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HERIT ADAPT

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Abstract

This deliverable, D.2.2.1, presents a comprehensive and unifying methodology for the pilot testing phase of the HERIT ADAPT project. Designed to ensure consistency, comparability, and replicability across all participating sites, the methodology provides a structured framework for territorial partners to validate the project's sustainable tourism model and its associated innovative solutions.

The document outlines a cyclical, multi-phase process that guides partners from the initial pilot specification—defining site-specific challenges and selecting a tailored subset of enhanced solutions and tools to test—through to the final evaluation and validation. Key stages detailed within include the strategic engagement of stakeholders through Territorial Working Groups (TWGs) to foster co-creation and local ownership, the operational execution of the pilot testing itself, and the rigorous monitoring of progress against a set of relevant common Key Performance Indicators (KPIs).

By establishing this standardized yet adaptable approach, the methodology ensures that insights gathered from diverse geographical and heritage contexts can be systematically analyzed, compared, and synthesized. The ultimate outcome is a robust evidence base for evaluating the effectiveness of the HERIT ADAPT model, facilitating its validation and subsequent scaling across the Euro-Mediterranean region.

Project Partners

Organization	Abbreviation	Country
Region of Western Greece	RWG	GR
ATHENA, Research and Innovation Centre in Information, Communication and Knowledge Technologies, Industrial Systems Institute	ATHENA	GR
European Public Law Organization	EPLO	GR
Sapienza University of Rome	SDR	IT
Municipality of Genoa	COMGE	IT
Dubrovnik Development Agency DURA	DURA	HR
Limassol Tourism Development and Promotion Co Ltd	LTC	CY
Old Royal Capital Cetinje	PCT/ORCC	ME
University of Granada	UGR	ES
Regional Tourism Agency Occitanie	CRTL	FR
Ministry of Tourism of the Republic of Bulgaria	MTRB	BR

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Date	Person	Action	Status
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Glossary

Use Case	UC
Key Performance Indicator	KPI

Summary

This document outlines a standardized implementation methodology for pilot testing the HERIT ADAPT Sustainable Tourism Model. The framework is designed to be a cyclical, evidence-based process that ensures consistency, enables comparative analysis across diverse sites, and validates the effectiveness of proposed solutions through rigorous, stakeholder-driven experimentation.

The methodology begins with a foundational Preparation and Co-Design Phase. In this initial stage, each pilot site conducts a comprehensive diagnostic to establish a baseline across environmental, cultural, socio-economic, and tourist flow data. Concurrently, Territorial Working Groups (TWGs) already established are enriched with participants, uniting the quadruple helix of public authorities, private businesses, research institutions, and local communities. The TWGs collaboratively define the pilot's specific scope, selecting a focused subset of enhanced solutions and tools from the HERIT ADAPT toolkit to test. Crucially, this phase concludes with the definition of a common set of Key Performance Indicators (KPIs), against which baseline measurements are recorded.

Following preparation, the Execution and Monitoring Phase commences, where the planned solutions are actively implemented in the pilot site. Throughout this operational period, quantitative data related to the predefined KPIs is systematically collected. This is complemented by continuous qualitative feedback gathered from both visitors and through regular TWG meetings, fostering a dynamic environment for shared oversight and real-time problem-solving.

