The DALIH database for recording disaster damage and loss data in cultural heritage

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Abstract. The Sendai Framework for Disaster Risk Reduction (SFDRR) upholds the development and implementation of measures to reduce hazard exposure and vulnerability to disasters. Among other aspects, the SFDRR recognizes the importance of cultural heritage for society, thus emphasizing the need to assess the impact that potential hazards may have on the built cultural heritage. Developing adequate risk assessment and management processes are fundamental towards this end and disaster damage and loss data are known to be essential for such processes. The development of systems, models and methods to collect and handle such data is, thus, seen as a worldwide priority. In this context, the paper presents a database framework for the worldwide collection of immovable cultural heritage disaster loss data currently under development. The concepts and technical aspects related to the data being collected and its structure are discussed, as well as the type of indicators being recorded. Challenges regarding disaster loss data collection for cultural heritage are discussed, as well as the benefits of these data for developing more rational disaster risk management approaches for cultural heritage.

Keywords: Cultural heritage, disaster damage, disaster loss data, database.

1 Introduction

Existing international frameworks and programs for disaster risk reduction (DRR) emphasize the need to develop and implement measures to reduce hazard exposure and vulnerability to disasters. Among other aspects, current DRR initiatives such as the Sendai Framework for Disaster Risk Reduction (SFDRR) [1] recognize the importance of cultural heritage and its irreplaceable value for society. Therefore, such initiatives clearly highlight the need to assess the impact that potential hazards may have on the built cultural heritage. Developing adequate risk assessment and management processes are fundamental towards this end and it is known that systematically collected and robust disaster damage and loss data are essential for such processes. The development of systems, models and methodologies to collect and handle such data should, therefore, be a worldwide priority.

Existing disaster loss data recording initiatives such as the EM-DAT/CRED, SIGMA/SwissRe, NATCAT/MünichRe or DesInventar/UNDRR databases are undoubtedly important sources of information in terms of the damage and losses that occurred in worldwide disasters. Recording such data is known to be useful for the purpose of loss accounting, forensic analysis of disasters and disaster risk modelling [2]. For example, this data can provide an objective baseline for risk assessment as well as for mitigation priority setting and decision making. However, the data recorded by these databases does not include damages and losses to cultural heritage. Therefore, without this important component, current loss estimation procedures are not able to provide a sound and comprehensive quantification of disaster impacts.

There is currently no systematic collection of data about the impacts of hazardous events on cultural heritage properties. Existing data on damages and losses to cultural heritage is scattered among various agencies (national and international) without any coherence and coordination. Furthermore, no standardized methods and tools have been developed for cultural heritage disaster data collection until now. Therefore, specific approaches and methods are required to address these issues. In this context, the proposed paper presents the online DALIH (Damage and Loss Inventory for Heritage - https://dalih.org/) database currently being developed for the worldwide collection of immovable cultural heritage disaster loss data. The concepts and technical aspects related to the data being collected and its structured organization are discussed herein, as well as the type and format of the indicators being recorded.

2 Why information about disaster impacts in cultural heritage is important?

As referred, detailed accounts of disaster impacts in cultural heritage assets are limited. Therefore, the positive effects of measures that are implemented for disaster risk reduction are difficult to determine when certain events reoccur. To illustrate this issue, reference is made to the impacts of the 2002 and 2013 European floods in Germany. After the event of 2002, flood risk management measures and policies were implemented and the 2013 flood provided an opportunity to analyse their effectiveness. According to [7], the improvements include a larger integration of flood hazard in spatial planning and urban development, an increase in mitigation and preparedness measures for individual properties, more effective flood warnings and disaster response coordination, and a more efficient maintenance of flood defense systems. With respect to cultural heritage, since limited information was shared about the assets that were affected by both floods, it is difficult to understand what measures were implemented, what was their effectiveness in 2013, and what issues remain to be addressed. Brief information about some of the impacts of the 2002 and 2013 floods to cultural heritage is available in [8], but it highlights that no detailed list of the damaged assets is available. The only piece of information allowing a comparison between the 2002 and the 2013 floods impacts to cultural heritage refers to the Garden Kingdom in Dessau-Wörlitz that was severely damaged in 2002 but was not affected in 2013 due to upgrades in the flood protection system.

