://www.msb.se/en/training--exercises/ovningar/modex--modul-exercises-for-the-eu-civil-protection-mechanism/
[34] For more details see: D2.2-Best practices and guidelines, UCPM-2022-KN-General - Project Number 101101703, 2023
[35] Ibidem, p. 4

Emergencies, an *ad hoc* advanced training is proposed to feed knowledge on the protection of cultural heritage to European standards, as for the other sectors.[36]

However, as this is a newly developed sector of civil protection, it would be desirable for other courses to better explore and address the technical and operational specificities required for effective interventions in this field. To adequately address the challenges of knowledge building in this sector, harnessing the potential of technology could have a significant impact, not only by reducing the costs and efforts required to organize this type of training and exercises, but also by creating spaces accessible to dedicated groups of experts, according to their skills and knowledge gaps. The following paragraphs will further explain how the use of virtual tools can assist the development of knowledge building, both in terms of e-learning and scenario-based training.

4.1   E-LEARNING TOOLS

Considering the definition provided by the Cambridge dictionary, e-learning means the use of tools that enable "learning done by studying at home using computers and courses provided on the internet".
The development and use of these technologies can assist in:

- **Defining tailor-made knowledge transfer according to the profile of the expert**: the use of e-learning tools could facilitate the provision of training dedicated to general content, such as elements related to the UCPM missions or assessment and treatment of specific assets, as well as specific topics related to DRM and/or CH. This will not only improve capacities in reducing the risk of disaster, but will also facilitate the possibility of involving other countries that are still unaware of the importance of safeguarding CH.

- **Providing a learning base for more widespread awareness and dissemination:** the possibility of attending training courses only in person limits widespread access for cost reasons or in case of any kind of physical obstacle. Cost is therefore an obstacle to greater awareness in this field. The possibility of conducting these courses online will also reduce organizational and management costs and facilitate stakeholder involvement.

- **Reducing risk of disaster by facilitating the involvement of communities in capacity-building programs:** communities play a key role in the protection of cultural heritage. They are in fact not only the 'holders' of the heritage to be protected, but also the first ones who can offer a response for its protection. Therefore, their preparedness capacities should be strengthened and their role within DRM operations clarified. This will avoid most of the risks to which CH is exposed and also limit the risk of trafficking or erroneous destruction. E-learning tools could be used to define easily affordable informative sessions.

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[36] For more details also see: https://civil-protection-knowledge-network.europa.eu/news/european-training-protection-cultural-heritage-risk

- **Increasing the potential of the Union Civil Protection Knowledge Network for knowledge sharing:** the implementation of specific training running on the UCPKN platform will better promote the adoption of an interdisciplinary approach at the European level in this field, having the possibility to reach countries that are not yet completely involved in this learning dynamics.

- **Promoting public participation in the development of a cultural heritage governance:** the availability of e-learning tools could help to develop or support the adoption of solutions, as well as informative sessions, likely to reinforce the capacity building processes, even in countries not yet fully aware of the importance of working in this field (especially outside Europe). Providing this training free of charge or at low costs could indeed facilitate wider access to this type of knowledge and strengthen public awareness of the importance of creating governance for cultural heritage protection. This could therefore promote the role of a stronger institutional framework, as well as facilitate the development of appropriate planning processes that take into account the challenges of effective cultural heritage protection.

4.2 VIRTUAL REALITY TOOLS

Based on the definition used by TRACENET, virtual reality tools can be described as a *"computer-generated environment with scenes and objects that appear to be real, making the user feel they are immersed in their surroundings".*[37]
VR can be used to create immersive simulations of cultural heritage sites, which can be used for a variety of purposes, including:

- **VR for documentation:** VR can be used to create accurate and detailed documentation of cultural heritage sites and objects. This documentation can be used for a variety of purposes, such as disaster planning, restoration, and education. It can be used to create digital records of cultural heritage sites that can be used for documentation and preservation purposes. VR can also be used to create virtual copies of cultural heritage sites, 3D models of buildings, monuments, and artworks, that can be accessed and enjoyed by people around the world in a safe and immersive way, even if the original site is damaged or destroyed.

- **Virtual tools to teach and guide planning activities**: VR can facilitate the elaboration of safeguarding plans for cultural heritage through worksheets and questionnaires that guide the participant through the necessary steps. The safeguarding plans can also be

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[37] For more details see: D2.2-Best practices and guidelines, UCPM-2022-KN-General - Project Number 101101703, 2023, p.5

incorporated in 3D or in Building Information Modeling (BIM) projects, which allows working with plans, indicating priorities, evacuation routes, etc.