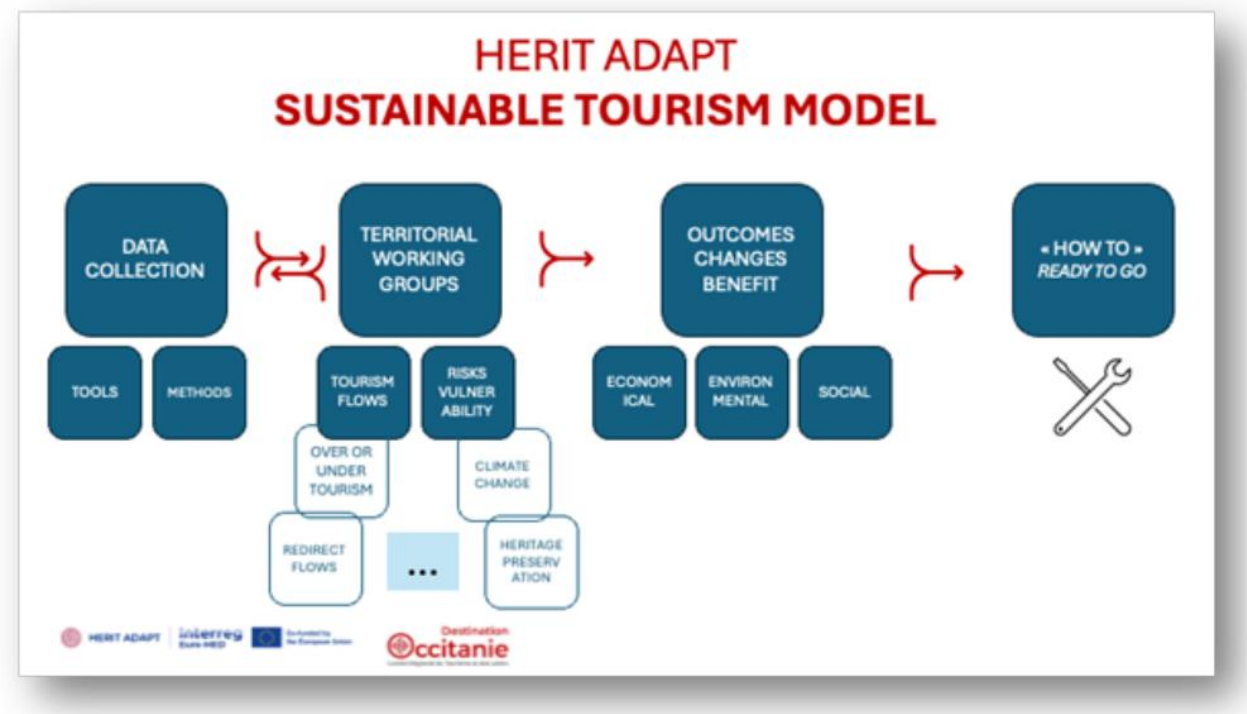
To ensure agility and learning, a Mid-Term Adaptation checkpoint is integrated into the process. Here, an interim analysis of collected data and feedback is conducted. These findings are reviewed by the TWGs to assess progress and collaboratively decide on any necessary adjustments to the testing approach, embodying a principle of adaptive management to keep the pilot aligned with its objectives.

The cycle culminates in the Final Evaluation and Validation Phase. A comprehensive analysis of all data from the entire testing period is performed to measure the overall impact and effectiveness of the interventions. Final stakeholder feedback is synthesized, feeding the activities of WP3. This formal validation captures methodology, results, lessons learned, providing an evidence-based case study.

Finally, the methodology emphasizes Learning and Transferability. The insights and validated outcomes from each pilot are shared across the HERIT ADAPT network of stakeholders. This transforms individual pilot experiences into a collective repository of best practices, directly enabling the replication and scaling of the successfully tested Sustainable Tourism Model to other territories within the Euro-Mediterranean region and beyond.

The HERIT ADAPT Sustainable Tourism Model

The HERIT ADAPT Sustainable Tourism Model elaborated in D.1.1.4 is a comprehensive, evidence-based framework designed to facilitate fortifying cultural and natural heritage sites across the Euro-Mediterranean region against pressures like these of overtourism and climate change. Recognizing tourism as a vital economic driver that must be balanced with preservation, the model moves beyond theoretical principles to offer a practical, actionable pathway toward resilience. Its core strength lies in the dynamic interplay of three interconnected pillars, which together form a cyclical process of assessment, collaboration, and adaptive action.



PILLAR 1: DATA-DRIVEN DIAGNOSIS AND UNDERSTANDING

This pillar establishes the evidence-based foundation for all subsequent actions. It moves from reactive guesswork to proactive, informed decision-making by systematically collecting and analyzing critical data across four key domains:

- *Tourism Flows and Impacts*: Quantifying visitor numbers, origins, and behaviors to understand patterns of overcrowding, seasonality, and their direct environmental footprint (e.g., energy consumption, waste generation).
- *Risk and Vulnerability Assessment:* Evaluating the specific threats climate change poses to each site and assessing the structural and ecological vulnerabilities of the heritage assets.
- *Socio-Economic Dynamics*: Analyzing tourism's role in the local economy, including job creation, revenue distribution, and the quality of interaction between visitors and host communities to ensure tourism delivers equitable benefits.

- *Cultural Heritage Documentation*: Utilizing innovative digital tools like 3D modeling, drones, and IoT sensors to create a high-resolution baseline of a site's condition, enabling precise monitoring of degradation and informing restoration efforts.

This continuous data stream provides the objective evidence needed to identify the most pressing problems, forecast future scenarios, and measure the impact of interventions.

