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The STORM experience (the importance of preparedness in natural disaster facing)

Silvia Boi, Maria Concetta Capua and Fabio Perossini

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S Boi[1], **MC Capua**[2], **F Perossini**[3]

[1] STORM Coordinator, Engineering Ingegneria Informatica SPA (silvia.boi@eng.it)
[2] Quick Damage Assessment expert, TUSCIA University (mariaconcetta.capua@gmail.com)
[3] STORM project innovation Manager; Director of Kpeople, UK (perossini@kpeople.com https://orcid.org/0000-0001-9028-3179)

Abstract. STORM project was the best opportunity to cope with the challenge of merging computer and communication technologies with human and cultural oriented practices in conservation and restoration. The result of this powerful synergy between these two approaches (technology and CH needs) in view of mitigating effects on cultural heritage, is expected to enormously increase the mitigation of the damages created by climate change disasters. The main question, coming from the experience gained, is how we can capitalize the acquired expertise in the future. This will probably be done using strategies which could rely on local financial support and the possibility to have advanced regulations provided by local authorities. Communication between different actors will play a major role in the future achievements: the project faced a big challenge in establishing good communication among different competences so to say that now, after a three year project, it should be great to start a new experience counting on the level of friendship and communication achieved during the STORM project. But communication is also the key element of emergency management. The recent event which affected the Notre Dame Cathedral (Paris, 15/04/2019), was a matter of discussion between STORM partners and during those discussion we concluded that probably the proper preparedness was not in place. Preparedness could have dramatically reduced the reaction time and the effectiveness of intervention after a disaster. As a final though we are convinced that new professions could grow from the project experience, starting from cultural heritage experts such as conservators, restorers, archaeologists, architects, art historian involving specific branches of engineering; that could create new job opportunities for all those people provided that they will receive the proper education and practice experience..

1.1. STORM at a glance

STORM aimed at defining, developing and assessing a technological integrated framework providing eco-innovative, cost-effective and collaborative methodologies to support all the involved stakeholders to better act in the prevention (to mitigate the effect of climate phenomena) and intervention (when a disaster occurs) phases.

(a) Pilots

The developed integrated solution has been tested through case studies in five different countries (Italy, Greece, UK, Portugal and Turkey), showing the type of risks that are most prevalent in each site and region, contributing to building a European risk map. For each site, the particular profile, materials, and risks (environmental and anthropogenic), have been identified in order to define the corresponding trial case, focusing only on cultural heritage sites, structures, and artefacts.

Non-invasive and non-destructive methods of surveying and diagnosis, were deployed in the STORM pilot sites. Specifically, three innovative methods, have proven their applicability, being successfully deployed in at least one site:

1. **Wireless Audio Sensor Network (WASN)** — deployed at the Baths of Diocletian, Mellor, and Tróia sites — have been successfully recognised and reported events of human presence (e.g., sound of mechanical and electrical tools, motorbikes, and people laughing).
2. **Fibre Bragg Grating (FBG)** — deployed at the Baths of Diocletian — allowed to assess strain of the lesion and plaster on the Hall I wall, as well as the SW Michelangelo's Cloister wall humidity.
3. **Induced fluorescence spectroscopy based on the spectral fluorescence signature (SFS) sensor** — deployed at the Tróia site — has demonstrated the capability of early detection of both chlorophyll- and non-chlorophyll-containing biofilms.

Moreover, the developed **cost-effectiveness analysis (CEA)** methodology was applied to use-cases chosen among some of the pilot sites, namely Roman Ruins of Tróia, Roman Baths of Diocletian, and Historical Centre of Rethymno to support decision making when planning heritage risk control measures, including Prevention and Preparedness actions. Some **new restoration and prevention techniques** have been put into practice in some of the pilot sites (e.g. Tróia and Baths of Diocletian). In this context, some **eco-friendly, natural and low-cost methodologies** have been identified and tested on three marble artefacts with a homogeneous attack of biodeteriogens, exposed in the garden of Michelangelo's Cloister at Bath of Diocletian, and proved to be efficient.
Regarding the potential improvement in government processes, based in the knowledge and data provided and through a legal adviser consultation, **seven prevention-focused concern recommendations for improvement of policies** were defined. The formulation of these recommendations is driven by international and European guidelines and good practices as well as intentionally open to allow a possible adaption to the national legal systems of the STORM partner countries and different communities. In addition, a risk- oriented approach for the implementation of procedures pertaining the preservation of heritage sites was proposed in 5 different areas and entitled as **STORM 5C WORDS**.