- **VR for restoration:** VR can be used to assist in the restoration of damaged cultural heritage objects. VR can be used to create virtual replicas of damaged objects that can be used to plan and execute restorations. For example, VR can be used to create 3D models of broken sculptures that can be used to plan their reconstruction. VR can also be used to create virtual environments to test restoration techniques.

- **VR for training and education:** Virtual reality technology is not only conducive to the overall protection and legacy of the cultural heritage (Wang Li, 2018), but it can also allow to maintain high learning standards, offering near-real environments for training while reducing the risk of impact and damage to the object of the practice. Virtual reality technology can offer a three-dimensional digital model for tangible cultural heritage which records real and accurate information on the texture, dimension or associated conservation issues, as well as their relationship to intangible cultural heritage. At the same time, having the possibility to simulate risks and also the behaviors and reactions of people in emergency contexts can also help to better cope with crowd management, particularly in very popular cultural heritage sites and buildings, where the interaction between rescue operation for people and for heritage is crucial in the emergency plans and rescue operations (Piacentini, 2012; Brondi, 2023). Indeed, having the possibility of simulating the real impact of hazard can help better understand the criticalities that may arise, also taking into account a multi-risk scenario, and provide solutions for monitoring and supporting the correct treatment of these assets. This could also sustain better knowledge on how to avoid or minimize the risks of cascading events that can result both from secondary natural or man-made events (e.g., trafficking or error in treatment/management).

    Furthermore, the use of VR can offer the possibility to better monitor and evaluate the actions to be tested during an exercise. Based on this increased capacity of monitoring operations, strategies and tactics can be analyzed and reshaped to ensure a better response; a better capacity to systematize the experience can also be put in place, collecting all useful data for the purpose of the exercise.

    Therefore, VR can be used to train emergency responders and cultural heritage professionals on how to protect cultural heritage in emergency.

In particular, VR can be used to train emergency responders in:

- risk and damage assessments on cultural sites and buildings
- the safe and effective handling of cultural heritage in emergencies
- shoring cultural buildings
- planning proper interventions
- planning and setting up temporary storage.

VR simulations can provide responders with realistic training scenarios that allow them to practice their skills in a safe environment. For example, VR simulations can be used to train responders in the use of equipment for the stabilization of damaged structures, the removal of hazardous materials, and the rescue of people from collapsed buildings; to train responders in the proper handling of cultural heritage objects, such as artworks and manuscripts; to plan evacuations, and assess damage. For instance, firefighters could simulate the evacuation of people and the use of fire extinguishers without any risk to the operators, and, in the meantime, they could learn how to act to avoid any damage to cultural objects and buildings. In the same way, cultural heritage operators could test the correct evacuation and intervention on cultural objects and surfaces in different disaster scenarios (flood, earthquake, fire...). Noteworthily, CNVVF has been exploring the adoption of specific VR training modules for rescuers based on actual CH 3D models, as a compensating measure for those difficult-to-reach CH, whereas the impact of common fire safety measures would not be acceptable.

At the same time, the availability of a cultural heritage scenario can be an opportunity for more people to practice disaster risk management operations, putting into practice and fine-tuning standard operating procedures, interoperability schemes, as well as techniques for intervening on cultural objects and buildings.
VR simulations can also be used to educate the public on cultural heritage and the importance of its preservation and protection. It can be used to create interactive exhibitions that allow people to explore cultural heritage sites and objects in a safe and immersive way, and to experience the construction of a historical building or the creation of a work of art.

- **VR in emergency:** VR technology could also be applied and exploited for the activities of acquisition, processing, study and preparation of interventions in case of events that could endanger the integrity of cultural property. In particular, in situations in which people's safety is at stake, in order to limit their exposure to danger, cultural heritage experts are not allowed to enter unsafe buildings; it is the emergency workers who intervene to bring the goods contained therein to safety. The possibility of using such a virtual representation system would be of great help in immediately understanding what the state of the places or goods of cultural interest was, their original location, etc., so that rapid and targeted action can be taken, even if the affected building is not known.

- **Increasing public awareness of cultural heritage:** The creation of immersive experiences can help people connect with cultural heritage in a new way. This can lead to increased public awareness and support for cultural heritage protection and, consequently, enhance the security of cultural heritage by increasing the active involvement of the community in the protection of their cultural heritage.

- **Facilitating discussion and contributing towards the development of a common prevention and protection culture:** the possibility to monitor and evaluate operations can support the capitalization on best practices and create a basis for improving standards operating procedures, approaches, etc. This will increase the teams' ability and effectiveness in responding to disasters.