PILLAR 2: MULTI-STAKEHOLDER COLLABORATION VIA TERRITORIAL WORKING GROUPS (TWGS)

The model recognizes that complex challenges cannot be solved in isolation. The second pillar operationalizes inclusivity through the establishment of Territorial Working Groups (TWGs). These platforms actively engage the "Quadruple Helix" of stakeholders:

- Public Authorities (for policy alignment and regulation),
- Private Businesses (for operational capacity and market innovation),
- Research and Academic Institutions (for scientific expertise and independent evaluation), and
- Local Communities and Civil Society (for ensuring social equity, cultural respect, and long-term local ownership).

The TWGs are not merely consultative; they are the engine of co-creation. They translate data into strategy, jointly defining priorities, co-designing solutions, and overseeing the implementation of pilot actions. This collaborative governance model builds trust, merges diverse forms of knowledge, and ensures that strategies are grounded in local reality, thereby enhancing their legitimacy and long-term sustainability.

PILLAR 3: IMPLEMENTATION OF ADAPTIVE AND INTEGRATED STRATEGIES

Armed with robust data and a coalition of committed stakeholders, the third pillar focuses on tangible action. It involves the implementation of targeted, integrated strategies designed to create a virtuous cycle of sustainability including Adaptive Tourist Flow Management, Climate-Resilient Preservation, Diversification and De-seasonalization, Technology-Enhanced Experience and Monitoring.

The power of the HERIT ADAPT model lies in the synergy of its pillars. Data (Pillar 1) informs the dialogue within the TWGs (Pillar 2), which in turn co-designs and champions the implementation of targeted strategies (Pillar 3). The outcomes of these strategies are then measured, feeding new data back into the system, thus creating a continuous feedback loop for learning and improvement. This structured yet flexible approach ensures the model is not a one-size-fits-all prescription but a replicable and adaptable framework for building truly resilient tourism destinations that can thrive in the face of contemporary global challenges.

Methodology

The HERIT ADAPT implementation methodology provides a structured, cyclical process for territorial partners to test, evaluate, and refine the HERIT ADAPT Sustainable Tourism Model in their specific pilot sites.

Phase 1: **Pre-Testing Preparation & Baseline Establishment**

- **Site-Specific Diagnostic**:
  - Conduct a comprehensive assessment of the pilot site exploiting the four data categories outlined in the model: Environmental, Cultural/Heritage, Socio-Economic, and Tourism Flow Management.
  - Use diverse tools like surveys, existing environmental data, visitor counts, stakeholder interviews.
  - Produce a detailed "State of the Site" identifying key challenges, risks, and opportunities.
- **Formation of the Territorial Working Group (TWG)**:
  - Identify and formally constitute the TWG, ensuring representation from all four stakeholder groups (public, private, academic, community).
  - Engage the TWG partners into regular meetings outlined in a meeting schedule following the pilot progress.
- **Co-Design of the Test Plan**:
  - Co-decide a number of interventions along with the TWG to test the HERIT ADAPT Sustainable Tourism Model in the individual pilot sites.
  - Clearly identify the Test Plan with defined objectives, a timeline, assigned responsibilities, and a list of required resources.
- **Define Baseline Key Performance Indicators (KPIs)**:
  - Before any intervention, measure and record the baseline for the KPIs relevant to the test (e.g., current visitor numbers in peak season, pre-intervention CO2 emissions, existing local employment figures in tourism).

Phase 2: **Testing & Active Monitoring**

- **Implement Interventions**:
  - Roll out the planned interventions in each different pilot site as per the Test Plan.
- **Continuous Data Collection & TWG Engagement**:
  - Systematically collect data related to the interventions and the defined KPIs. Hold regular TWG meetings to share preliminary findings, discuss operational challenges, and gather qualitative feedback.
  - Use different tools like Data dashboards, feedback forms, meeting minutes.
  - Produce a live dataset and a log of stakeholder feedback to be exploited.

Phase 3: **Mid-Term Adaptive Management**

- **Interim Analysis**:
  - Analyze the data and feedback collected in the first half of the testing phase. Compare results against the baseline KPIs.

- **Adjust Interventions**:
    - Decide with the TWG any necessary adjustments to the interventions, taking into account the interim analysis.
    - Produce an updated Test Plan.

Phase 4: **Final Evaluation & Reporting**

- **Comprehensive Data Analysis**:
    - Conduct a final analysis of all data collected throughout the testing period against the baseline and objectives.
    - Produce the complete dataset with pre-post analysis.
- **Stakeholder Feedback Synthesis**:
    - Gather final feedback from the TWG and other participants (e.g., visitors, local businesses) through a concluding workshop or survey.
    - Synthesize the qualitative feedback.
- **Draft the Pilot Evaluation Report**:
    - Compile a final pilot evaluation report that includes
        - an Executive Summary,
        - a Methodology,
        - a pre- and post-intervention data comparison,
        - an Analysis of successes, challenges, and unexpected outcomes,
        - Tested KPIs and their results,
        - Lessons learned and recommendations for scaling or making the intervention permanent,
        - Assessment of the model's transferability to other sites.