(b) Sensors

The development of the STORM ground-based sensors, namely **wireless acoustic sensor networks**, **accelerometers**, **crack meters**, **vibrational sensors**, **optics-based sensors, geophysical sensors** was finalised as well as the experimentation of the different damage assessment methods and techniques, namely **Radar Interferometry, Electrical Resistivity Tomography** (ERT), **Ground Penetrating Radar** (GPR), **Digital Photogrammetry** (with regular and multispectral images) and **Terrestrial Laser Scanning**, through field surveying activities at all STORM pilot sites (Mellor, United Kingdom; Diocletian Baths, Italy; Rethymno, Greece; Tróia, Portugal; Ephesus, Turkey).

(c) Services

STORM project counted also to some key services developed specifically for emergency management, **Implicit Social Media Crowdsensing, Implicit Mobile Crowdsensing, Explicit Social Media Crowdsensing** and **Explicit Mobile Crowdsensing** have been implemented and tested in the Baths of Diocletian (explicit) and Rethymno (implicit) pilot sites.
During the project a dedicated **risk assessment and management systems** have been reviewed for each pilot site. Using the existing risk management system as a base, and combining this with the knowledge obtained in field, **a comprehensive risk management strategy** and their corresponding measures have been proposed and the **risk treatment strategies** have been developed for each pilot site while considering their specific requirements. All these components were integrated in the **Quick Damage Assessment** service that is going to be addressed in the next section.
All the services have been improved according to the users' feedbacks and the overall graphic layout of the Dashboard was revised. A sophisticated user interface was provided in order to make the dashboard usable and simple for end-users.

(d) Frame of Reference

Another important asset implemented in STORM is the **Frame of Reference** encompassing documents on: (1) Constituent materials of the Cultural Heritage assets; (2) Classification of Hazards and Climate Change-related Events; (3) Heritage Disaster Risk Reduction phases, Conservation intervention processes & Relevant Actors; (4) Emergency Services & Actors; (5) a Glossary of Terms; and (6) the STORM Ontology.

1.2. How to improve the preparedness and provide effective Quick Damage Assessment

Although discussion around preparedness is running almost worldwide, a wide spread unpreparedness is still present when facing an emergency caused by exceptional climatic events although those events are increasingly frequent (structural collapses and unpredictable damage). Even the recent event that took place at the Notre Dame cathedral should suggest questions how a plan to face the emergency could have been more effective to speed up the process when fighting on the fire front.

In the project natural hazards both sudden and slow ones were addressed, with complete information to optimise the possible arrival routes to the emergency site, involving trained staff that already know what to do and what difficulties they will encounter were the strength*s* of the process put into practice during the experimental phases.

