D8.6 Reports on pilot testing

Deliverable number	D8.6
Deliverable title	**Reports on pilot testing**
Nature[1]	**R**
Dissemination Level [2]	**PU**
Author (email) Institution	**Dimitrios Vamvatsikos (divamva@mail.ntua.gr)** **Dora Karali (d.karali@risa.de)** **Elena Manoli (e.manoli@cyric.eu)**
Editor (email) Institution	**Andreas Papadopoulos (a.papadopoulos@cyric.eu)**
Leading partner	**CyRIC**
Participating partners	**All technical partners**
Official submission date:	**31/05/2023**
Actual submission date:	**24/07/2023**

[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other

[2] **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services), **CI**=Classified, as referred to in Commission Decision 2001/844/EC

Modifications Index

Date	Version
01/09/2022	0.1 Table of content
08/10/2022	0.2 First version Tønsberg and Rhodes
05/12/2022	0.3 Added Granada pilot
22/02/2023	0.4 Updated version
03/05/2023	0.5 Updated Venice pilot
19/04/2023	0.6 Prepared for internal review
14/07/2023	1.0 Final version

This work is a part of the HYPERION project. HYPERION has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 821054.

ACRONYMS AND ABBREVIATIONS

CH	Cultural Heritage
UEQ	User Experience Questionnaire
ML	Machine Learning
UAV	Unmanned Aerial Vehicle

Table of Contents

List of Tables

List of Figures

Executive Summary

This document is an outcome of Task 8.5 "Pilot Implementation". It presents an overview of the HYPERION pilot activities that have been performed for all four pilot sites. Specifically, it outlines the supporting hardware that has been installed at each pilot site, the specific scenarios for the pilot site and the training and demo events that had taken place for each one. Overall, the HYPERION platform has been successfully piloted in four Cultural Heritage sites, namely Rhodes (Greece), Tønsberg (Norway), Granada (Spain), and Venice (Italy). The pilot partners participated to the pilots by using and evaluating the system after dedicated training sessions that were organized physically or remotely. The provided feedback was helpful to evaluate the overall system and our feedback analysis results are documented in Deliverable 8.7.

1 Introduction

1.1 Purpose and scope

This document is an outcome of Task 8.5 "Pilot Implementation" towards the piloting and validation of the integrated Hyperion release as presented in Deliverable 8.5. This deliverable focuses on outlining the actions performed prior to the pilots as well as the pilot locations and attendants.

The HYPERION platform aims to assist representatives of local authorities and cultural heritage managers in gaining a deeper understanding of the threats and risks facing tangible Cultural Heritage (CH) sites. By providing valuable insights, the platform enables more informed decision-making for a prompt and effective response, ultimately contributing to the sustainable preservation and revitalization of historical regions at risk.

During the pilot activities the end users had the opportunity to experiment with the HYPERION system that was hosted online and credentials were shared with the pilot partners. The following HYPERION functionalities were demonstrated to the participants for all pilot sites:

- Visualization of measurements from weather stations and smart tags monitoring devices that were deployed to each site
- Hyperion weather forecasting capabilities and evaluation of climate evolution scenarios
- Hazard scenario simulations focusing on the impact of flood and seismic events to the pilot site CH buildings as well as the impact of these events to residents and businesses.
- Testing of the SG simulator output with representative Tier 1 structures
- Land deformation using Machine Learning (ML) and UAV technology
- 3d models and point clouds for prominent CH structures created using Machine Learning (ML) and UAV technology
- Assessment of the resilience of the CH area to the governing hazards and management of the resulting risk
- Visualization of user stories (comments and photos) from the Communities' Engagement tool
- Predictions on material deterioration of selected (Tier 1) CH structures facades resulting from the HygroThermal simulator
- Assessment of the impact of climate change on the deterioration of CH structures.
- Incorporation of multiple hazard models in a logic tree to properly quantify uncertainty and reflect the current state of knowledge
- Assessment of socioeconomic impacts on the CH core community for multiple flood, seismic, and weather scenarios
- Prioritization of intervention actions based on risk
- Determination of financial mitigation tools, focusing on reciprocal business agreements and parametric insurance products

2 Pilot support actions

The HYPERION solution is a complex system integrating together various software and hardware components. To support the pilot activities, several hardware and software components had to be integrated.

In terms of hardware, we have installed smart tags and weather stations in Tier 1 buildings at the four pilot sites of Rhodes, Venice, Granada, and Tønsberg.

Smart tags are edge network devices, equipped with environmental sensors, used for monitoring the environmental conditions and changes in the vicinity of Tier 1 building walls, by acquiring accurate air temperature and humidity measurements.

To monitor the environmental microclimate conditions and changes, and assess climate risk parameters for the buildings, microclimate stations were also designed and deployed. The microclimate/weather stations provide measurements of a set of atmospheric parameters, such as the air temperature, humidity, UV index, and wind direction and speed. In the case of the HYPERION pilots, the weather stations were installed in the vicinity of the Tier 1 buildings of the CH site.

In terms of software components, the HYPERION system integrates the various software components developed by the technical partners. These include the mesoscale operational weather forecasting model, socioeconomic impact, natural hazard, vulnerability, and risk assessment models, EO services, middleware, mobile application, and HRAP interface. A complete overview of the HYPERION integrated system architecture, components and integration tests is presented in Deliverable 8.5 "Final version (V2) of the HYPERION System and Acceptance tests".

The HYPERION solution offers an extensive range of capabilities to its end users, primarily local authorities. During the pilot activities specific scenarios per pilot site were demonstrated depending on each pilot site characteristics. For example, the Venice demo focused on flood hazards, the focus for Tønsberg was weather-related deterioration, while earthquakes and weather effects were demonstrated for Granada and Rhodes.

The following sections present some of the scenarios demonstrated per pilot site as well as the supporting hardware and locations of installation.

3 Rhodes (Greece) Pilot

For Rhodes pilot activities 1 weather stations and 10 smart tags were installed at 4 Tier 1 buildings as outlined in the table below.

Table 1 Rhodes hardware installations

Site	Building	Place of Installation	Quantity
Smart tag	Saint Nikolas lighthouse and fort	Inner side	2
		Outer side of the fort	2
	Nailac Pier	Outer side	1
		Inner side	1
	Roman Bridge	Outer side	1
		Dam east of the Roman bridge	1
	Grave complex in Rhodini	Tomb of the Ptolemies	1
		Korinthian tomb	1
Weather station	Dodecanesse Ephorate of Antiquities		1

The demonstration of the system to Rhodes has taken place online. Pilot partners were trained to explore different layers/datasets on top of region maps and review the details that are available. Datasets are organized in groups according to categories (Tier 1 structures, Priority lists, EO data, Communities' engagement, General/Cadastral) to facilitate navigation.

Users have the option to choose any Tier 1 structure and access detailed information, including its location, description, hygrothermal simulator data, 3D models, and sensor data. Figure 1 presents a map view of Rhodes pilot site for Naillac Tower. By clicking on a structure, users can find a brief description along with the sensors attached to it as well as the results of the Machine Learning (ML) and UAV technology.

Users can choose to view the point cloud, 3d models and detailed views of the structure as shown in Figure 2.