Phase 5: **Learning & Knowledge Transfer**

- Share the evaluation report with the broader HERIT ADAPT network and other stakeholders. Present findings to wider audiences.
- Contribute best practices and case studies to the overall HERIT ADAPT Sustainable Tourism Model, enhancing its replicability for other territories.

The proposed implementation methodology ensures a rigorous, evidence-based, and participatory approach to testing, allowing territorial partners to validate the HERIT ADAPT Sustainable Tourism Model's effectiveness in their unique context.

Testing Approach per Pilot site

The current chapter presents the approach followed by each Herit Adapt Pilot site during actual pilot testing. This approach is unique per site, in the sense that both the Sustainable Tourism Model and the Pilot Testing Implementation Methodology are dynamic and adaptable to address the specific needs, challenges and characteristics of each individual site, showcasing also the **replicability potential** of the project in other territories.

In terms of the Sustainable Tourism Model, emphasis is placed on selecting the right tools and methods to ensure successful implementation and replicability across different EuroMed countries and pilot sites. A selection of possible tools, solutions and artifacts available to project partners for integrating into the Herit Adapt Model for their Pilot sites includes the following:

- Cultural Heritage Site 3D modeling solution and ensuing 3D model (Western Greece, Montenegro, Cyprus)
- Cultural Heritage 3D model annotation tool (WARMEST ART3MIS)
- Cultural Heritage AI enabled defect detection and piece matching
- XR solutions (Rome)
- Infrastructure and solution envisaged in Dubrovnik
- Infrastructure and solution envisaged in Genoa
- Data analysis solution envisaged in Occitanie
- Emotionally Intelligent Destinations (EID): Cultural heritage tourist product based on audiovisual storytelling and emotional narratives (UGR)

Selection and integration of the proper tools into the initial model has led to a **uniquely tailored Sustainable Tourism Model** for each specific site. This modeling approach, together with the pilot testing implementation methodology followed in each area of interest are presented in the following sections.

Canigo Grand Site / Villefranche de Conflent, France

Villefranche de Conflent is situated in the Pyrenees Mountains at the most southern part of Occitanie. It is a fortified city built in the 12th century and remodeled by the architect Vauban. Today Villefranche de Conflent is a highly protected area, part of the Unesco World Heritage, with a little bit more than 200 inhabitants and several hundreds of thousand tourists.

Specific Objectives

The choice of Herit Adapt pilot site of Villefranche de Conflent was clear. We chose a heritage pilot site being already exposed to climate change variations and having a strong touristic impact.

Two specific objectives were chosen :

1) Objectify the tourism flows

2) Determine and raise awareness concerning the vulnerability to risks caused by climate change

Our pilot action contributes to the Herit Adapt sustainable tourism model with a solid method on how and where to start taking action. This means to anticipate on the basis of solid data and observation.

Individual issues related to each pilot

The experimentation in Villefranche de Conflent addresses the following issues:

Issues related to Tourism Flow Management:

- **The lack of precise data** on visitor numbers and patterns creates challenges in managing peak tourism seasons and regulating visitor flows.
- **Over-tourism risks** damaging the cultural and natural heritage, especially in areas with limited infrastructure for high visitor numbers.
- **Coordination between local and regional stakeholders** is necessary to implement effective flow regulation and ensure sustainable tourism practices.

Infrastructure and Accessibility:

- Villefranche de Conflent's mountainous location presents **logistical challenges for mobility and transport**.
- **Improvements** are needed in transportation infrastructure to ensure smooth visitor access while **minimizing environmental impact**.

Stakeholder Engagement:

- **Raising awareness** among local communities, regional authorities, and visitors is crucial to fostering support for sustainable tourism practices.
- **Collaboration** between local, departmental, and regional entities is required to align tourism offerings with sustainability goals.

Economic and Cultural Opportunities:

- The site offers potential for economic growth by **attracting responsible tourism**.
- Promoting the site as a destination with a focus on sustainability and cultural heritage can **enhance visitor engagement** and **benefit local communities**.

Issues Related to Climate Change

Water Resource Management:

- The region faces challenges related to water scarcity, exacerbated by climate change and increasing visitor demand.
- Addressing water management issues is a priority to ensure both sustainable tourism and the preservation of local ecosystems.