(e) The Quick Assessment process

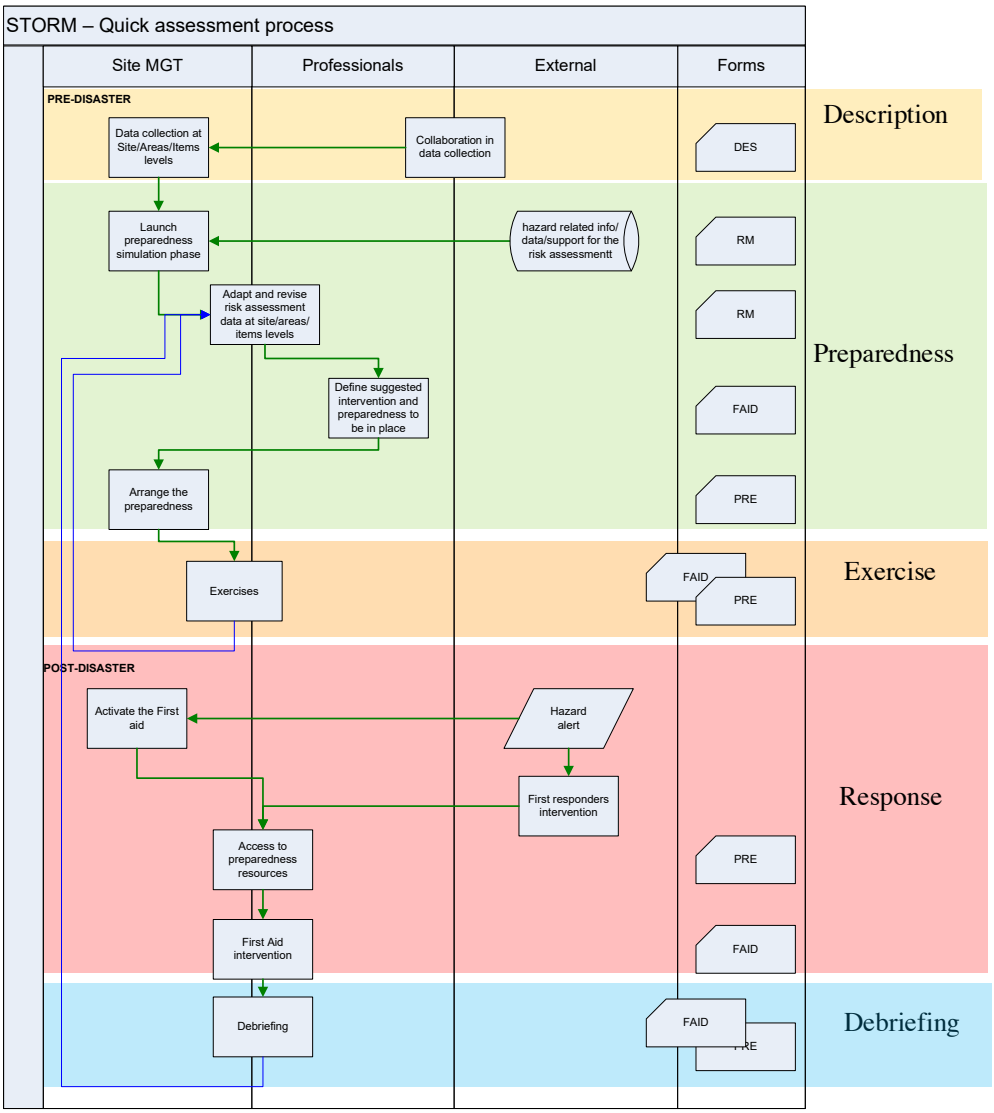
In a nutshell, if we can't prevent it, we can't be caught off guard, the Preparedness and First aid phase were the strength of what has been called: **Quick Assessment Process.**

The process definition started from requirements and methodologies defined starting from data collection forms identified by the Italian government after the L'Aquila earthquake in 2009 (MIBAC, 2013).

Quick Damage Assessment process components:

- **Description**: during this phase, all existing data related to the site/area/item are collected through the Dashboard through DES Service;
- **Preparedness**: starting with a hypothetical specific hazard to the site (determined based on the risk assessment), planned actions, complementary measures and requested are collected through the Dashboard through DES Service;
- **Exercise** (***Drill***): the occurrence of a hazard is simulated and planned emergency actions are tested. Based on the results of the drill, the information collected can be updated as well as the simulated actions are inserted in the platform;
- **Response (*First Aid*)**: in this phase, the interventions are performed following the actions planned (during Preparedness and Exercise) for the specific situation. All the operations performed are registered and stored in a *Diary;*
- **Debriefing**: after the emergency, a debriefing phase will assess the results of the emergency phase.