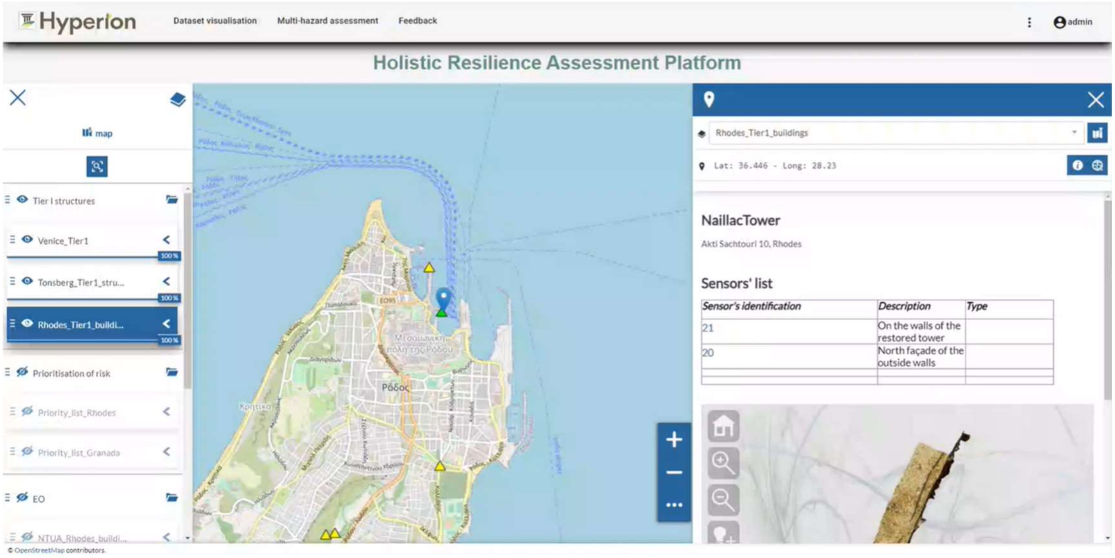

Figure 1 HRAP Map View with information about Rhodes site

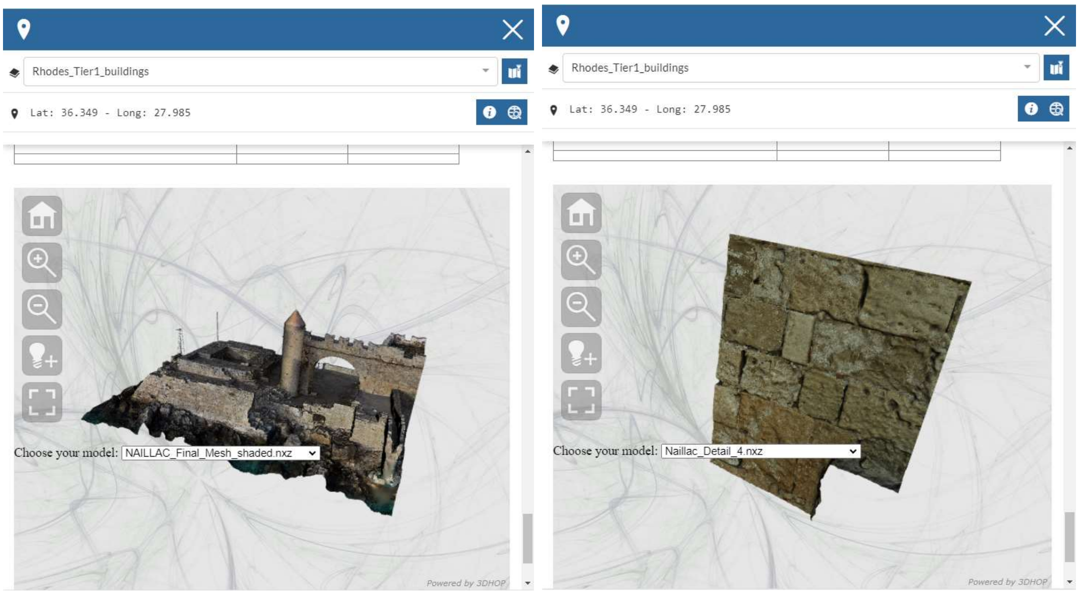

Figure 2 3d models generated for structure of Rhodes

Among the available datasets, a significant layer for each pilot city provides guidance for the prioritization of risk. This layer utilizes colors to represent a range of direct monetary losses (i.e., lost value of buildings), which are then applied to the map. As shown in Figure 3, the highest priority region for Rhodes is the historical city center, especially its western part indicated in red in the middle of the map. This shows the highest direct losses (in absolute terms), as well as enormous indirect losses due to being the center of the touristic activity of the island. Some large losses also appear in the southern end of the city, but this is because of the large area involved, which is actually many times larger than the vulnerable city center.

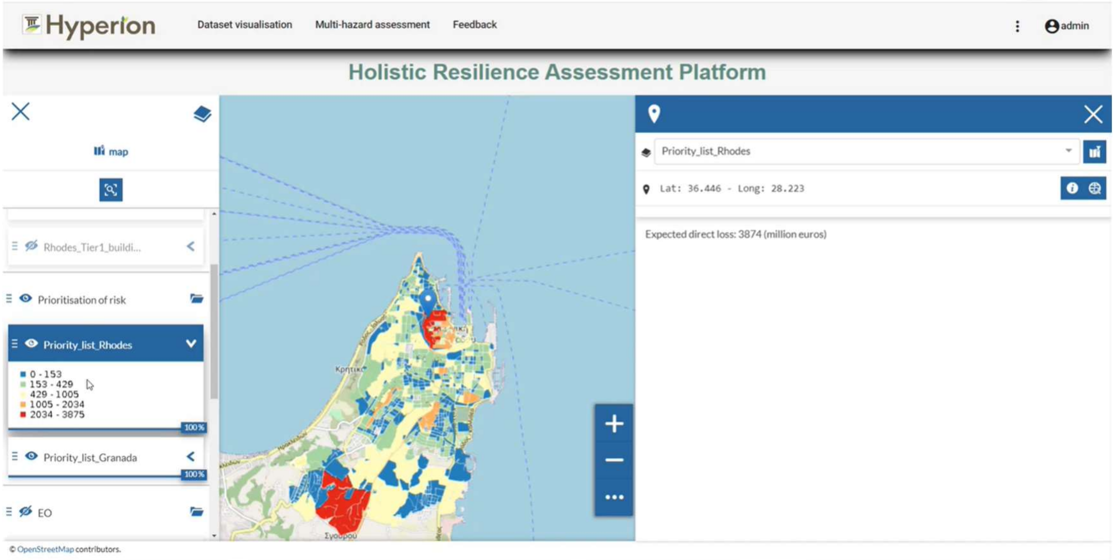

Figure 3 Prioritization of risk layer for Rhodes

The core part of the platform is the multi-hazard assessment, which enables users to explore different scenarios and employ both short-term and long-term planning modes. This functionality assists regional operators in making informed decisions by providing them with the necessary tools and information.

During the short-term planning mode for Rhodes, users are required to select a Peril, which can be either Weather or Seismic. When Weather was chosen and for either nowcasting or forecasting mode, six layer options become available on the map for the weather related parameters (humidity, temperature, cloud coverage, precipitation, wind speed and direction). In Figure 4, the layer displays the temperature forecast for the next 3 hours.

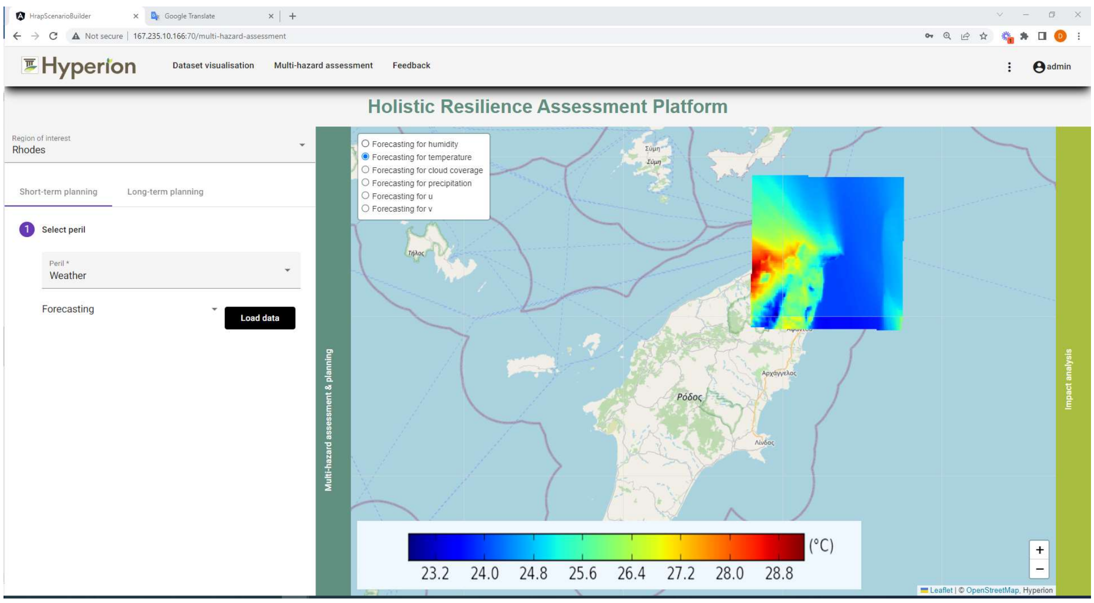

Figure 4 Multi Hazard assessment during short term planning with Weather Peril

In Figure 5, the seismic mode was selected, which prompts the need for additional information. This includes specifying a particular asset of interest to the user, obtaining the earthquake magnitude range (minimum and maximum), identifying the point of interest by clicking on the map, determining the earthquake distance, and setting the IM (Intensity Measure) threshold. Upon receiving this information, the multi-hazard assessment will generate a list of pins on the map. These pins represent potential events that align with the selected criteria.

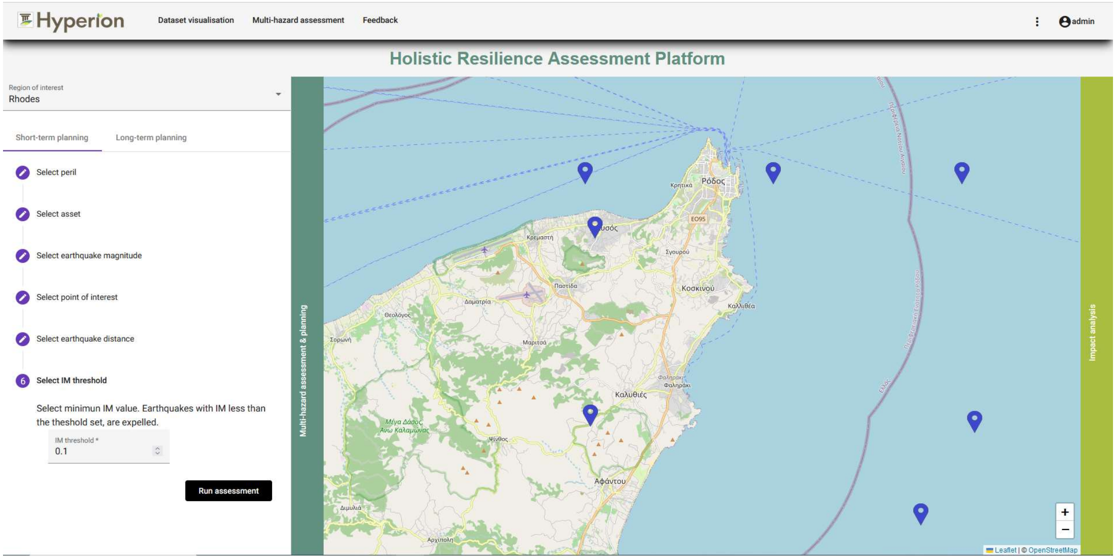

Figure 5 Multi Hazard assessment during short term planning with Seismic Peril

When a user clicks on a specific point, they can access more information and continue with the assessment. The user has the option to filter the map using 11 different categories. The corresponding color range for the selected category is displayed at the bottom of the screen, sorted by color. This allows each building to be associated with its respective value based on the color within that range.
Furthermore, on the right-hand side of the screen, the impact analysis is presented (see Figure 6). Here, users can observe graphs depicting the direct losses (in millions) per business type, as well as the graphs illustrating the indirect losses (in millions) per business type. Additionally, the number of buildings and the expected damage state percentages are displayed. Moreover, users can access socioeconomic results, including the Downtime Diagrams, the socio-economic model, and the impact analysis results (see Figure 7).