Vulnerability Assessment:

- The mountainous terrain and surrounding ecosystems are vulnerable to the impacts of climate change, including biodiversity loss and extreme weather conditions.
- The pilot project emphasizes conducting risk analyses to identify and mitigate these vulnerabilities effectively.

Raising Awareness of Climate Impacts:

- Efforts are needed to educate stakeholders and visitors about the implications of climate change on the site and its surroundings.
- Connecting climate issues with tourism management can help align local actions with broader climate adaptation goals.

Sustainable Practices and Monitoring:

- Tools like OTO (Regional Tourism Intelligence Tool) is being tested to collect data on tourism flows and risks while integrating climate resilience into tourism planning.

HERIT ADAPT Sustainable Tourism Model Evaluation

Understanding Risks and impact

Infrastructure

No infrastructure has been built in the context of the pilot.

Technology

CRTL Occitanie used the Regional Tourism Intelligence Tool "OTO - Observation Tourisme Occitanie".

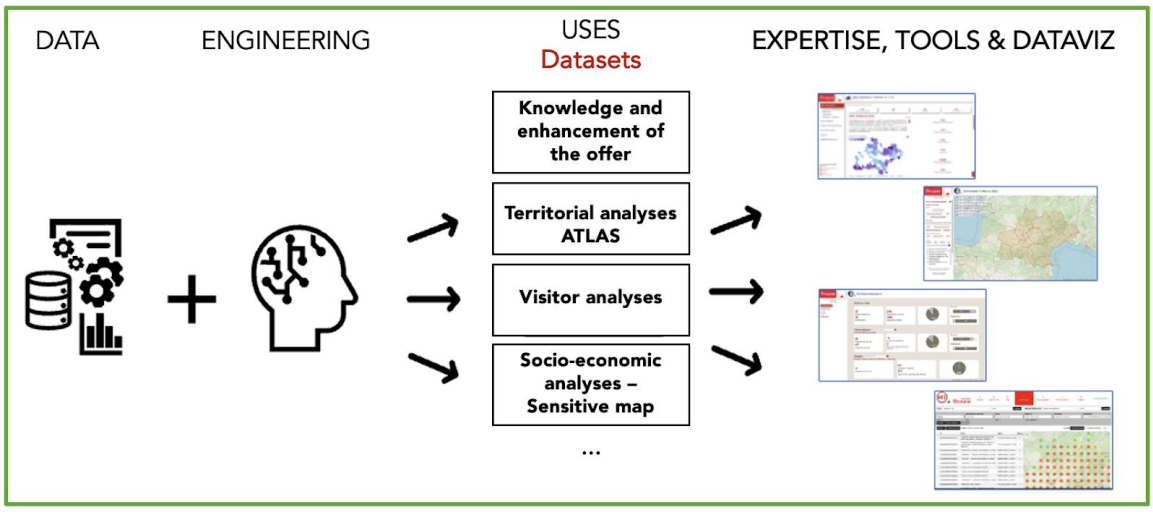
OTO was built using an Agile methodology: prototypes were co-designed and tested with users before full deployment. This ensured functionality was relevant, intuitive, and responsive to real-world needs. Dashboards and tools were created in close collaboration with Departmental Tourism Agency (ADT) partners, tourism offices, and local governments.

OTO offers a modular architecture with thematic entry points:

- **Territories & Mobility**: understanding the link between infrastructure and visitor flows
- **Sustainable Tourism**: visualizing resilience, carbon-free travel, and vulnerability
- **Tourism Observation**: analyzing seasonal trends, accommodation, and sentiment
- **Tourism Supply**: accessing offer data at all scales
- **Professional Development**: sharing training, podcasts, and resources

The platform's success lies in its **combination of technical sophistication and user-centric design**. By simplifying complex data and aligning outputs with local challenges, OTO enables all actors—from policy makers to local agents—to make better-informed decisions and collaborate more effectively.

Today, OTO stands as a regional benchmark in tourism intelligence and a pioneering example of how data can serve transition, inclusion, and long-term territorial resilience.