Summarising the process is based on the collection of the greatest possible amount of useful data to form the basis of the historical and material knowledge of the place and the artefacts it contains. A group of specialists analyses and dissects the presumed risks by examining the hypothetical emergency scenarios, with the help of an analysis tool, developed during the STORM research: **Storm Project Risk Management** they can determine the level of exposure of an area or of an items and the vulnerability associated with each relevant type of disaster, established the priority of intervention in case of emergency, the procedure is planned and materials and equipment are identified as the number of people in the team, the whole process is tested and simulated, it should be kept in mind that each emergency is unique, and it is useful to define several simple actions to be performed in each kind of emergency to minimize the damage for each cultural heritage structure or case.



The importance of capacity building and training for staff and other professionals is evident, so that they are aware of the latest practices as well as the prevention and monitoring tools available on the site also through periodic training directly in the field.

(f) The use of the STORM platform

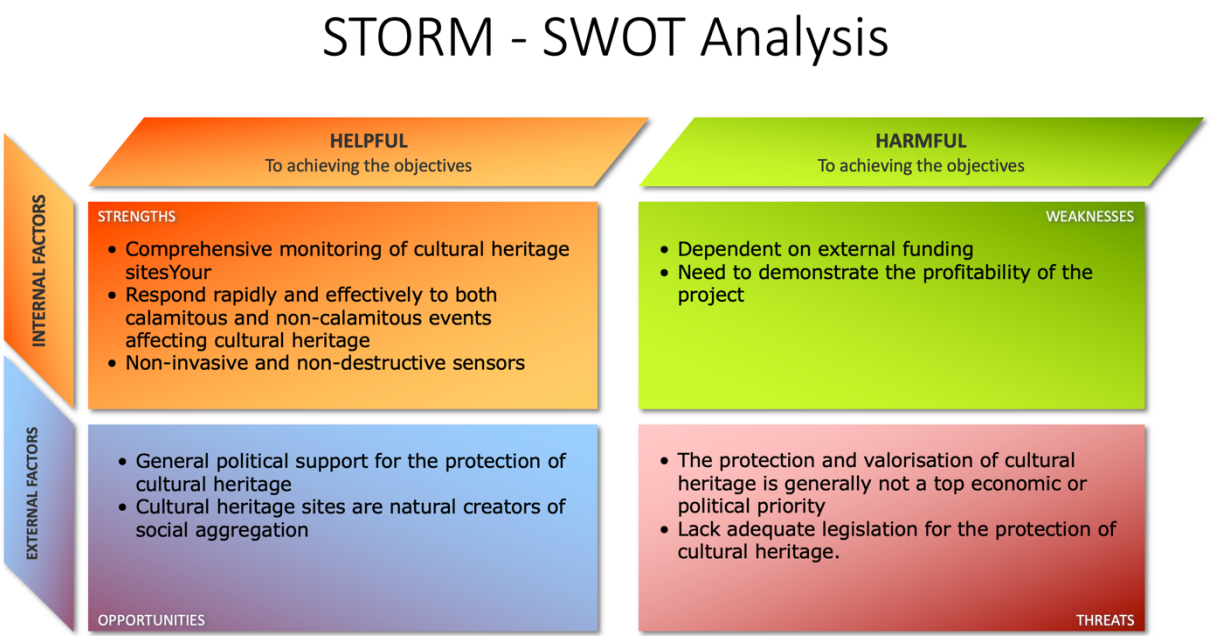
The experimented STORM platform allowed the availability and facilitates the communication of the data collected during the study and feeding phase of the database that takes place in peacetime. When the alarm is triggered, the platform sends a message to the group that accept the availability and activate the task; all data information is available on portable instruments that allow the emergency team on the field to have specific instructions and useful indications for intervention. By viewing the site plans, operators are facilitated in identifying possible routes, as well as the localization of the areas for the shelter of valuable materials or equipment. The recent conservation history and photographic images of the individual artefacts are also available and of great help in the recognition and collection of seriously damaged works.