Fires are also cases where the unavailability of detailed information on damage and losses to cultural heritage has a significant influence in our ability to reduce disaster risks and impacts. The significant media coverage of single events like the fires of the National Museum of Brazil (2018) or Notre Dame (2019) hides the fact that fires in heritage assets are unfortunately too common. For example, based on data available from a UK database that seems to have been discontinued [9] there were 164 fires recorded in heritage buildings between January and April 2019. Still, for many of these fires, the available information is insufficient for developing deeper analyses and studies that may provide adequate knowledge to propose fire risk mitigation measures. As an example, reference is made to the fact that many fires occur during maintenance or renovation activities in heritage buildings, but there is usually limited information about the real causes of those fires to adequately support the development of safety procedures that could be implemented when these activities are being carried out.

These two examples highlight the need to establish robust systems and methods for collecting disaster damage and loss data for cultural heritage. Currently, one critical aspect is that this lack of data is responsible for a biased view of the real effects of hazards on heritage assets, a situation that is further intensified in scenarios involving cascading hazards (when one hazard triggers another hazard) or coupled hazards (when one hazard changes the conditions for the occurrence of another hazard at a later time). Simultaneously, it leads to risk assessments that underestimate the potential consequences of futures events.

3 Overview of the DALIH database for cultural heritage

To address some of the referred issues, a database specifically devised for the collection of cultural heritage disaster loss data named DALIH (Damage and Loss Inventory for Heritage - https://dalih.org/) (Fig. 1) has recently started being developed within the project RIACT (Risk Indicators for the Analysis of Cultural heritage under Threat - http://riact.fe.up.pt/). The database aims to provide a standard for loss and damage recording in immovable cultural heritage supported by international institutions such as UNESCO, ICOMOS, ICCROM or ICOM, as well as other organizations dealing with cultural heritage. The main purpose of the DALIH database is to record the occurrence of damage and losses in worldwide immovable cultural heritage properties caused by natural or man-made hazardous events. The main objective of this initiative is to develop an efficient tool that will provide institutions managing and protecting cultural heritage with:

- a systematic and standardized recording of cultural heritage disaster-related data, from both natural and man-made hazards;
- a reliable accounting of cultural heritage losses;
- adequate data for the analysis of disaster trends and risk mitigation needs in cultural heritage.

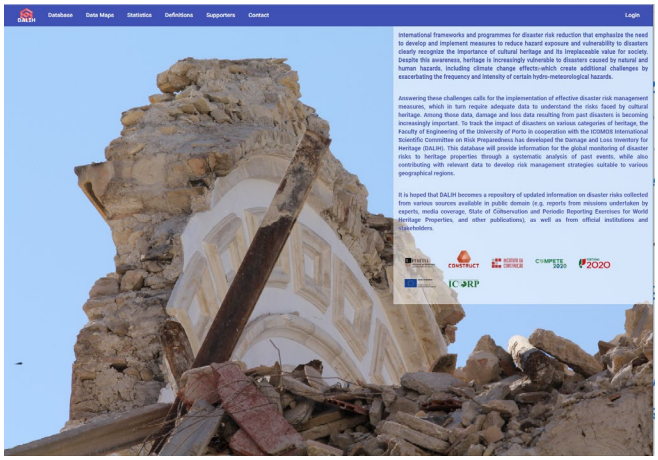

Fig. 1. View of the initial page of the DALIH database (https://dalih.org/).

One of the key issues of the database development was the definition of a simple system of categories for the type of cultural heritage properties that are considered by the database. Although several classifications and definitions of cultural heritage categories can be found in the literature, i.e. see [3-6], none of these approaches was seen to be entirely satisfactory in order to accommodate different types of immovable cultural heritage assets in a simple, general and structured way. Therefore, the following system of Heritage Categories was developed which establishes the importance of a certain immovable cultural heritage item:

- **World Heritage**: World Heritage property or property on the tentative list of the World Heritage program. It can be a cultural, natural or mixed property, and it can be a single or a multiple unit property.
- **Protected by the Hague Convention**: Cultural property on the general protection list or on the special protection list (first protocol to the Hague convention of 1954 for the protection of cultural property in the event of armed conflict), cultural property on the enhanced protection list or on the tentative list for enhanced protection (second protocol to the Hague convention of 1954 for the protection of cultural property in the event of armed conflict). It can be a refuge intended to shelter movable cultural property in the event of armed conflict or an immovable cultural property of Greatest Importance to Mankind. It can also be a single or a multiple unit property.
- **National Heritage**: Property on a National Heritage list. It can be a cultural, natural or mixed property, and it can be a single or a multiple unit property.
- **Sub-National Heritage**: Property on a Sub-National Heritage list. It can be a cultural, natural or mixed property, and it can be a single or a multiple unit property.
- **Local Significance Heritage**: Property that is not listed but still holds local significance. It can be a cultural, natural or mixed property, and it can be a single or a multiple unit property.
- **IUCN protected area**: Natural heritage property that is classified according to the protection categories of IUCN. It can be a strict nature reserve, a wilderness area, a national park, a natural monument or natural feature, a habitat management area or species management area, a protected landscape or protected seascape, or a protected area with sustainable use of natural resources.

Given that some of these categories may overlap (e.g. a UNESCO World Heritage Sites can also be a Listed National Heritage), more than one Heritage Category can be assigned to a certain cultural heritage property. As seen from the definitions, for some of these categories, two additional descriptors are also assigned to describe the type of heritage property. These descriptors establish that a given cultural heritage property belongs to one of the following Unit Identification types:

- **Single unit property**: an individual monument or a natural landscape
- **Multiple unit property**: a group of monuments, an historic landscape, an historic town, an urban block of cultural significance

and can belong to one of the following sub-categories:

- **Cultural heritage property**: A sub-category that includes historic monuments and buildings, town sites, or archaeological sites.
- **Natural heritage property**: A sub-category that includes natural areas of relevant biodiversity, ecosystems or geology.
- **Mixed heritage property**: A sub-category that includes sites that contain elements of both natural and cultural significance.

It is noted that within this classification for immovable cultural heritage, a museum building together with its collections is treated as a single unit property.

The hazardous events recorded by the database range from small-scale events that only affect a single cultural heritage property to large and widespread ones that affect a larger number of heritage assets. The database records basic identification and information about the main hazardous event (and secondary events that may have been triggered by the main event) such as the hazard type/subtype, the GLIDE number, geographical information (country, continent, location, latitude and longitude) and temporal information (start/end date, local time), (Fig. 2). The list of hazards that is considered by DALIH is consistent with the more recent UNDRR hazard definitions and classification [14, 15] and also includes certain man-made hazards considered in [16].

For each event, the database records information about the cultural heritage properties affected by the event. This includes basic descriptions about the cultural heritage properties before they have been damaged along with a description of the damages and losses they suffered. The damage description can be illustrated using additional media such as photos, videos or reports that can be uploaded into the database. Each cultural heritage property affected by an event is then associated to a Heritage Category and a Unit Identification type (according to the previously referred classifications), to one or more Property Classes (e.g. religious facility, archaeological site, residential facility, landmark, nature reserve, park, marine zone, rock formation, etc.), to a Value (qualitative) and to one or more Construction Materials (only for built properties). In terms of disaster data, the database records the (qualitative) damage level of each cultural heritage property, available information on economic losses and data regarding emergency procedures that may have been activated following the disaster.

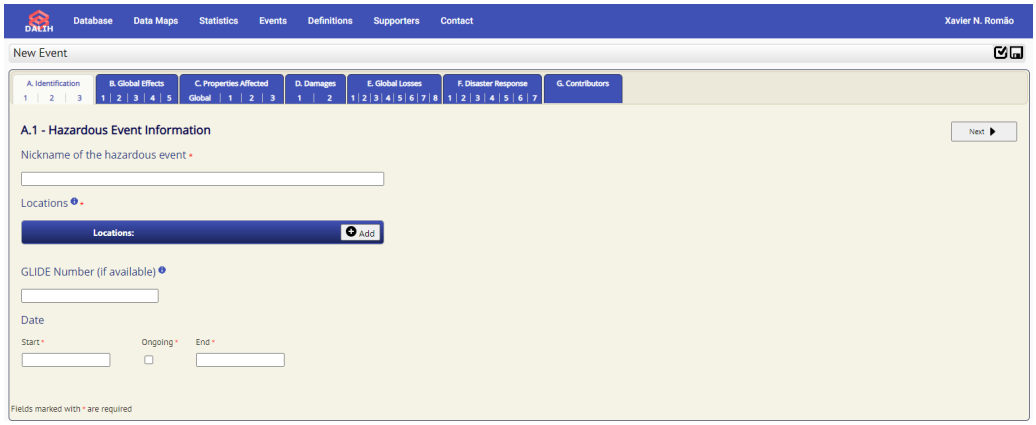

Fig. 2. First screen of the DALIH database where the main hazardous event is identified.