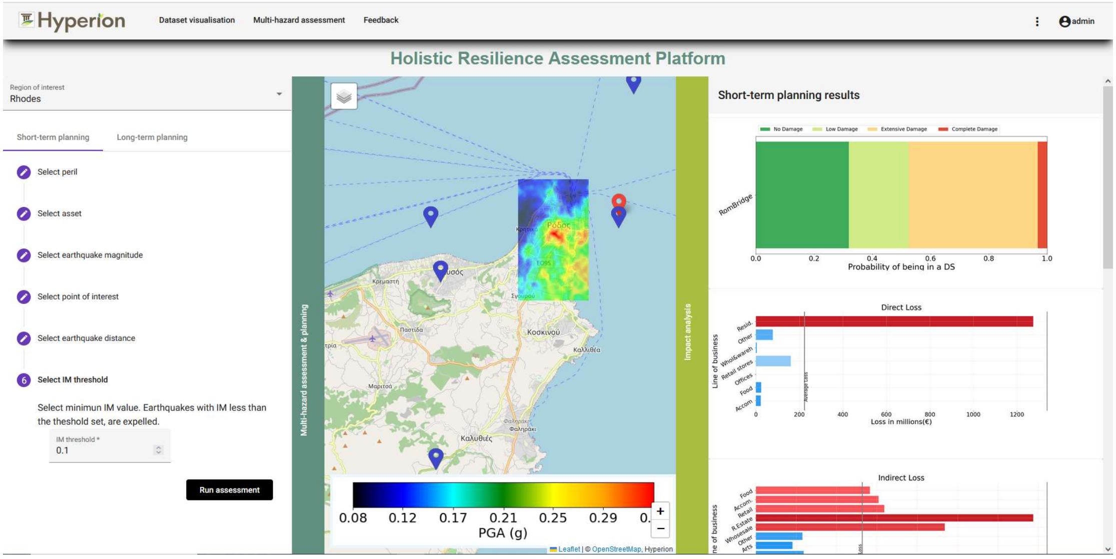

Figure 6 HRAP Multi-hazard assessment and impact analysis Rhodes site for short-term planning

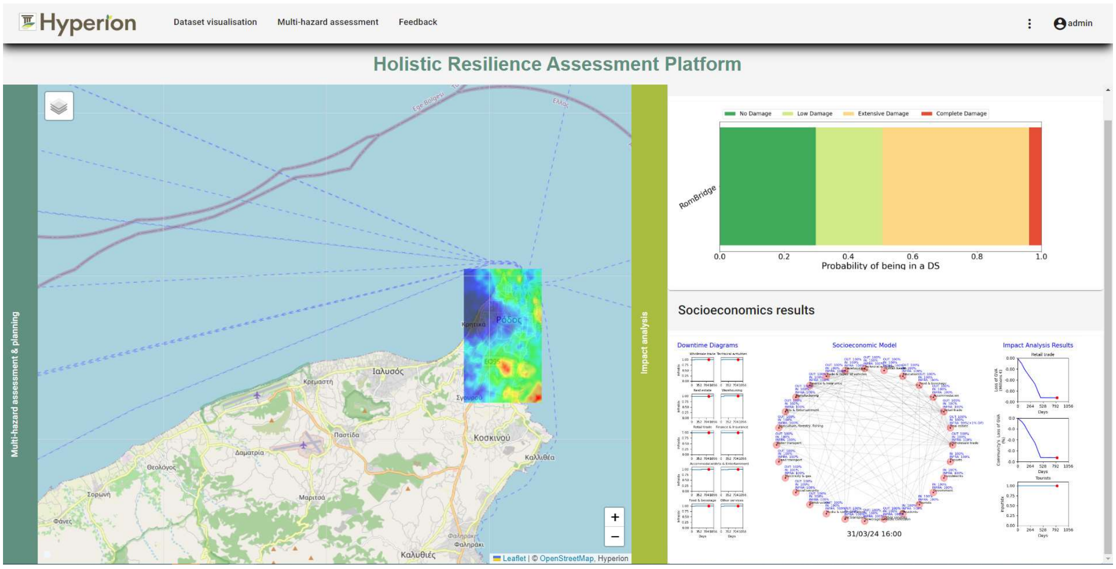

Figure 7 Socioeconimic results

For Rhodes, an assessment can be conducted on the water network in addition to the buildings. The selection process for short-term planning is similar to that of the buildings. The results for the seismic water network are displayed in Figure 8. The user can once again choose from 2 different layers and observe the corresponding color range at the bottom of the screen, which varies depending on the selected layer.

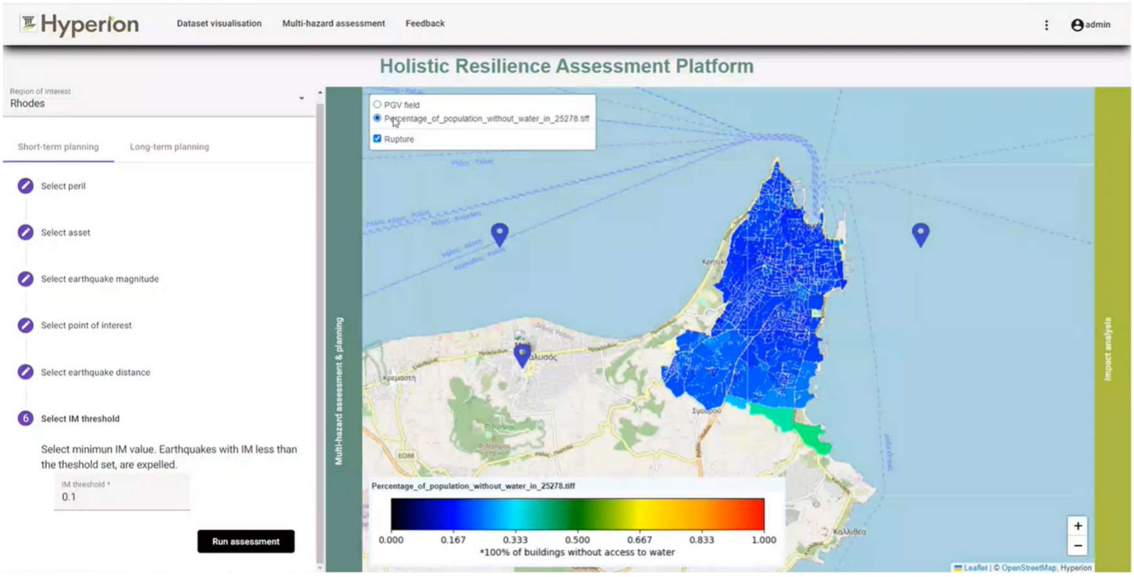

Figure 8 HRAP Multi-hazard assessment for the water network in Rhodes

Long-term planning empowers users to explore the projected outcomes of various types of weather and seismic events. If the user chooses Weather as the selected Peril, they can then navigate through a range of climate change scenarios and initiate the assessment process. Additionally, the impact analysis, illustrated in Figure 9, is located on the right-hand side of the screen. The results showcase projections for each EuroCordex scenario over the years, providing valuable insights for decision-making.

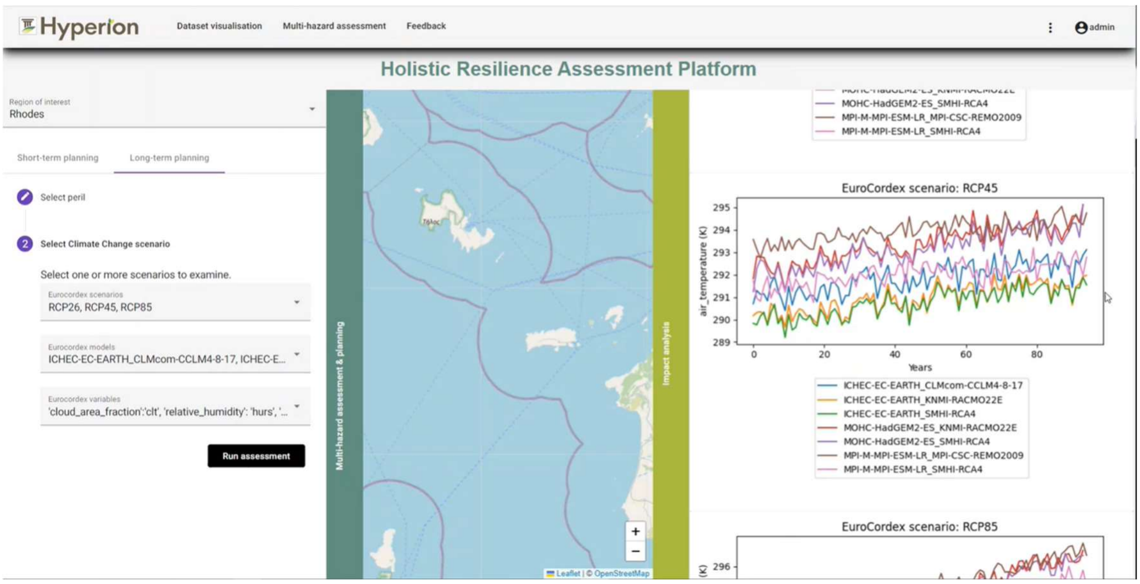

Figure 9 HRAP Multi-hazard assessment and impact analysis Rhodes site for long-term planning

In long-term planning, if the user chooses Seismic as the selected peril, they must first select the asset and then choose a specific building typology or leave it undefined before running the assessment. Results appear in Figure 10.

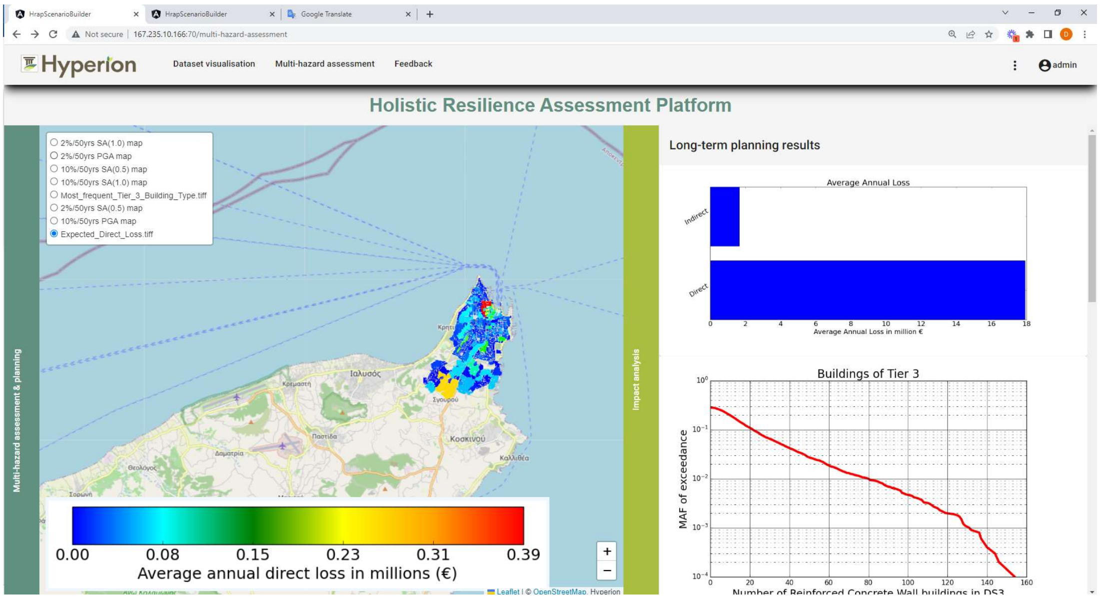

Figure 10: Long term impact assessmnt for seismic events

Lastly, within the map view, there exists a community engagement layer where multiple pins are displayed. Citizens can utilize the Pluggy tool to upload details and pictures of affected assets, as demonstrated in the Figure below. This enables administrators to review the feedback with the general HRAP interaface (Figure 11) and consider it for future decision-making processes.