1.3. The capitalisation of STORM achievements in view of a better preparedness against climate change

After a deep analysis of possible pathways to promote the future use of STORM project, also considering the strong dependence from political choices, three main tools have been identified: the first one, the SWOT analysis to better focus the project, the role of stakeholders and their motivation and the mission oriented innovation canvas as an overall map to drive future initiatives to improve preparedness and to provide emergency related added value services to climate change affected cultural patrimony.

(g) SWOT analysis

One of the key instrument to better understand the possibility to capitalise results achieved in the research is to apply the SWOT analysis to identify the better way to proceed: In this section, an introduction and explanation of the overall STORM outcomes SWOT analysis is reported.



(i) Strengths

Comprehensive monitoring of CH[1] sites: The use of cutting-hedge technological instruments and the greater human attention and sensibility for CH preservation, represent an ideal and innovative combination that foster an unprecedented comprehensive monitoring of cultural heritage sites.

Respond rapidly and effectively to both calamitous and non-calamitous events affecting CH: The collaboration and knowledge-sharing between experts and the public, combined with automated reasoning mechanisms, makes it possible to respond rapidly and effectively to both calamitous and non-calamitous events affecting cultural heritage.

Non-invasive and non-destructive sensors: All the data sensing tools are non-invasive and non-destructive. This enables the best possible preservation of cultural heritage.

(ii) Weaknesses

Dependence on external funding: The project is dependent on external funding because of the elevated cost of some of its valuable elements. Highly technological systems and sensors are expensive and need

[1] CH: Cultural Heritage

to be funded by public institutions and/or public private partnerships. Therefore, there is a need to demonstrate the profitability of the project.
Need to demonstrate the profitability of the project: The project relies on the participation of tourists and communities living nearby CH sites. These groups may have other priorities and interests or may have few time to dedicate to crowdsourcing.

(iii) Opportunities

General political support for the protection of CH: Nowadays, politics are becoming more and more interested and sensitive to the safeguarding and protection of Cultural Heritage. In all the involved countries, there is a general political support for the protection of cultural heritage. This support creates a favourable environment for the implementation of the project.
CH sites are natural creators of social aggregation: Cultural heritage sites are natural creators of social aggregation. This mechanism facilitates the crowdsourcing of fundamental information for the protection of cultural heritage, as well as quick responses to destructive events. The natural tendency of CH sites to create indirect revenue (hotels, restaurants…) could represent a stimulus for local communities in order to be involved and valorise as much as possible cultural heritage through an effective participation to STORM.

(iv) Threats

The protection and valorisation of CH is generally not a top economic or political priority: Cultural heritage protection and valorisation is not always one of the top economic or political priorities. This is mainly due to the current economic crisis.
Lack of adequate legislation for the protection of CH: Some states lack adequate legislation for the protection of cultural heritage. This might result in lack of funding and/or bureaucratic problems that could represent an obstacle for the STORM expansion.

(h) The role of stakeholders

From the very beginning was clear for all the actors that it was mandatory not only to identify potential stakeholders' categories but also to establish a common framework for communication in order to address not only the research but also its future exploitation.

Stakeholder	Area of Interest
I.1 - Cultural Heritage Authorities	Sustainability: They have a clear mission, some of them are public institutions, not to make business but to provide services to keep the cultural patrimony in a good shape (conservation), increase its fruition, protect it from hazards and intervene in case of disaster. In our framework, they are considered "users" and "buyers".
I.2 - Site Owners	
I.3 - Civil protection	
I.4 - Fire fighters	
B.1 - Large enterprises	Business: All organisation and single persons, interested in being part of the business generated by activities to address climate change threats for the cultural heritage, converge in this category.
B.2 - SMEs	
B.3 - Professionals	
R.1 - Research centres	Research: This group include all types of organisation having interest to go further ahead in the research started by the project or to use its content for training.
R.2 - Universities	

(i) Mission Oriented Innovation model

Inspired by the Osterwalder and Pigneur methodology[2], the mission oriented innovation can be considered a wider view of innovation model considering the STORM framework as a whole; here follow a description of its components:

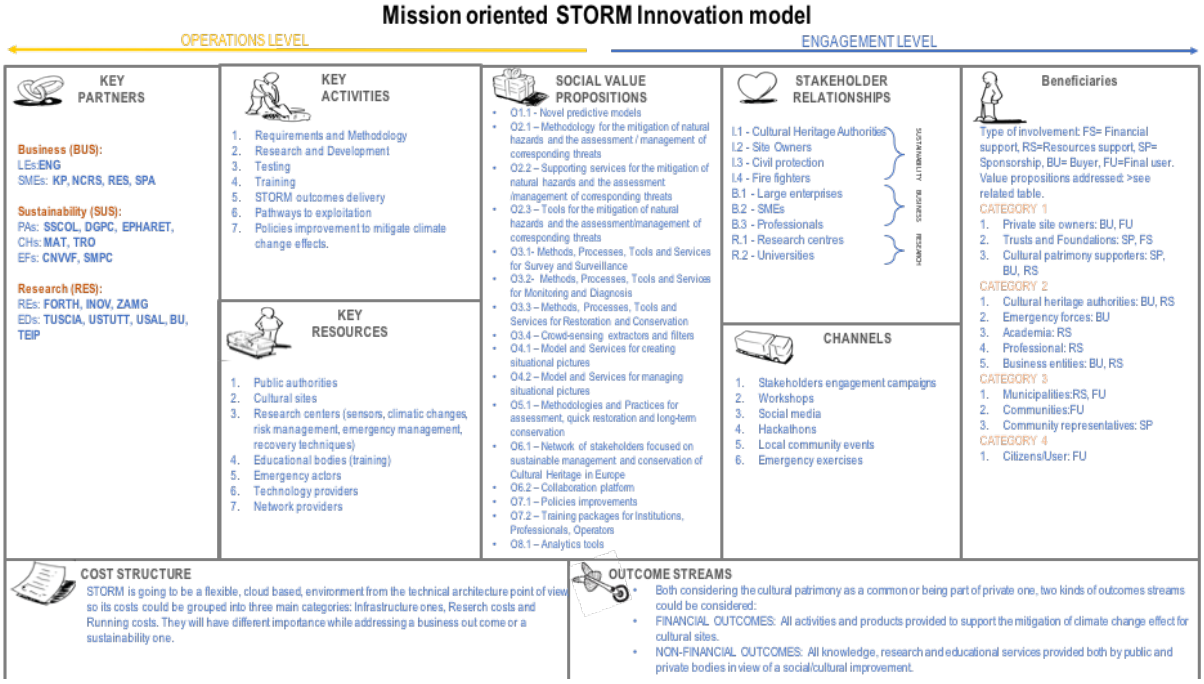
- Values (social, scientific and economic) Proposition: In this section, all exploitable results identified in section 3 of this document are reported, independently from the type of value (Sustainability, Research or Business), they are focused on.
- Stakeholders relationships: In the first part of the project 9 types of stakeholders have been identified as per section 2 of this document. Here following the relationship map explained in that section they are grouped according to the type of exploitation they are supporting in the project.
- Channels: STORM engagement strategy is based on the involvement of stakeholders in events that could be workshops, hackathons, involving the five pilot sites, Emergency exercises organised by emergency forces as well as the dissemination through social media of project's outcomes.
- Key Resources: The most exciting challenge in STORM project is the need to harmonise so different competences and related behaviours creating new iterative processes involving most of them with a common goal.
- Key activities: Requirements and Methodology, Research and Development, Testing, Training, STORM outcomes delivery and the definition of policies that could help the community in safeguarding cultural heritage affected by climate change.
- Key Partners: Starting from consortium partners the project considered in three main categories according to the STORM exploitation pathway the are expected to join
    - Business partners: ENG, RESIL, NCRS, SPA, KP.
    - Sustainability partners: MAT, TROIA, SSCOL, EFARET and BU for the part related to Ephesus pilot site, CNVVF, SMPC (for the part related to civil protection), DGPC,
    - Research, Academia: TEIP, TUSCIA, USTUTT, USAL, ZAMG, BU, INOV, FORTH[3]
- Beneficiaries: Four categories of beneficiaries, based on the type of benefit they could gain, have been identified: Cat 1: Cultural site owner and/or supporter; Cat 2: active actors in the STORM process; Cat 3: Institutional users/sponsors; Cat 4: Citizens/users.
- Cost structure: The future cost structure to keep STORM growing and alive could be summarised into three main categories of costs:
    - Maintain the infrastructure: the core infrastructure on which STORM environment is built should be kept up and working while services will be enlarged and improved themselves. That means a cloud based and flexible approach is welcome in order to guarantee the flexibility in terms of costs over the technical one.
    - Support further research: STORM is providing outcomes as results of a research project. Those results will need pre-commercialisation activities and in the same time further research should keep the environment open to future challenges. Research should also address social aspect related to cultural heritage values and the opinion of citizens.