Data collection

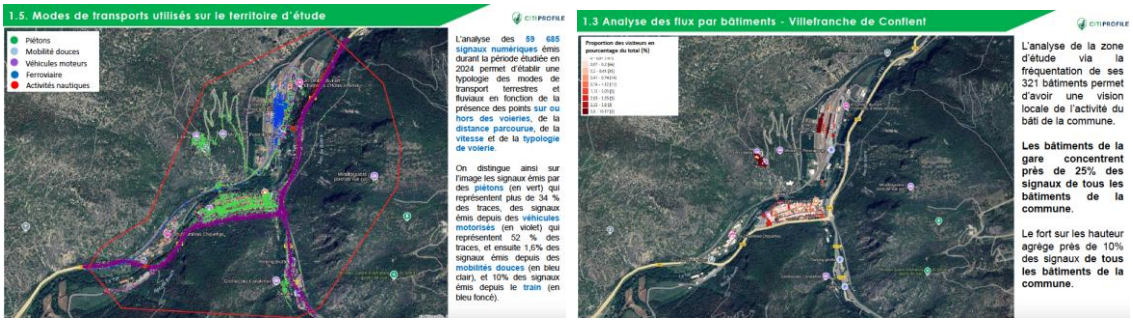
During the experimentation in Villefranche de Conflent, Occitanie, the following data has been collected (profiting from the already existing data within the tool and adding important data). There are tourism flow data and vulnerability check data:

1) Flux vision Orange data set

- **analysing tourism flows** concentrated on mobile telephone data
- **data concerning flows**, tourist origins and socio-democratic profiles
- The data set is integrated directly into **OTO**.

2) City profile data set

- **Exploiting a large data set of GPS human traces**, based geolocation algorithms and calculation methods
- The **automated analysis for diagnosing** land use in the study area makes it possible to determine:
    - The spatial and temporal density of activity
    - The municipalities and IRIS zones (*IRIS* stands for “Ilots Regroupés pour l’Information Statistique,” which are French statistical units used by INSEE.) of origin of visitors
    - The main points of attendance within the study area
    - The modes of transportation used within the territory
    - The hours, days, and temporal patterns of visits



Examples : on first results of CityProfile in Villefranche de Conflent (transport modes used by the visitors, flows per buildings in Villefranche de Conflent).

The data set will be added in OTO.

3) Ecocounters

- **3 ecocounters** have been installed at the tree entry points of the fortified city, measuring the tourism flows
- **The results are analysed** every end of month
- The ecocounters are **installed from August 2025 to August 2026**

The ecosensors are put in place and followed up by the associate partner : Syndicat Mixte Canigo Grand Site.

The data set will be integrated into **OTO**.

4) Vulnerability diagnosis

In order to assess the vulnerability towards risks caused by climate change, the CRT Occitanie is working with the Regional Economic Agency ADOCC (our associate partner) and the Region Occitanie (associate partner as well) on :

4.1 Diagnosis and identification of all vulnerabilities that the pilot site is confronted with, or that are connected to the pilot site. A data analysis goes parallel to a discussion with the efficient

stakeholders. The CNPP 5011 - "Analyse de vulnérabilité aux risques climatiques" referential has been used for the diagnosis. This part is orchestrated by AD'OCC with CRT Occitanie.

4.2 Transform the anaysed risks into positive solutions and raise awareness. A special training will be performed by the team of Villefranche de Conflent and the CRT Occitanie. Following this training, 2 TWG will work on the possible positive outcomes with the stakeholders. This part is developed in partnership with the Region Occitanie and AD'OCC.

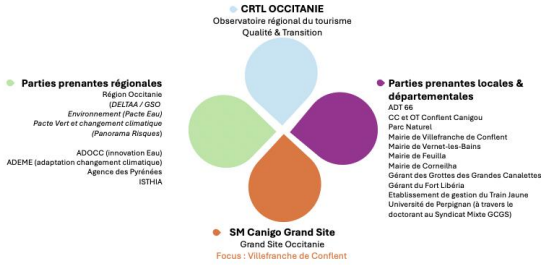
Mapping to tools / solutions

The solution used in the context of Herit Adapt was the Regional Tourism Intelligence Tool (OTO).

Stakeholder engagement

Without stakeholder engagement, the whole process of experimentation would not have been possible. The following stakeholder groups were created during the pliot

- **a territorial working group (TWG Herit Adapt)** with stakeholders from the local level (private and public), the departmental level (mostly public bodies) and regional level (the Region Occitanie, Universities, etc). The list is still growing.



- **a technical territorial working group** in order to concentrate on the technical questions : tourism flows and climate change diagnosis

Stakeholders were involved throughout the whole process of vulnerability check and risks caused by climate change. **Citizens** have not yet been mobilized, as we are working with the stakeholders on positive perspectives, raising awareness moments and first actions to plan.