The definition of the (qualitative) Value that is assigned to the cultural heritage property is based on the following four categories of value that are well established in [10]:

- **Evidential value**: Derives from the potential of a place to yield evidence about past human activity (physical remains, written records, archaeological deposits, etc.).
- **Historical value**: Derives from the ways in which past people, events and aspects of life can be connected through a place to the present (divided into (a) illustrative value: the extent to which it illustrates something unique or rare; (b) associative value: the extent to which it is associated with a notable family, person, event or movement).

- **Aesthetic value**: Derives from the ways in which people draw sensory and intellectual stimulation from a place (either as a result of conscious design or the seemingly fortuitous outcome of the way in which a place has evolved and been used over time).
- **Communal value**: Derives from the meanings of a place for the people who relate to it, or for whom it figures in their collective experience or memory (these can include (a) commemorative and symbolic values: the meanings of a place for those who draw part of their identity from it, or have emotional links to it; (b) social value: places that people perceive as a source of identity, distinctiveness, social interaction and coherence; and (c) spiritual value: emanate from the beliefs and teachings of an organized religion, or reflect past or present-day perceptions of the spirit of place).

Each category of value is then assigned with a qualitative score according to the following ranks which are based on a proposal from the National Trust of Australia [11]:

- **Exceptional value**: The asset has features of exceptional/international significance or that contain elements with a significance beyond national boundaries.
- **Considerable value**: The asset has features of considerable/national significance, possibly reflected in a statutory designation such as that of a listed building or an equivalent nationally graded asset.
- **Some value**: The asset has features of some significance that are important at a regional level, either individually or for the value as a whole.
- **Limited value**: The asset has features of limited/local significance.
- **Unknown value**: The asset has features of unknown significance resulting from a lack of sufficient information on which to base a sound analysis of its value.
- **No value**: The features of the asset have no significance.

When recording the loss of cultural value in a given category of heritage property (World Heritage, Protected by the Hague Convention, National Heritage, Sub-National Heritage, Local Significance Heritage, or IUCN protected area) due to a specific event, an average loss across the previous four categories of value is defined using a 5-level score (0% - 25%; 25% - 50%; 50% - 75%; 75% - 100%; unknown). Regarding the previously referred damage levels recorded for each cultural heritage property, these are defined according to the following qualitative scale:

- **Completely destroyed**: The property has been razed and has no potentially salvageable elements left standing above ground.
- **Almost destroyed**: Several principal parts of the property are missing or severely compromised; the property appears to be beyond repair or recovery, but still has some identifiable elements standing.
- **Heavily damaged**: The property has suffered significant structural damage to its main elements or in several parts of the structure; typically, this would be used to describe a property that exhibits collapse of some of its elements.
- **Lightly damaged**: The property does not have damage that compromises the main structure or character of the property.
- **In good condition or undamaged**: The property shows no sign of damage.
- **Unknown damage**: The extent of the damage is unknown resulting from a lack of sufficient information.

4 Case study events available in DALIH and analyses that can be performed

The development of the DALIH database is particularly important given the possibility of using the data it collects in different steps of the cultural heritage risk management cycle. Performing a detailed risk assessment of cultural heritage properties is often a difficult task, given the complexity and the multidimensional value of cultural heritage. In these situations, using additional damage and loss data from past events recorded by disaster databases can be particularly helpful. Furthermore, the data collected by disaster databases is also relevant for the analysis and decision-making step, as well as for the risk mitigation and treatment step. Information on past experiences can provide valuable guidance for the definition of the approaches that are best suited to protect a certain cultural heritage asset or to create awareness regarding the need to develop new risk mitigation measures. To illustrate some of these issues, a few case study events are

discussed in the following using data available in DALIH. The images that presented in the following are obtained from the data mapping and statistical processing outputs that are also part of DALIH.