[2] Osterwalder, A., & Pigneur, Y. (2010). Business model generation: a handbook for visionaries, game changers, and challengers. John Wiley & Sons.

[3] Engineering – Ingegneria Informatica S.p.A.:ENG, INOV Inesc Inovação - Instituto de Novas Tecnologias:INOV, Foundation for Research and Technology, Hellas:FORTH, Technological Educational Institute of Piraeus:TEIP, Resiltech:RESIL, Soprintendenza Speciale Per il Colosseo il Museo Nazionale Romano e l'area Archeologica di Roma:SSCOL, Università della TUSCIA:TUSCIA, Kpeople ltd, :KP, University of Stuttgart:USTUTT, Ministero dell'Interno - Corpo Nazionale Vigili del Fuoco :CNVVF, Mellor Heritage Trust's:MAT, Sparta technologies:SPA, Salford University (Archaeology, Climatology):USAL, Nova Conservação:NCRS, Troiaresort – Investimentos Turísticos, S.A.:TRO, Portuguese General Direction of Cultural Heritage :DGPC, Município de Grândola – Serviço Municipal de Proteção Civil:SMPC, Zentralanstalt für Meteorologie und Geodynamik:ZAMG, Ephorate of Antiquities of Rethymno, Hellenic Ministry of Culture and Sports:EFARETH, Bogazici University:BU

- Running costs: All services developed in STORM will have running costs. For those where the decision is going toward a public domain access costs should be covered by public or private funds dedicated to the specific activity. For services provided under a business mechanism all running costs should be part of the business model of the entity who will deliver those services. Due to the fact STORM is a very multidisciplinary environment, running costs could be spread between several actors.

- Outcome streams: addressing a patrimony that in most countries is owned by the communities and or by philanthropic organisations and considering the proposed approach would like to trace not only revenues stream but in general outcomes stream. Two categories of outcomes have been identified:
  a) FINANCIAL OUTCOMES: for business actors, revenues are coming from having STORM outcomes (business ones), on the market following the time to market described in the following part of the document.
  b) NON-FINANCIAL OUTCOMES: for non-business oriented partners, STORM outcomes (sustainability and research ones), are expected to dramatically improve from one side the mitigation of effect generated by the climate change and from the other side to provide food for thought in the research arena. Both those outcomes should have a tangible social impact.



1.4. Conclusion

STORM has been an impressive opportunity to experience the powerful synergy between technology and CH needs in view of mitigating effects on cultural heritage, increasing the mitigation of the damages created by climate change disasters.

Last but not least, STORM has increased the awareness on how digital innovation can bring a strong support to the safeguard of our cultural heritage and identity.

The experience done in the STORM project shown how it is important to have the right perception of risks in order to apply best actions[4].

[4] Li, X., & Liu, T. (2019). Community participation effects on preparedness behaviour through risk perception: Empirical data of hazardous chemicals from China. International Journal of Disaster Risk Reduction, 101421.