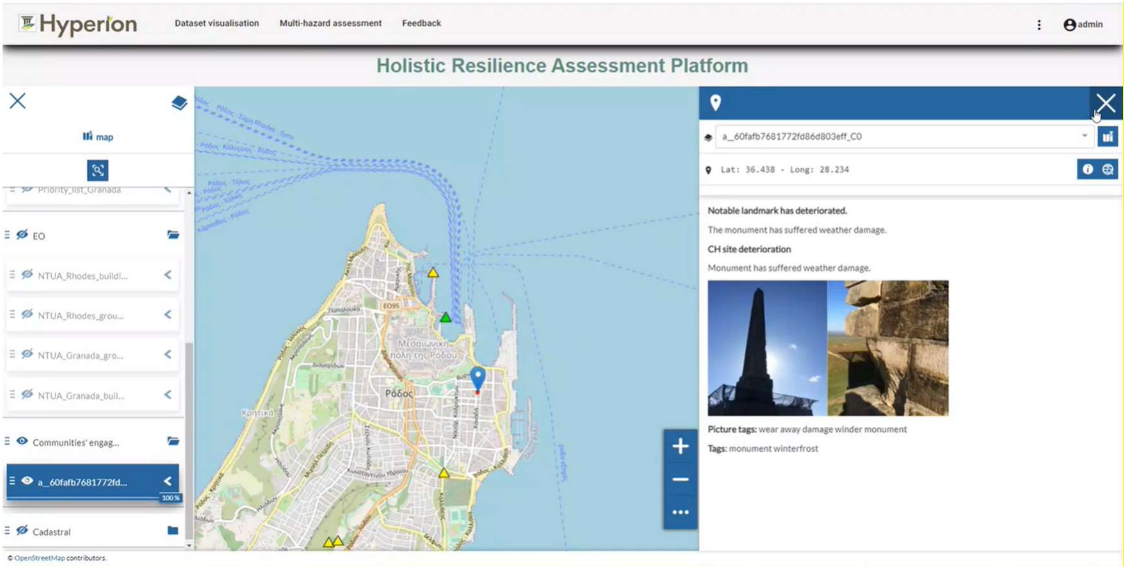

Figure 11 Communities feedback

4 Tønsberg (Norway) Pilot

For Tønsberg pilot activities 1 weather stations and 12 smart tags were installed at 4 Tier 1 buildings as outlined in the table below.

Table 2 Tønsberg hardware installations

Site	Building	Place of Installation	Quantity
Smart tag	The Heierstad Loft	Outer side	2
		Inner side	1
	Fadum storehouse	Outer side	2
		Inner side	1
	The Western Tower	Outer side	2
	Bentegården	Outer side	2
		Inner side	2
Weather station	Castrum area		1

The demonstration of the system for Tønsberg pilot site has taken place online. All HYPERION functionalities were demonstrated to the pilot partners and focus was given to the weather hazard, and especially the hygrothermal effects of weather on the CH assets of Tønsberg and their deterioration over time.

Users focus on their region of interest and navigate through the available datasets. Tier 1 structures are indicated with triangles and, by selecting one of them, users can access detailed information, including location, description, hygrothermal simulator data, 3D models, and sensor data. Figure 12 presents a map view of the Tønsberg pilot site and by clicking on a structure, e.g. HeierstadLoft, users can find a brief description along with the sensors attached to it as well as the results of the Hygrothermal simulator. Figure 13 demonstrates the outcome of clicking on a sensor from the list. In the subsequent window, users can observe the most recent details, such as temperature and battery level, and review the historical data within the chosen timestamps.

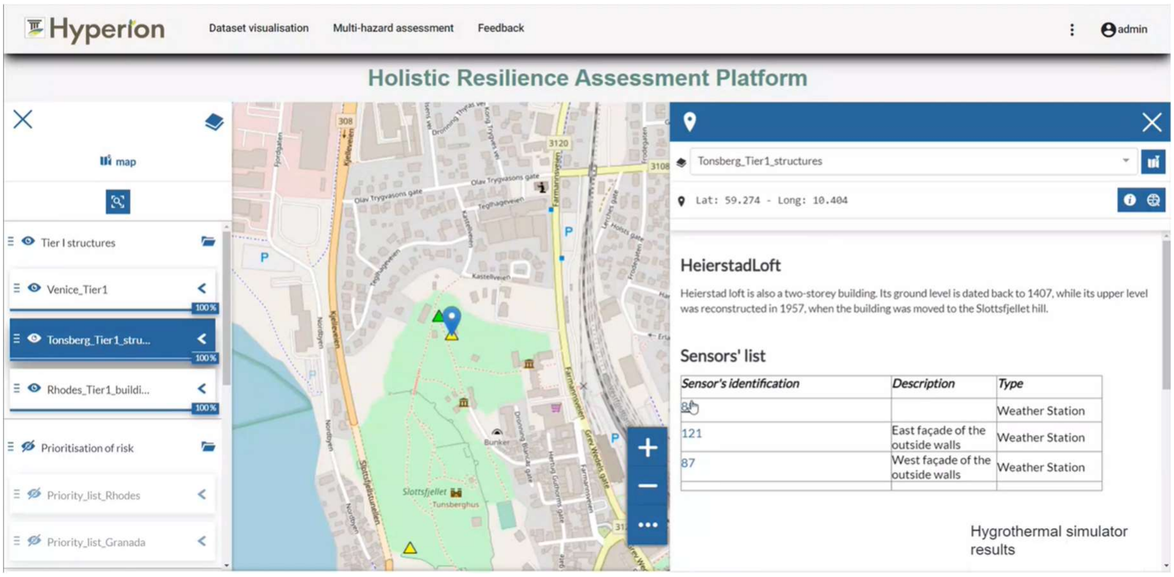

Figure 12 HRAP Map View with information about Tønsberg site

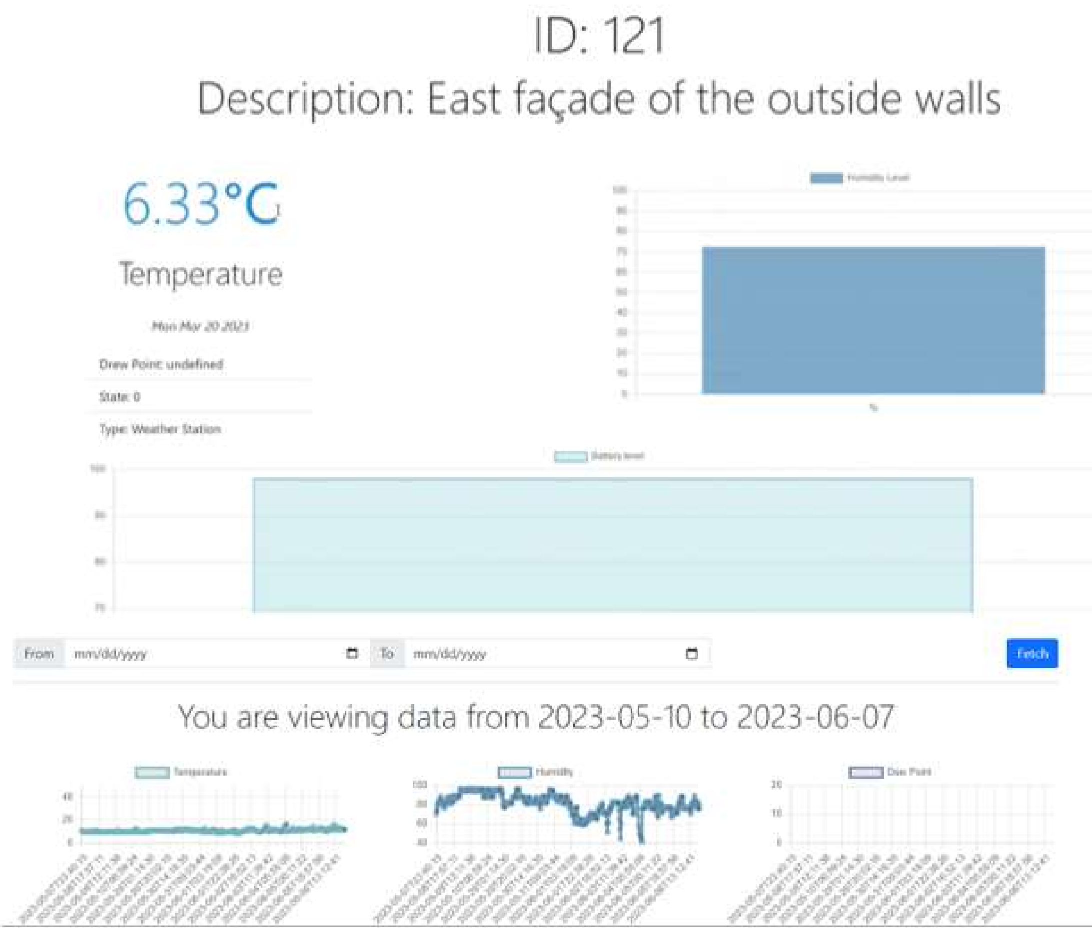

Figure 13 Detailed information for the selected sensor

As seen in Figure 14, the 3d model of the structure appears and it's facades are colored according to the *mould growth index, one of the parameters of* material degradation; resulting from the HT simulation model. The user can explore the projection of the material degradation over the next 80 years and according to the climate change scenarios that were studied in the HYPERION project.