The first case that is discussed refers to the Lorca (Spain) earthquake that occurred on May 11, 2011. The earthquake caused extensive damage to both recent and older constructions in Lorca [12]. With respect to cultural heritage, damage occurred in monuments and historic constructions, and assessment campaigns were carried out to collect damage data which was then used to estimate costs for the emergency stabilization and repair of certain damaged heritage constructions. Based on several reports, scientific publications and news, a total of 107 damaged heritage constructions were identified. Fig. 4 shows a partial of the spatial distribution of some of the heritage constructions damaged by the 2011 Lorca earthquake, as well as some statistics about these constructions in terms of their level of damage. The usefulness of this type of information is multi-fold by itself, but it can lead to additional insights about the vulnerability of these types of constructions if it is superimposed with seismic micro zonation studies of the area that can provide local insights to explain differences in the level of damage between different historic constructions (e.g. see [17]), and it can also be used to develop better models to predict seismic risk by trying to reproduce the impacts of the earthquake (e.g. see [18]).

Fig. 3. Spatial distribution of some of the cultural heritage properties damaged by the 2011 Lorca earthquake, overlapped with statistics of the total number of cultural heritage properties damaged by the 2011 Lorca earthquake in terms of their level of damage.

The second case that is discussed refers to a series of fires that affected heritage constructions in the UK between January and June of 2020. The data was collected from [9] and shows that, within those 6 months there were 226 fires that damaged heritage buildings. Fig. 5 shows the spatial distribution of the damaged heritage constructions, as well as statistics about the source of the fires. Based on this aggregated statistics, it is interesting to note that "arson" is a significant source of fires in the UK. This means that fire risk reduction actions that need to be implemented must go beyond traditional measures of fire detection and control, and address the specific issue of arson by enhancing security to prevent unauthorised entry and to monitor people inside and outside a heritage construction [13]. A further spatial disaggregation of this information can also provide insights on the regions where this issue appears to be more relevant. Fig. 4a also shows a lack of uniformity in the occurrence of fires in heritage constructions across the UK territory. This issue may also be the subject of further analyses by relevant stakeholders to understand if there are underlying conditions for this nonuniform distribution of fires or if it is simply due to the fact data collected from [9] was mostly gathered from news and, therefore, may be incomplete.