- **Assisting the learning experience of intangible cultural heritage**: there is no systematic research and design specification on how to convey the intangible cultural heritage knowledge and value in experiential courses. This leads to the learners' emphasis on the experiential process and lack of knowledge of the content of intangible cultural heritage itself (Yi Ji, 2021).[38] Recent research demonstrated that the use of virtual reality to protect intangible culture makes people ignore the factors of time and space, and accurately understand the unique charm of traditional culture (Yanyan Du, 2022).[39] Therefore, virtual reality tools can also be adapted to better define actions related to this field, by providing adequate rooms to simulate the complexities of crowd actions particularly related to intangible issues, such as religious processions and pilgrimages.

- **Promoting Culture-based disaster risk management operations and cross-cultural understanding:** Cultural heritage protection implies not only a particular focus on the rescue of the assets but also on the way to deal with it, the material to be used, the rescue or recovery techniques to be applied. This is particularly evident in the process of intangible cultural heritage protection, where local knowledge should also be known and preserved in DRM phases. Access to virtual reality tools could also promote a wider knowledge of characteristics and cultural connotations that can be context-specific. This can also help people from different cultures to learn about each other's heritage and foster cross-cultural understanding.

- **Enhance the visitor experience.** VR can be used to create interactive exhibitions that can provide visitors with more immersive and engaging experiences. This can help to attract more visitors to cultural heritage sites and objects.

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[38] For more details: https://dl.acm.org/doi/10.1145/3490355.3490373
[39] For more details, see: https://doi.org/10.1155/2022/5146193

5. Conclusions

Although virtual reality has immense potential in safeguarding cultural heritage, challenges remain. These include funding constraints, technological barriers and the need for international cooperation in sharing resources and expertise. Such challenges include:

- **Cost.** Compared with other traditional tools, VR technology can be very expensive, which can limit its availability to smaller organizations and institutions.
- **Accuracy.** VR simulations must be accurate and up-to-date to be effective.
- **Training.** VR requires specialized training, dedicated to specific actions. It can't be used for all purposes. VR training can be used for the improvement of many technical aspects, mentioned above, but manual skills, for example, cannot be trained.
- **Lack of real interaction among actors:** the lack of interaction among all involved actors can be a barrier for some organizations. Interaction and comparison among all the involved stakeholders are essential to reach shared decisions. It can be difficult to recreate this kind of interaction in VR.
- **Maintenance:** maintenance of VR tools needs to be constant and continuous. It also needs to be undertaken by specialized operators, not easily reachable and always available.

- **Data interoperability:** collecting numerous CH 3D models most often means managing massive data. The organisations responsible for protecting CH are numerous too. It is then reasonable to leave that massive data where it is stored, while implementing common interoperability services to ensure seamless exchange of data between the many entitled actors and avoid to trap it in unreachable data silos.

However, as technology continues to advance, it is plausible to think that the application of virtual reality in the protection of cultural heritage will become increasingly effective.
VR has the potential to be a valuable tool for cultural heritage protection in emergencies. VR can be used for documentation, training, restoration, and education. As VR technology continues to develop, it is likely that these challenges will be addressed, and that VR will become an increasingly important tool for protecting our cultural heritage. By exploiting the power of virtual reality, we can better ensure the preservation of our shared cultural treasures for future generations, even in the face of emergencies and adversity.
It is therefore urgent to invest resources and efforts in the production of tools and solutions to improve interoperability among different actors ensuring a coordinated approach that also includes CH protection in different contexts facing those risks generally experienced by DRM operators.

Bibliography

Avveduto G., Tanca C., Lorenzini C., Tecchia F., Carrozzino M., Bergamasco M., Safety training using virtual reality: a comparative approach, 2016, last access 12/11/2023 [https://www.iris.sssup.it/handle/11382/518446]

Brondi R., Carrozzino M., Lorenzini C., Tecchia F. Using mixed reality and natural interaction in cultural heritage applications, 2016, last access 12/11/2023 [https://www.iris.sssup.it/handle/11382/513402?mode=complete]

Brondi, R., Avveduto G., Carrozzino M., Tecchia F., Bergamasco M., Immersive technologies and natural interaction to improve serious games engagement 2016, last access 12/11/2023 [https://www.iris.sssup.it/handle/11382/509764?mode=complete]

Calandra, D., De Lorenzis, F., Cannavò, A., & Lamberti, F. (2023). Immersive virtual reality and passive haptic interfaces to improve procedural learning in a formal training course for first responders. Virtual Reality, 27(2), 985-1012. . last access 18/11/2023 [https://link.springer.com/article/10.1007/s10055-022-00704-9]