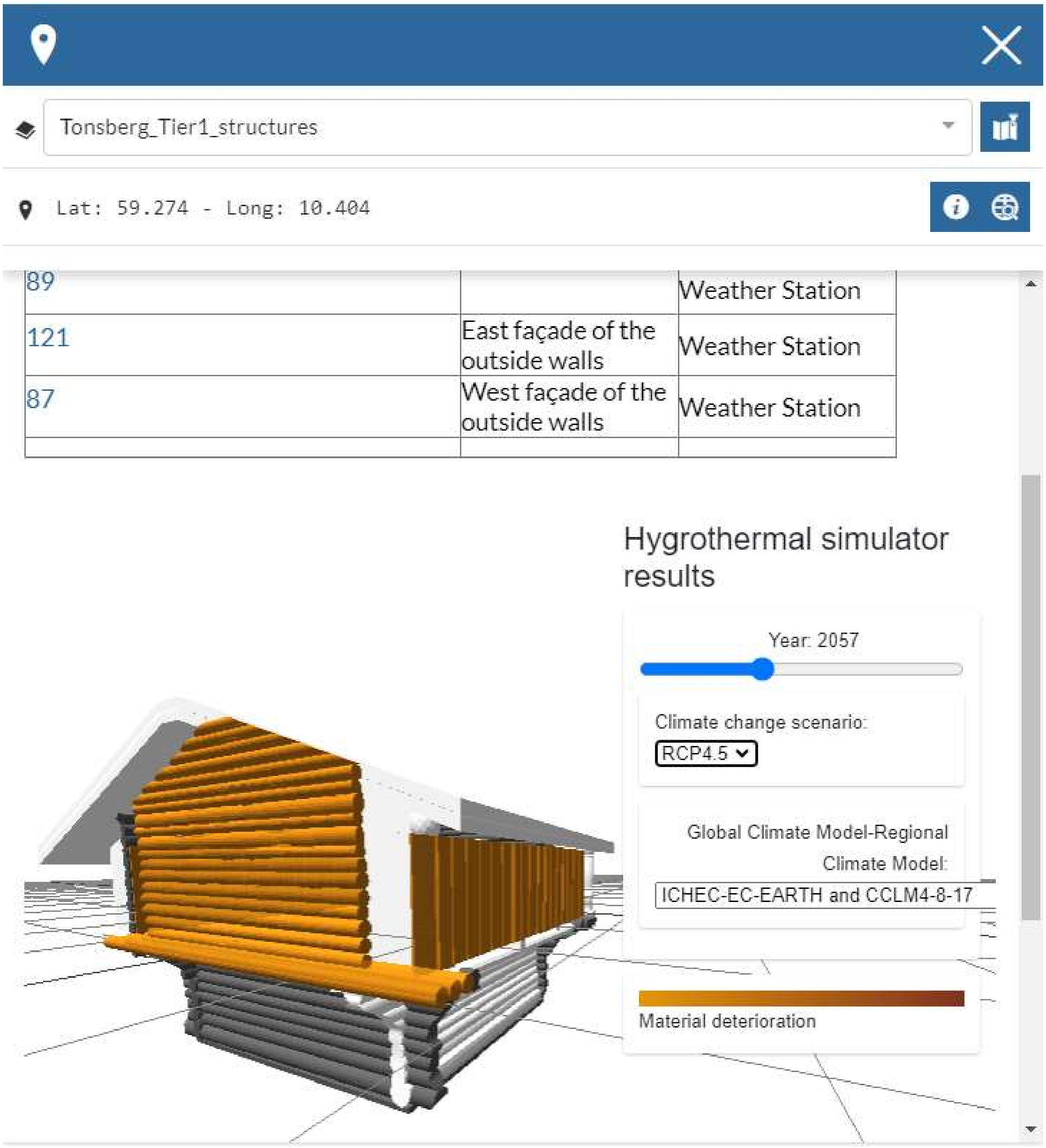

Figure 14 Material degradation projection

Furthermore, the multi-hazard assessment enables users to explore both short-term and long-term planning modes. This functionality assists regional operators in making informed decisions by providing them with the necessary tools and information.

During the short-term planning mode for Tønsberg, users can select the weather peril for either nowcasting or forecasting mode. In each case, six layers become available on the map for the weather related parameters (humidity, temperature, cloud coverage, precipitation, wind speed and direction) in a wide disctric around Tønsberg. In Figure 15, the layer displays the nowcast for wind speed.

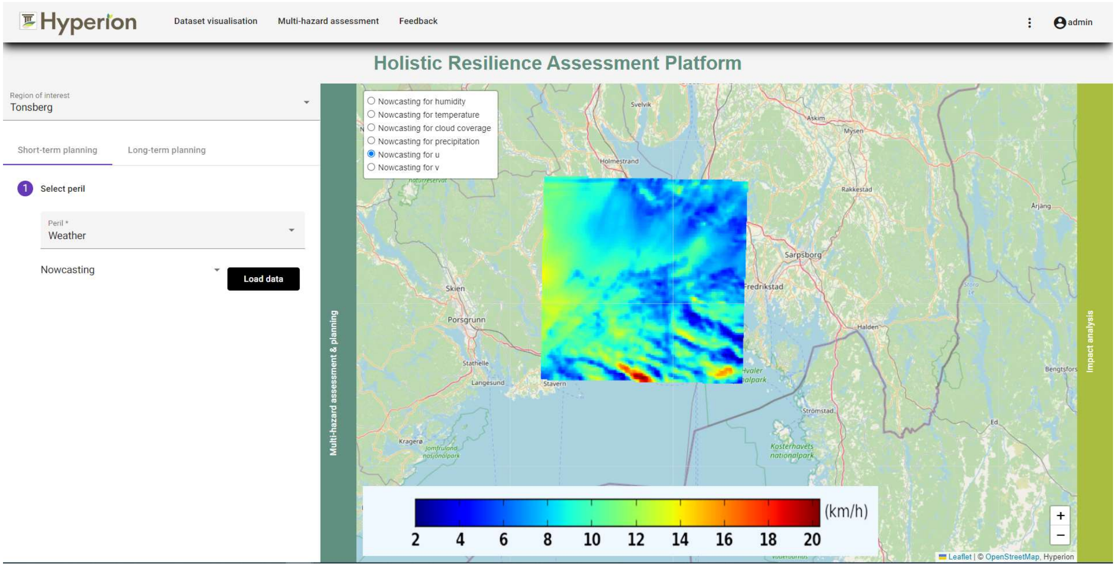

Figure 15 Wind speed nowcasting

Long-term planning empowers users to explore the projected outcomes of various scenarios for weather. The impact analysis, illustrated in Figure 16, showcase projections for each EuroCordex scenario over the years, providing valuable insights for decision-making and, specifically for the Tønsberg case, the impact on the average annual visitors for the years to come, normalized to 2022. In this case, the number of tourists has been found to be positively correlated with the daily temperature, thus the effect of the changing climate (higher daily temperatures) is expected to drive more tourists to Tønsberg, all else being equal.

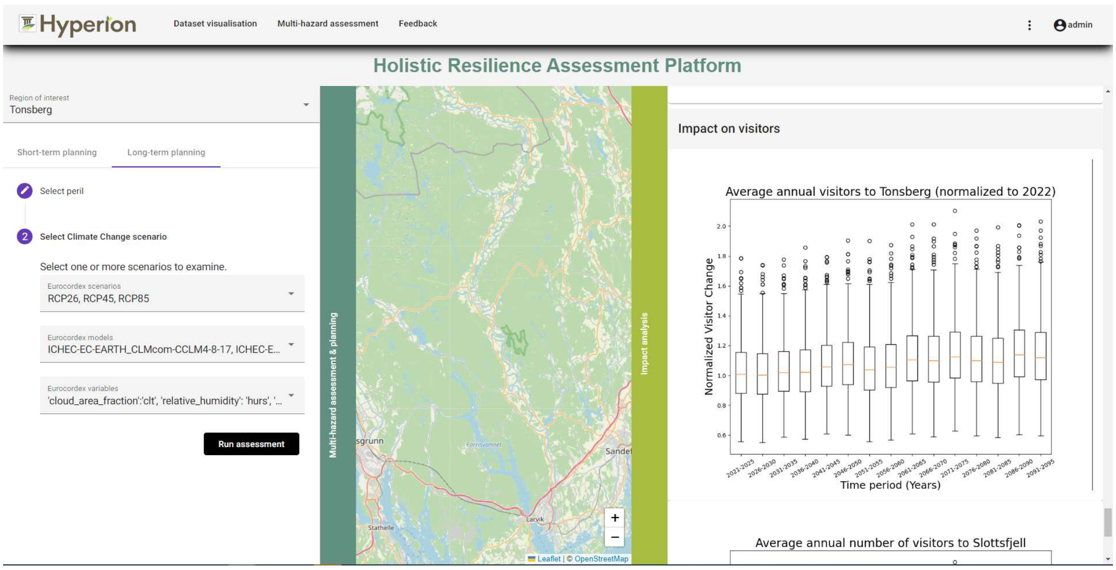

Figure 16 Impact on Tønsberg visitors

5 Granada (Spain) Pilot

For Granada pilot activities 1 weather stations and 6 smart tags were installed at 1 Tier 1 building as outlined in the table bellow.

Table 3 Granada hardware installations

Site	Building	Place of Installation	Quantity
Smart tag	San Jerónimo Monastery	Outer side	5
		Inner side	1
Weather station	Faculty of Civil Engineering		1

The demonstration of the system has taken place in Granada in November 2022. The event focussed on presenting the HYPERION system to the invited stakeholders for the Granada pilot activities. Also, the event aimed to facilitate the adoption and exploitation of HYPERION's results in the near future.

Figure 17 Demonstration of the HYPERION system for Granada pilot activities

During the Granada pilot activities, the demonstrated scenarios included an introduction to the overall features of the system and then focused on Granada Tier 1 buildings. Specifically, the following scenarios were demonstrated.

The user logs into the platform and selects the region of Granada. He is presented with a hierarchy of risk prioritization for the region (see Figure 18), noticing that the monastery is in the high prority region that corresponds to annual direct losses of 1.9M euros in case of damage.