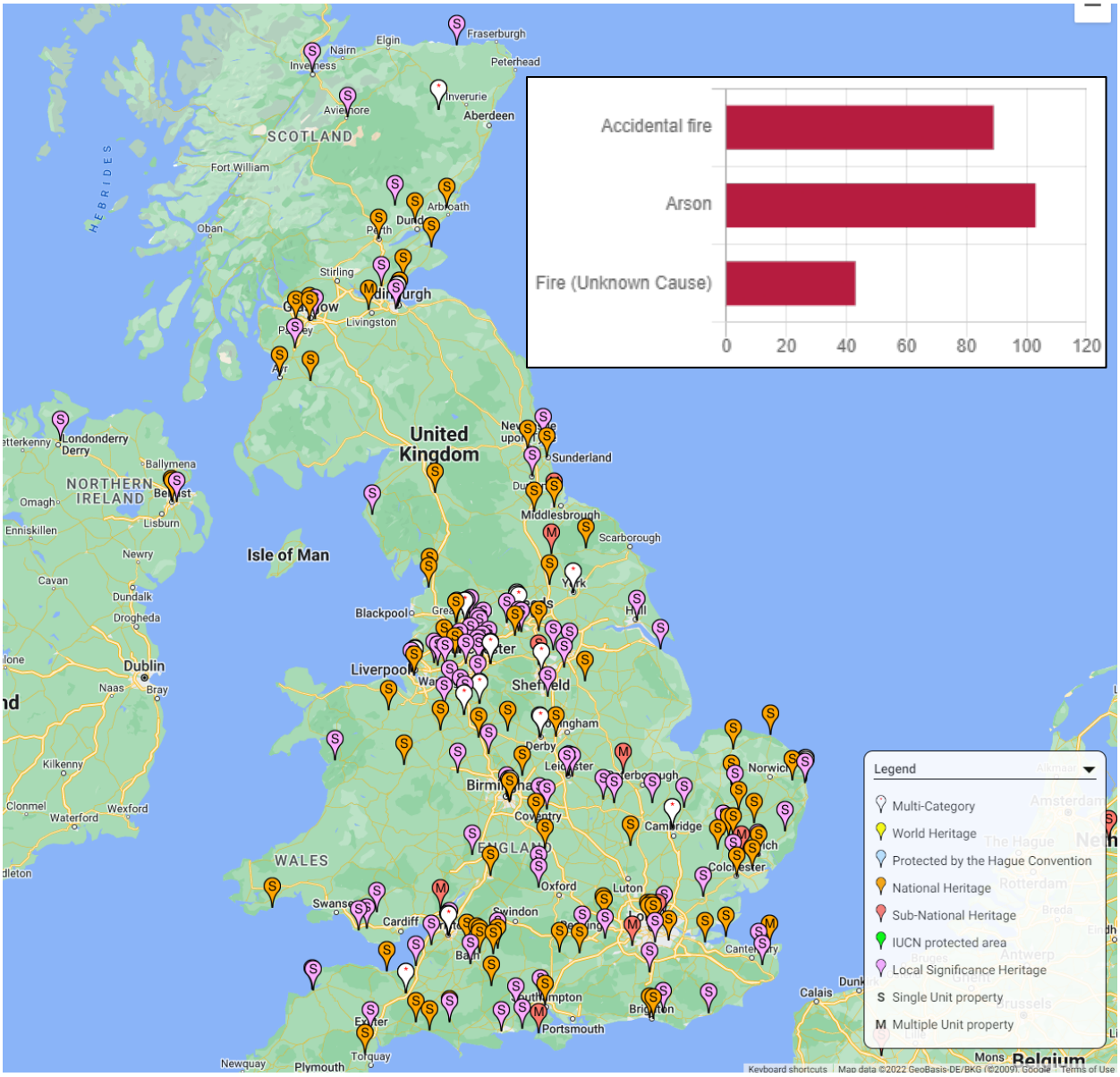

Fig. 4. Spatial distribution of fires in the UK that damaged cultural heritage properties between January and June 2020 overlapped by statistics of the total number of fires according to the source of the fire.

The third case that is discussed refers to part of the heritage constructions damaged in Puerto Rico by the 2017 Hurricane Maria. Fig. 6a shows the spatial distribution of 95 damaged cultural heritage properties reported in the inventory carried out by the Para la Naturaleza organization [19]. This inventory is believed not be exhaustive, but it provides the only detailed information that was found about the impacts of this event on cultural heritage properties. Another report [20] mentions the existence of more damaged cultural properties but detailed data are not available for sharing. The available information is also able to provide statistics about these properties in terms of their level of damage (Fig. 6b). Further analyses can be performed about the vulnerability of the affected properties if this information is overlapped with a map of the wind velocities likely to have been experienced during the hurricane [21] (Fig. 7). Performing this type of analysis can provide important insights about the wind vulnerability of different types of heritage properties, which can then be utilized for developing adequate hurricane risk mitigation measures that can prevent damage in future events.

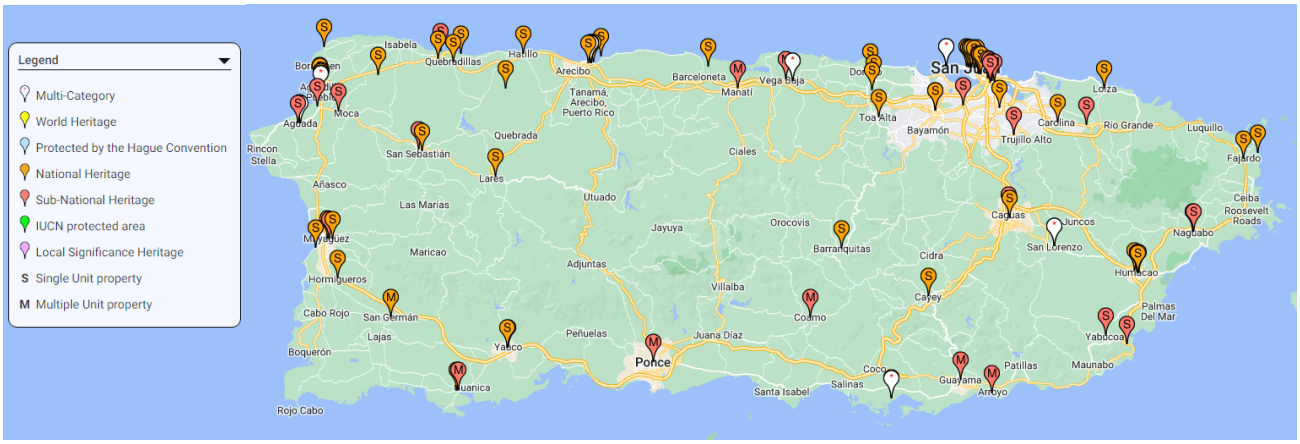

Fig. 5. (a) Spatial distribution of cultural heritage properties damaged by the 2017 Hurricane Maria in Puerto Rico; (b) Statistics of the total number of cultural heritage properties damaged by the 2017 Hurricane Maria in Puerto Rico.