Outcomes and long-term benefits

Accessibility

- By addressing the risk, mostly caused by climate change, of cutting off Villefranche de Conflent on the only road, different access possibilities are already in place.
- Alternative action possibilities could be discussed within the TWG.

Diversification and De-seasonalization

- The pilot site has visitors all year around, but the shops and restaurants are not all open all year. Tourist presence is guaranteed.
- There will probably be a tourism flow variation in the future, as tourists from the sea side come to Villefranche when the weather is bad or too hot.

Training and capacity building

- The first capacity building will be on how to analyse a vulnerability check and how to work on first solutions with positive outcome, to discuss with the stakeholders.
- Raising awareness will follow with the stakeholders and citizens.

Strategy dimension

- **Problem Context:**
  - need to objectify tourism flows
  - water management
  - vulnerability and risks
- **Strategy & Goals:**
  - the tools (OTO + Flux Orange + CityProfile + Vulnerability method) are **implemented all at the same time** and they complete each other.
  - **the following SDGs are activated** :
    - N°17 : Partnerships for the goals
    - N°13 : Climate action
- **Tools/Methods:**
  - OTO
  - Eco sensors
- **Expected Outcomes & Impact:**
  - Tourism flows objectified in the pilot site
  - Vulnerabilities towards risks caused by climate change
  - Build a territorial working group having a positive dynamic concerning climate change

KPIs

A. Environmental Sustainability:

- Visitor Flow Density
- Ratio visitors/inhabitants
- Number of risks identified caused by climate change and possible solutions addressed

B. Socio-Cultural Sustainability

- Local Community Benefit & Engagement
- Upskilling
- Stakeholders involved
- Solutions and positive perspectives

C. Economic & Operational Sustainability

- Contribution to Adaptive Management Capacity
- Cost effectiveness of Monitoring/Interventions
- Average Visit Duration vs. Control Group/Baseline
- Average Visitor numbers

D. Visitor Behaviour Change Towards Sustainability

- Visitor Awareness & Knowledge Gain

Temple of Apollo Hylates, Limassol, Cyprus

Apollon Hylates, a sanctuary, was an important religious centre. Originally, the site consisted of a temple, a circular monument, and a formalized Archaic Altar and Precinct. During the Roman period the site was extended with the addition of the south and north buildings, which may have been used for the display of votives or the accommodation of visitors. Most of the monuments belong to the site's 1st century AD restorations and consist of Apollo's temple (which has been partly restored), pilgrim halls, the 'palaistra' (where athletes exercised and played games), a bath complex, and a holy precinct.

Specific Objectives

The pilot experimentation in the Limassol site aims to test and demonstrate innovative, sustainable practices that minimize environmental impacts while enhancing visitor experience in a lesser-known cultural and natural heritage area. The specific objectives are as follows:

1. **Reduce Environmental Footprint of Tourism Activities**
   - Implement eco-efficient management practices (e.g., waste reduction, energy-saving technologies, sustainable mobility options) to decrease resource consumption and pollution.
   - Contributes to the Environmental Sustainability pillar by promoting low-impact tourism and the responsible use of local resources.
2. **Enhance Visitor Experience through Smart and Sustainable Solutions**
   - Develop digital tools and interpretative materials to improve visitor engagement, accessibility, and understanding of the site's cultural and natural values.
   - Supports the Innovation and Digital Transition dimension, using smart technologies to create meaningful, educational, and sustainable tourism experiences.
3. **Encourage Year-Round Tourism**
   - Promote the site as an alternative to mass-tourism destinations to balance visitor flows and reduce seasonality.
   - Contribute to Socio-Economic Sustainability by spreading tourism benefits across communities and reducing pressure on heavily visited areas.
4. **Strengthen Community Involvement and Local Value Chains**
   - Engage local stakeholders (municipalities, Universities, NGOs and students) in to ensure shared benefits and stewardship of heritage assets.
   - Align with the Governance and Community Participation component, fostering collaboration and long-term site resilience.
5. **Monitor and Evaluate Sustainability Indicators**
   - Collect data on environmental impact, visitor satisfaction, and socio-economic benefits to inform adaptive management and policy recommendations.

- Reinforce the Monitoring and Adaptive Management approach, ensuring continuous improvement and replicability across other pilot sites.

Through these objectives, the Limassol pilot will serve as a **living laboratory** for testing sustainable tourism strategies that balance **heritage conservation**, **visitor satisfaction**, and **local development**. HERIT-ADAPT model will provide measurable evidence on how integrated, participatory, and technology-supported approaches can make cultural and natural heritage sites more resilient and sustainable.