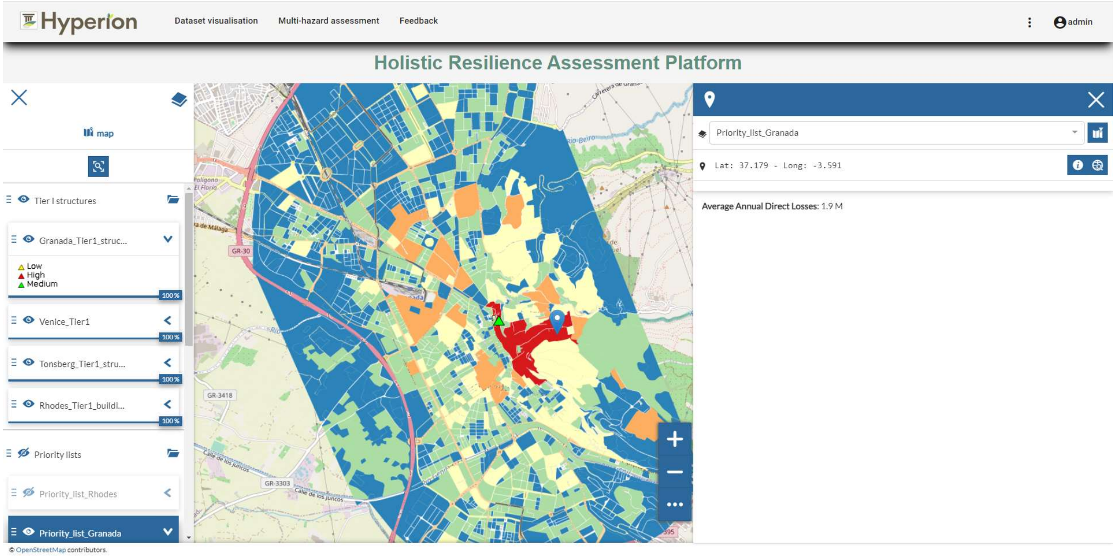

Figure 18 Risk prioritization for Granada

When clicking over the pin of the Monastery in the map, an info window popups showing the data identified by the coordinates; in our case the 6 sensors installed in the inner and outer sides of the structure. Figure 19 shows the details.

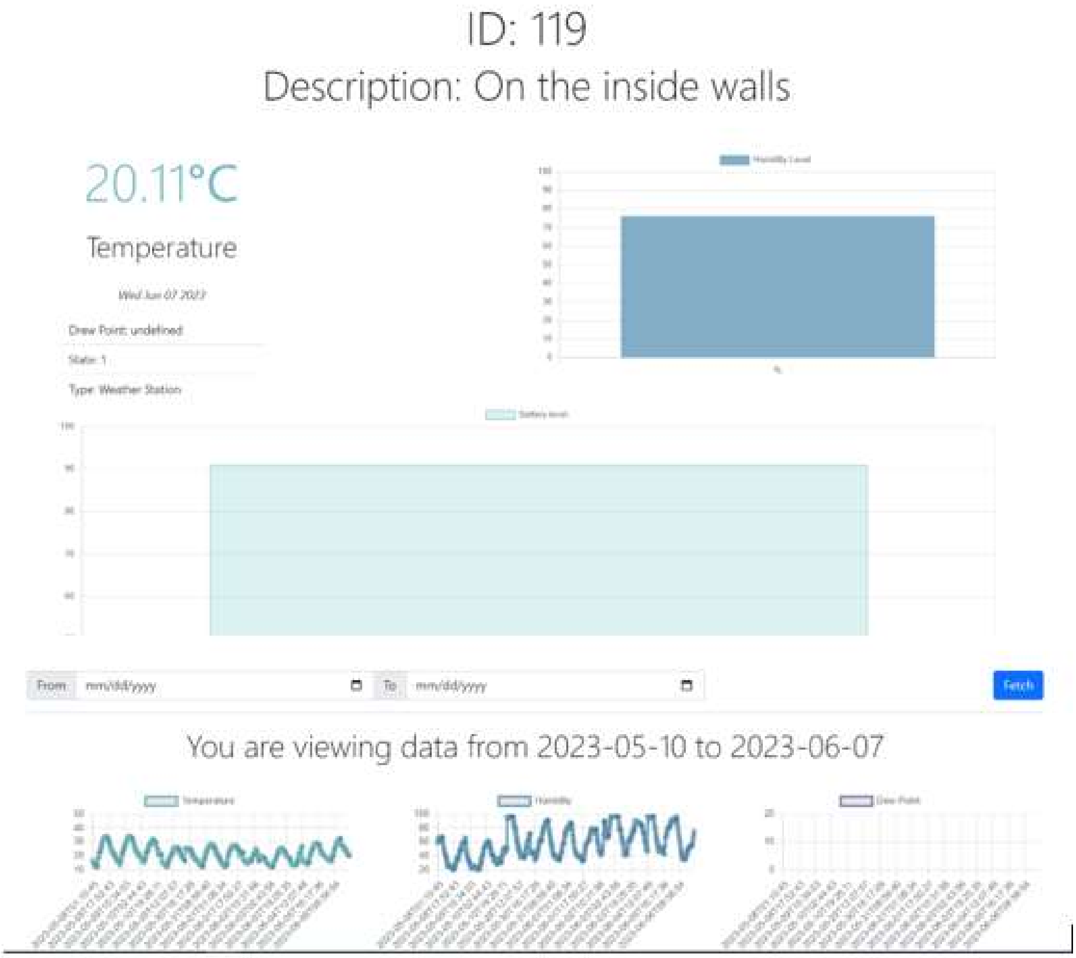

Figure 19 Sensor on the inside walls of San Jeronimo

The user then needs to investigate how the region will be affected in case of an earthquake and initiates a seismic scenario. Selecting a range of earthquake magnitudes, the monastery as the point of interest and a distance of 100 km, the system filters possible events that fall under these criteria (see Figure 20).

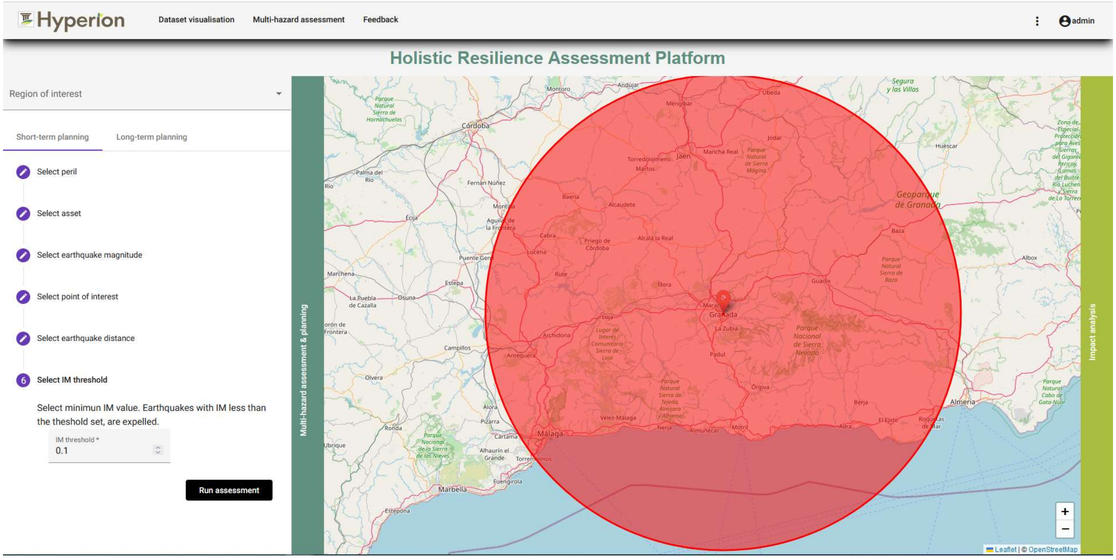

Figure 20 Filtering seismic phenomena

As a result of the assessment, the platform displays for regions on the map the expected number of buildings per damage state for each building typology, i.e. reinforced concrete frame or unreinforced mansonry (see Figure 21).

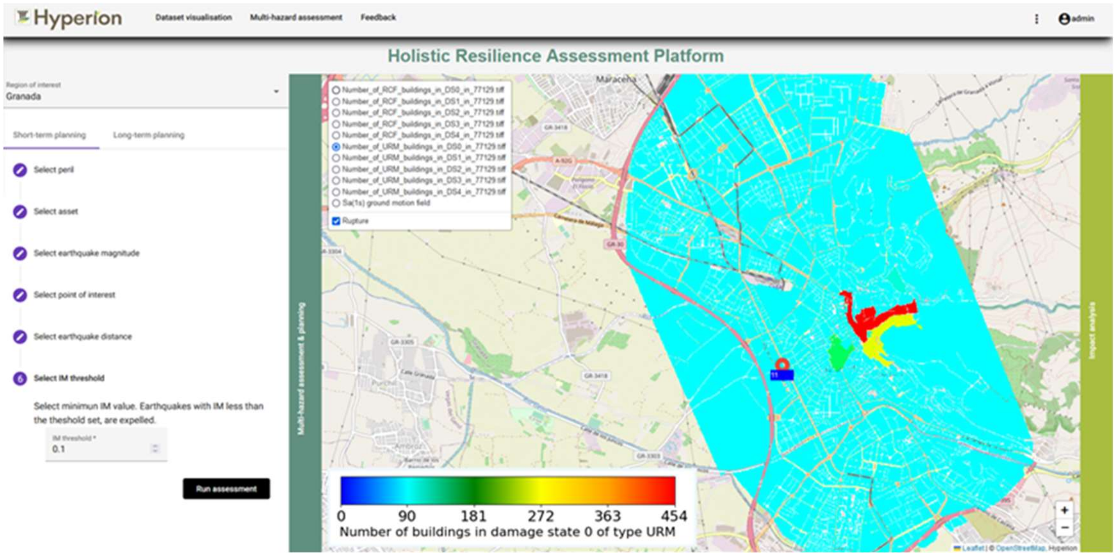

Figure 21 Number of damaged-state-0 (i.e., undamaged) unreinforced masonry buildings for the selected scenario

Further impact analysis results (Figure 22) display the probabilities of Granada's Tier 1 structures being in a damage state; S. Jeronimo, Mol. Marques and P.Elvira, the indirect and direct losses and a graph (Figure 23) that depicts the percentage of buildings, grouped by typologies, that will be found in the various damage states.