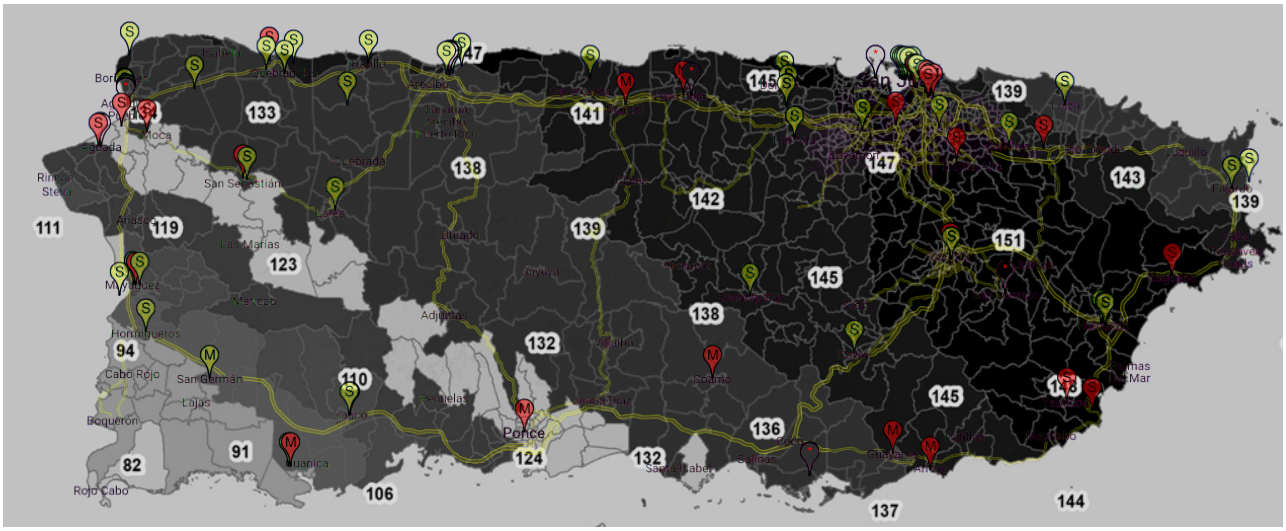

Fig. 6. Overlap of the damaged cultural heritage properties with the map of wind velocities (in miles per hour) likely to have been experienced during the 2017 Hurricane Maria in Puerto Rico.

5 Conclusion

International frameworks and programs for DRR are clear in their objectives of reducing hazard exposure and vulnerability to disasters. Furthermore, the importance of cultural heritage and its irreplaceable value for society is also clearly acknowledged in these objectives. However, how can disaster loss reduction be measured in cultural heritage if there is no reliable loss data on the impacts that disasters have on this sector? Currently, it is clear that existing disaster loss accounting systems underestimate the true cost of disasters as a result of several factors. One of the factors is the inability to account for the disaster impacts on cultural heritage. Disaster loss databases are therefore important tools to analyse patterns and trends of disaster losses and disaster risk based on past events. By understanding these patterns and trends, future losses can be mitigated by the implementation of efficient targeted measures. Furthermore, disaster loss data can also be used to determine if disaster risk management is actually being efficient in reducing risks as a result of DRR policies and investments.

The development of a database specifically devised for the collection of cultural heritage disaster loss data such as the DALIH database is therefore fundamental and will provide important data for the development and preparation of better heritage-focused disaster mitigation strategies for the future. Aside from presenting the concepts and certain technical about the DALIH database aspects, the benefits of these data for developing more rational disaster risk management approaches for cultural heritage are discussed and illustrated using data from several events recorded in DALIH. While these and other benefits may be immediately grasped by the availability of these data, the main challenge for developing this database is seen to be at the level of data collection and validation. Following a certain event with impacts in cultural heritage properties, it is not clear if such impacts are collected and recorded by relevant institutions or authorities. And if they are, they are seldom shared with wider research community that could use this essential data to enhance disaster risk assessment and management approaches for cultural heritage.

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