Carrozzino M., Piacentini V., Tecchia F., Bergamasco M., Interactive Visualization of Crowds For The Rescue Of Cultural Heritage In Emergency Situations, 2012 last access 12/11/2023 [http://www.sciresit.it/article/view/9581]

De Lorenzis, F., Pratticò, F. G., & Lamberti, F. (2022). HCP-VR: training first responders through a virtual reality application for hydrogeological risk management. In Proc. 6th International Conference on Human Computer Interaction Theory and Applications (HUCAPP 2022) (pp. 273-280). SCITEPRESS. last access 18/11/2023 [https://www.scitepress.org/Papers/2022/110078/110078.pdf]

Duguleana M., Carrozzino M., Virtual humans in cultural heritage ICT applications: A review, 2018 last access 12/11/2023 [https://www.iris.sssup.it/handle/11382/522428]

European Commission, Shaping Europe's digital future, last access 12/11/2023 [https://digital-strategy.ec.europa.eu/en/news/commission-proposes-common-european-data-space-cultural-heritage]

Galdieri, R. Carrozzino M., Natural Interaction in Virtual Reality for Cultural Heritage, 2019 last access 12/11/2023 [https://www.iris.sssup.it/handle/11382/525854]

Lamberti, F., De Lorenzis, F., Pratticò, F. G., & Migliorini, M. (2021, July). An immersive virtual reality platform for training CBRN operators. In 2021 IEEE 45th Annual Computers, Software, and Applications Conference (COMPSAC) (pp. 133-137). IEEE. 2019 last access 12/11/2023 [https://ieeexplore.ieee.org/document/9529711]

Mastrolorenzo G., Petrone P., Pappalardo L., and Michael F. Sheridan, The Avellino 3780-yr-B.P. catastrophe as a worst-case scenario for a future eruption at Vesuvius, 2006, last access 12/11/2023 [https://www.pnas.org/doi/abs/10.1073/pnas.0508697103]

Marsella S., Post-seismic assessment of cultural heritage buildings: an experimental and real case of use of the LiDAR, PROCULTHER-NET Technical Bulletin, p. 47, 2023. last access 12/11/2023 [https://civil-protection-knowledge-network.europa.eu/system/files/2023-06/PROCULTHER_NET_TECHNICAL_BULLETTIN_N2.pdf]

Octavian M. Machidon a, Mihai Duguleana b, Marcello Carrozzino c, Virtual humans in cultural heritage ICT applications: A review, 2018 last access 12/11/2023 [https://www.sciencedirect.com/science/article/pii/S1296207417301796]

PROCULTHER Project. Title: Key Elements of a European Methodology to Address the Protection of Cultural Heritage during Emergencies, Città di Castello: LuoghInteriori, 2021. ISBN 978-88-6864-370-6. last access 12/11/2023 [https://www.proculther.eu/wp-content/uploads/2022/06/PROCULTHER-Methodology.pdf]

PROCULTHER-NET, *Ex-Ante Feasibility Study on the Establishment of a Thematic Community* (Deliverable D.2.1) submitted to DG ECHO on 17 October 2022

PROCULTHER-NET, Module for Training of Trainers and Ad Hoc Training (Deliverable D3.2), submitted to DG ECHO, submitted to DG ECHO on 27 September 2023

PROCULTHER-NET, Technical Bulletin, II issue, last access 12/11/2023 [https://civil-protection-knowledge-network.europa.eu/system/files/2023-06/PROCULTHER_NET_TECHNICAL_BULLETTIN_N2.pdf]

SOS Heritage, Handbook of good practices for digitalisation and promotion of cultural heritage, 2023. Last access date 18/11/2023 [https://www.sos-heritage.eu/wp-content/uploads/2023/05/D3.1-Handbook-of-good-practices-for-digitalisation-and-promotion-of-cultural-heritage.pdf]

TRACENET, D2.1-Survey analysis and status-quo of ICT solutions for civil protection needs, UCPM-2022-KN-General - Project Number 101101703, 2023

TRACENET, D2.2-Best practices and guidelines, UCPM-2022-KN-General - Project Number 101101703, 2023

Yanyan Du, Protection of Intangible Cultural Heritage Based on VR: Taking Xiuyan Jade Carving Craft as an Example, Mathematical Problems in Engineering, vol. 2022, Article ID 5146193, 8 pages, 2022. last access 12/11/2023 [https://doi.org/10.1155/2022/5146193]