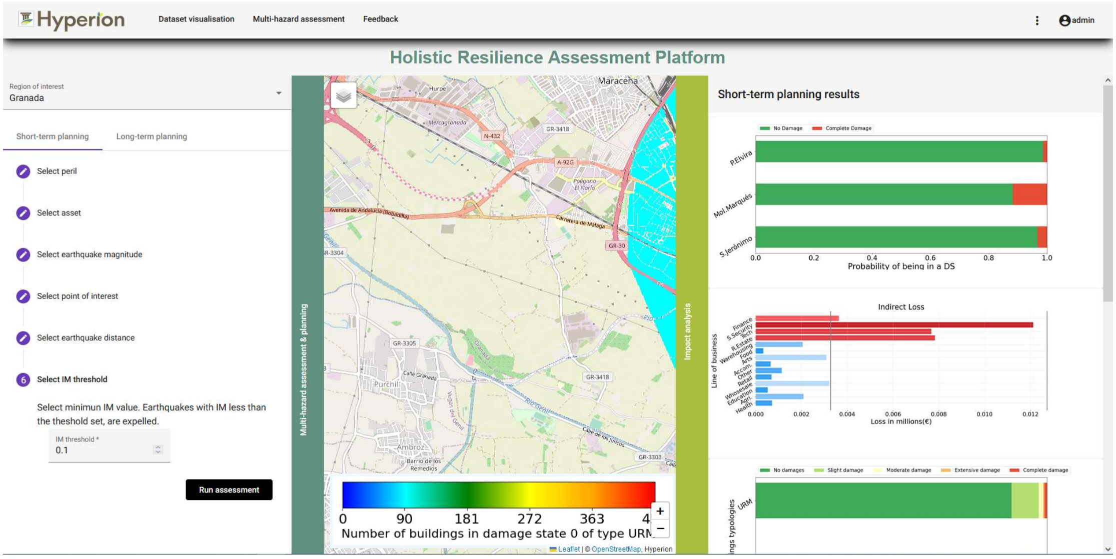

Figure 22 Impact analysis results for Granada, showing the condition of Tier 1 buildings, as well as the indirect losses per sector of the economy.

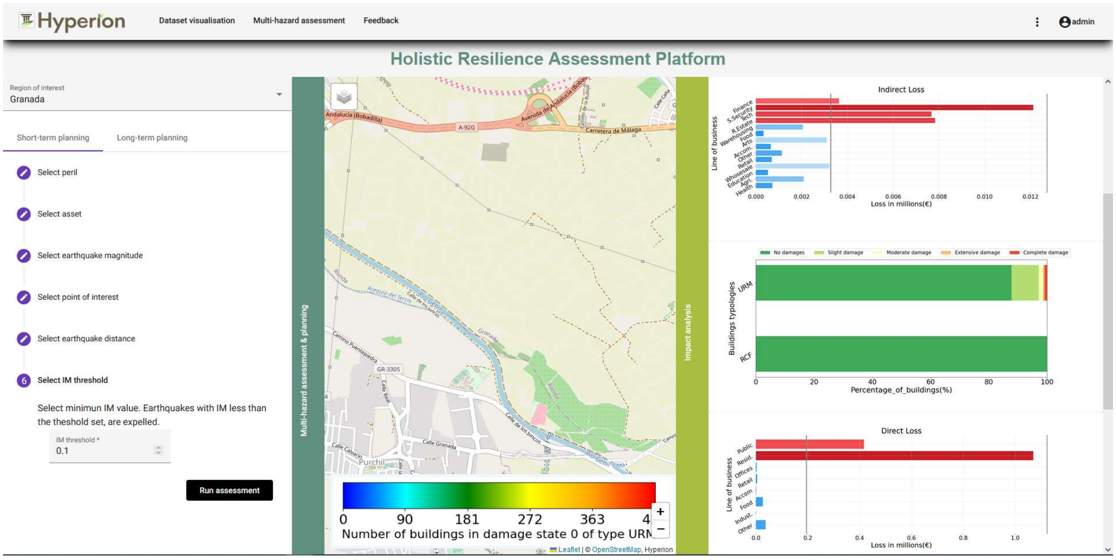

Figure 23 Percentage of buildings, grouped by typologies, in the various damage states

For long-term planning, the average annual losses are estimated by HRAP and shown in the map of Figure 24. Highest losses are reported in the historical city center. This coincides with the highest concentration of vulnerable unreinforced masonry buildings, as shown in Figure 25 (red color). Areas outside the city center mainly comprise reinforced concrete frame structures (shown in blue), built in more recent times and being much less vulnerable to damage.

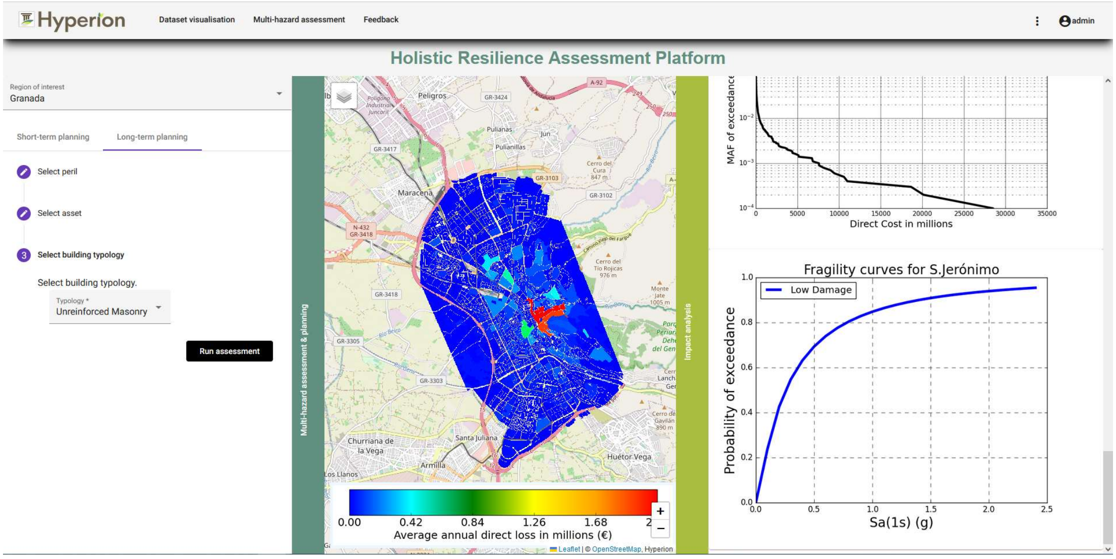

Figure 24 Average annual direct losses in millions of euros (middle) together with Tier 1 building fragilities (right)

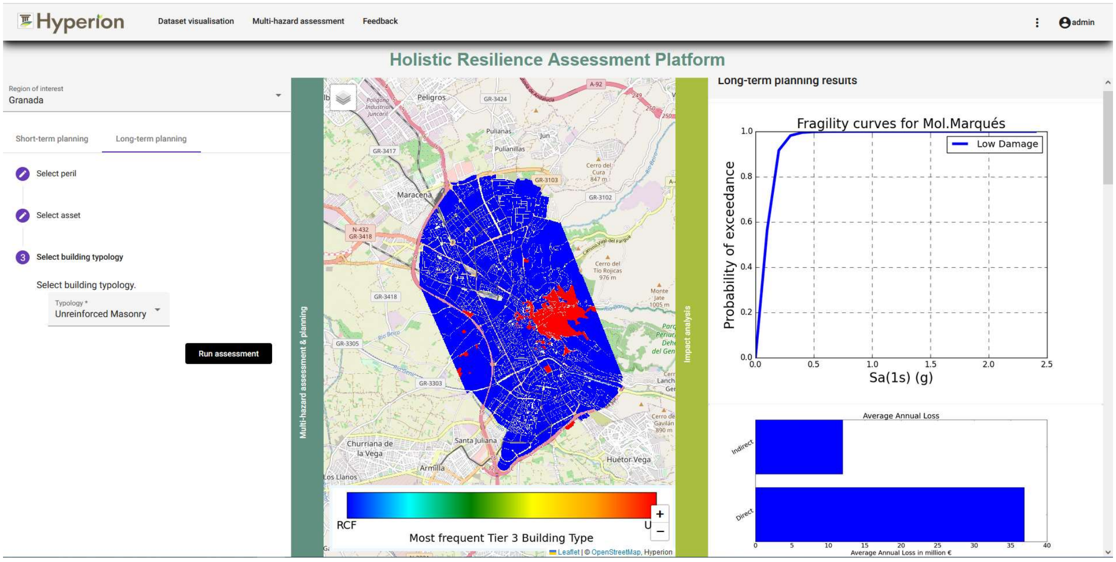

Figure 25 Map of exposed assets, showing the most frequent building types in Granada. Blue indicates reinforced concrete buildings, while red indicates unreinforced masonry structures

6 Venice (Italy) Pilot

For Venice pilot activities 1 weather stations and 6 smart tags were installed at 1 Tier 1 building as outlined in the table below.

Table 4 Venice hardware installations

Site	Building	Place of Installation	Quantity
Smart tag	Torre dell'Orologio (Clock Tower)	Outer side	5
		Inner side	1
Weather station	Torre dell'Orologio (Clock Tower)		1

During the Venice pilot activities, the system was demonstrated to the invited stakeholders in Venice in April 2023. A series of interactive presentations and demonstrations were held, showcasing the results of HYPERION and introducing the integrated resilience assessment platform developed during the project.

Figure 26 Demonstration of the HYPERION system for Venice pilot activities

The Venice pilot activities in addition to the overall system functionalities, focused on accessing flood scenarios at the St. Marco square as well as the socioeconomic impact of such events. The following paragraphs outline the Venice specific scenarios that the stakeholders experimented with, and the demonstration was focused on.