Yi Ji, Shengyang Zhong, Bin Zhang, Sean M. Clark, Constructing Embodied Interaction of Intangible Cultural Heritage Course through Immersive Virtual Reality. CCHI 2021: 133-138 last access 12/11/2023 [https://doi.org/10.1145/3490355.3490373]

Wijkmark, C.H.; Metallinou, M.M.; Heldal, I. Remote Virtual Simulation for Incident Commanders—Cognitive Aspects. *Appl. Sci.* 2021, *11*, 6434. last access 12/11/2023 [https://doi.org/10.3390/app11146434]

Wijkmark, C., Heldal, I., Metallinou, MM. Can Remote Virtual Simulation Improve Practice-Based Training? Presence and Performance in Incident Commander Education. *Presence: Teleoperators and Virtual Environments* 2019; 28 127–152. last access 12/11/2023[https://doi.org/10.1162/pres_a_00346]

Webliography

American Institute for Conservation, https://learning.culturalheritage.org/products/nhr-collections-emergency-response-training , Last access date 18/11/2023

ALIPH, e-learning platform, https://elearning.aliph-foundation.org/resource-topic/museum, last access 22/10/2023

BELICE project, https://www.beliceproject.eu/download-area/, last access 22/10/2023

Centre de Recherche et de restauration de Musées de France (C2RMF), https://c2rmf.fr/webinaire-plan-de-sauvegarde-des-biens-culturels, Last access date 18/11/2023

CNVVF, 3D point cloud, https://pointclouds.vigilfuoco.it/welcome, last access 22/10/2023

COMMISSION DECISION C(2021) 4647 of 29.6.2021 setting up the Commission Expert Group on the common European Data Space for Cultural Heritage and repealing Decision C(2017) 1444. Last access date 09/11/2023 [https://ec.europa.eu/transparency/expert-groups-register/core/api/front/expertGroupAddtitionalInfo/42330/download]

Council of the European Union. 18/06/2021. *Concept on Cultural Heritage in Conflicts and Crises. A Component for Peace and Security in European Union's External Action.* Last access date 22/10/2023 [*https://data.consilium.europa.eu/doc/document/ST-9962-2021-INIT/en/pdf*].

CyArk project, https://www.cyark.org/projects/, last access 22/10/2023

dPlan, https://www.dplan.org/about Last access date 18/11/2023

EAMENA, https://www.futurelearn.com/courses/endangered-archaeology-remote-sensing/2 and https://www.youtube.com/playlist?list=PLKHFxabu_5SFjiuZgHqnir1QiFCqijhzH

MDEM, Emergency Plan template, https://mdem.org.uk/resources/emergency-plan-template/ Last access date 18/11/2023

Museum of London, Introduction to Emergency Planning, https://www.museumoflondon.org.uk/Resources/e-learning/emergency-planning-tool/index.html

E-PATRIMOINE PLATFORM, https://loirevalley-worldheritage.org/News/Articles/All/The-e-patrimoine.org-platform-is-offering-a-MOOC-on-gardens, last access 22/10/2023

FCSVM, CP MODEL CIVIL PROTECTION MASSIVE OPEN DEVELOPED E-LEARNING, https://www.montesca.eu/2.0/cpmodel/?lang=en, last access 22/10/2023

HEART, 2021 Virtual HEART week, Public Lecture Recording, https://www.youtube.com/playlist?list=PLQ59x86gKVvJYmh45nTKXH7_eBM8vIHC , last access date 18/11/2023

Historic England, https://historicengland.org.uk/advice/technical-advice/emergency-and-fire/response-plans/ , last access date 18/11/2023

ICCROM lectures, https://www.iccrom.org/resources/iccrom-lecture-series/past, last access 22/10/2023

ICCROM, Preventing Fires to Save Lives and Heritage, https://www.iccrom.org/news/preventing-fires-save-lives-and-heritage, last access 22/10/2023

ICCROM, YouTube, https://www.youtube.com/user/ICCROM07/featured, last access 22/10/2023

MODEX, definition, https://www.msb.se/en/training--exercises/ovningar/modex--modul-exercises-for-the-eu-civil-protection-mechanism/ last access 22/10/2023

Mosul Museum web site, https://www.wmf.org/project/mosul-cultural-museum, last access 22/10/2023

PROCULTHER website, https://www.proculther.eu/ last access 22/10/2023

PROCULTHER-NET website, https://civil-protection-knowledge-network.europa.eu/projects/proculther-net, last access 22/10/2023

TRACENET, website, https://civil-protection-knowledge-network.europa.eu/projects/tracenet, last access 22/10/2023