Entering HRAP, the user focuses on Venice and chooses Flood as the Peril. A flood height of 1.70m above mean sea level is chosen. This is a fairly severe event that can have major consequences. The resulting flood water depths appear in Figure 27. The highest depths appear in the unprotected coastline, but this is of little concern. Most importantly, the airport remains safe, but parts of Venice are indeed flooded. Zooming into San Marco Square (Figure 28), it becomes obvious that some of the most significant flooding will occur right there, reaching 1.2 to 1.3m. By selecting to view the socioeconomic impact, the influence diagrams and related timeseries of recovery appear per Figure 29. Apparently, even under such a severe event, Venice is used to flooding. It will take about 22 days to full recovery, but some tourism will be lost. Accomodation, Food & Beverage, and other service sectors are the hardest hit. By the 6th day, 20% of the tourists have left or cancelled reservations and about 1.7 million euros have been lost. The user may also view additional short- or long-term information on the projected weather, viewing different EuroCordex scenario predictions, for example regarding temperature till 2100 in Figure 30.

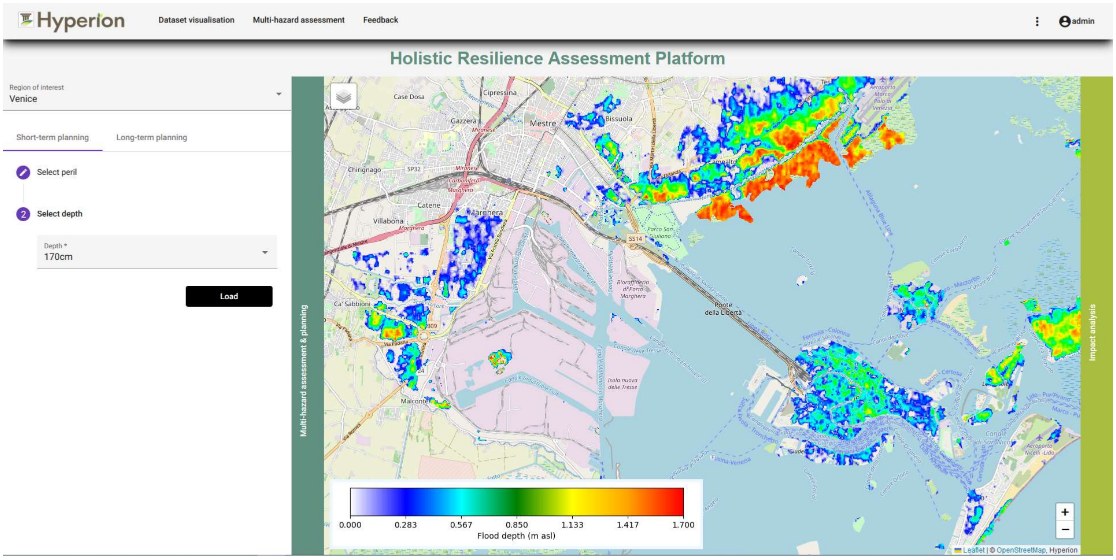

Figure 27 Map of flood depth in Venice. The coast shows the highest depths, but it is also the one that is of least concern.

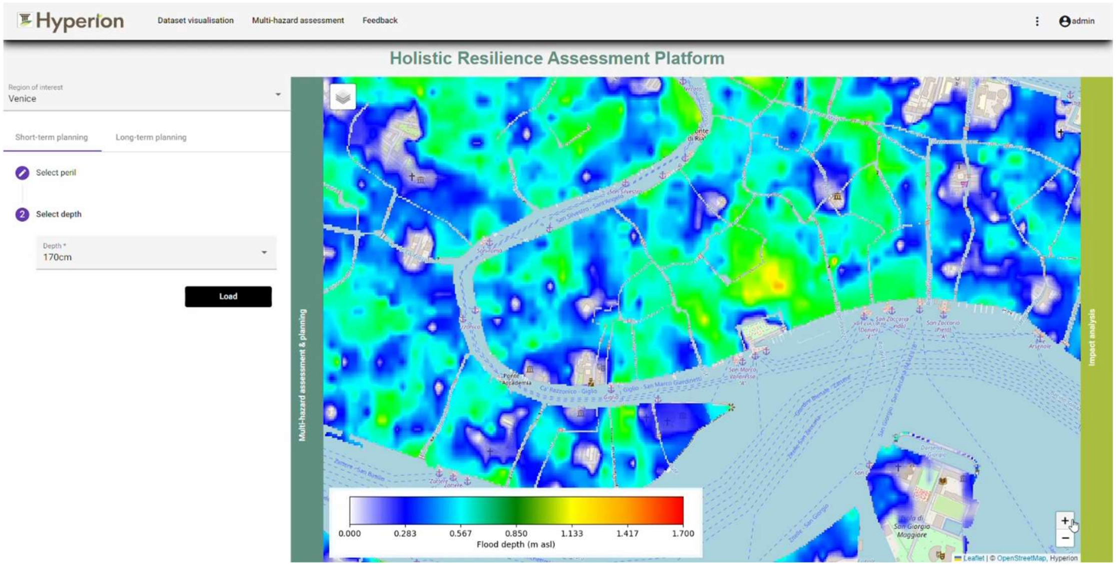

Figure 28 Map of flood depth in Venice, zooming in on the area of San Marco Square.

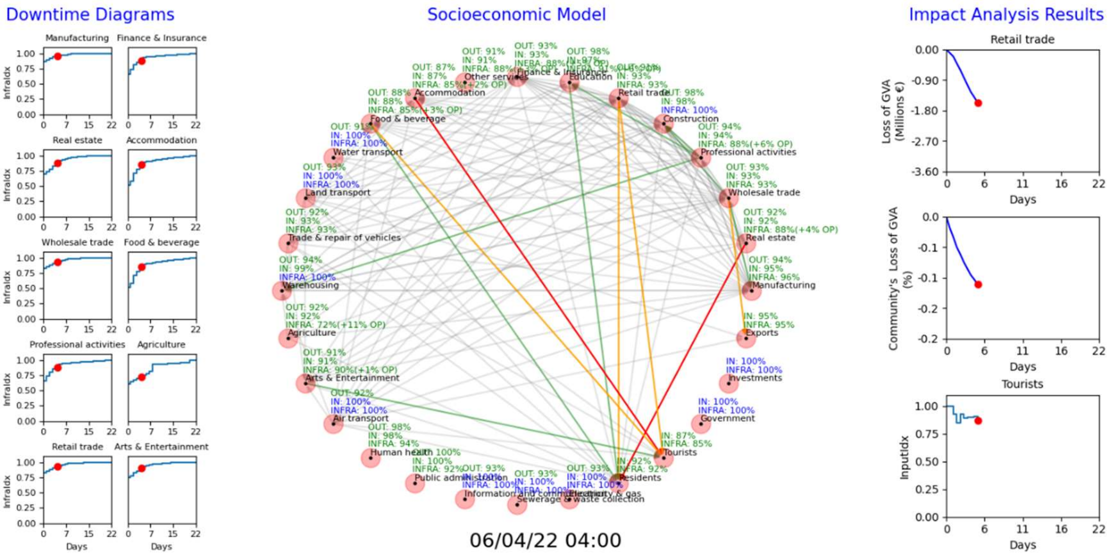

Figure 29 Business impact of the 1.7m flood event on Venice, showing the recovery of different economy sectors, as well as the impact in terms of tourism and GVA (gross value added) losses

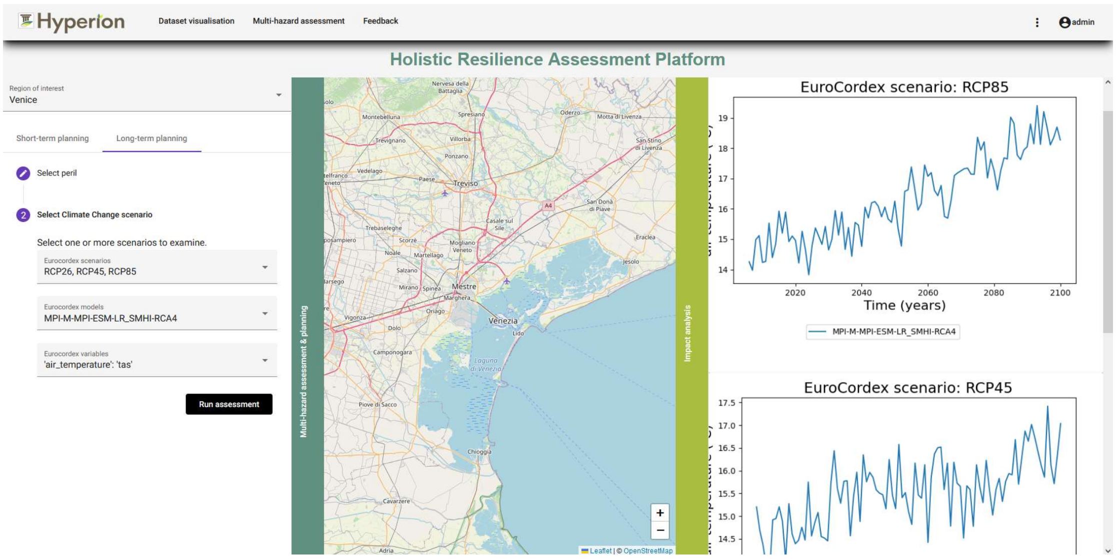

Figure 30 EuroCordex scenario predictions for aur temperature from 2020 to 2100. RCP85 is the most severe scenario, showing high average temperatures, while RCP45 is considered a more moderate one.

7 Conclusions

HYPERION is a complex system that integrates hardware and software components to provide a range of capabilities to local authorities. Users can explore different map layers and datasets, experiment with various scenarios and long-term planning modes, and generate impact analysis graphs. Moreover, HYPERION offers a mobile application for citizens to report any losses or observed deterioration of cultural heritage sites, providing valuable information for risk management. Overall, the platform provides an integrated approach to risk management, enabling authorities to mitigate potential disasters and minimize losses.

The pilot activities of the HYPERION system focussed on the four pilot sites of Tønsberg (Norway), Granada (Spain), Rhodes (Greece), and Venice (Italy). The functionalities of the system were demonstrated to the end users who were also given access to the live environment for further experimentation.

After their familiarization with the HYPERION system, they provided feedback for the system through an integrated questionnaire. Their feedback was considered for improving the system and fixing bugs, to confirm the successful operation of the HYPERION system as per the initial requirements, and to derive recommendations for further improvements. The analysis of the feedback is detailed in Deliverable 8.7 "Trials assessment and recommendations".