Individual issues related to the pilot

A. Geographical area

Coastal: The Temple of Apollo Hylates faces several challenges as it is located near the coastal area of Kourion in Limassol region. Many challenges are exacerbated by climate change, human activities and economic issues**.**

B. Preservation challenges of cultural / natural heritage

- **Environmental factors and climate change impact:** The rain, strong wind and extremely hot weather, dry and humidity can cause natural erosion and deterioration of the temple.
- **Human Impacts:** Tourists can walk and approach the Temple. This can lead to increased foot traffic, pollution and physical damage to the site.

C. Managing and Optimizing flows:

The pilot site, as many popular tourist areas in Cyprus, has a lack of pedestrian friendly infrastructure, especially to people with disabilities, making it difficult for tourists to have access. Another challenge is the insufficient public transport in Limassol due to limited routes. There is also a lack of regulations for the protection of the site from high tourism and appropriate strategies for protection from climate change.

D. Reducing negative impact on climate and raising awareness:
Waste Management: the lack of good waste management can lead to environmental degradation.
Raise Awareness campaigns: Organization of digital campaigns and events to raise awareness of climate issues related to the selected area.

HERIT ADAPT Sustainable Tourism Model Evaluation

The evaluation of the HERIT ADAPT pilot in Limassol, focused on the Temple of Apollo Hylates, highlights a well-structured and promising implementation of the Sustainable Tourism Model (STM). Governance and stakeholder engagement are strong, with an active Territorial Working Group (TWG)

bringing together the Limassol Tourism Development & Promotion Company, the Department of Antiquities, The Deputy Ministry of Tourism, and other local and national authorities, demonstrating effective multi-level collaboration.

Digital and technological integration is of high importance, with the development of a high-resolution 3D model of the temple showcasing advanced digital heritage practices. However, while the pilot emphasizes heritage resilience and climate adaptation, there is limited publicly available evidence of active environmental monitoring systems, resulting in a moderate rating for heritage and environmental risk management. Similarly, tourism flow and sustainability efforts are conceptually integrated into the Sustainable Tourism Model. Overall, the pilot demonstrates strong foundations in governance, technology, and output delivery, with key opportunities to strengthen real-time monitoring, visitor-flow management, and community-based citizen science to ensure long-term sustainability and resilience.

Understanding Risks and impact

Infrastructure

No infrastructure was built during the pilot.

Technology

Key Technologies

High-resolution 3D photogrammetry / laser scanning for digital documentation of the archaeological site

Data collection

Data collection is an important step in the process of documenting the Temple of Apollon Hylates. The precision and completeness of the gathered data can significantly affect the accuracy and fidelity of the resulting 3D model. This stage ensures the capture of all geometric and visual elements of the structure, leaving minimal room for gaps or distortions during the next phases of reconstruction. By integrating laser scanning and drone photogrammetry a comprehensive and multidimensional approach to the documentation process is achieved.

The process begins with the use of terrestrial laser scanning to capture the temple's accessible sections with an extremely high level of precision. The laser scanner is strategically placed around the structure to achieve full coverage while minimizing occlusions from architectural features or nearby objects. By emitting laser beams and measuring their return times, the scanner records millions of data points, creating a detailed point cloud that represents the geometry of the temple. All scans are aligned using the scanner's native software and alignment is optimized until the required accuracy is achieved. At the end of this stage the final alignment report is evaluated to verifying that all the alignment deviances are less than 3mm. This step provides a foundational dataset with sub-centimetre accuracy for the lower and mid-level sections of the structure.

To document the higher and less accessible parts of the temple, drone photogrammetry is used. A pre-planned flight path ensures that the drone captures images from multiple perspectives and elevations while also focusing on both horizontal and vertical orientations to achieve the optimal coverage. Adequate image overlap, usually 60-80%, is maintained to ensure seamless stitching

during the photogrammetric processing. Each image is geotagged using the drone's onboard GPS system.

For areas requiring detailed surface information, an increased number of high-resolution images is captured using the drone's onboard camera. These images focus on intricate features such as carvings or small architectural elements that demand high fidelity in the final model.

After the data collection is complete, the datasets from the laser scanner and drone camera are cross-referenced to verify completeness. Any identified gaps are addressed with additional scans or images. The resulting integrated dataset serves as a robust foundation for generating an accurate and visually rich 3D model of the temple. The thorough and precise data collection process is vital for ensuring the success of the documentation project, as it captures not only the structure but also its contextual relationship with the surrounding environment, leveraging synergies with the wider area to enhance the final output.

Finally, the pilot also incorporates citizen engagement and participatory data collection components, encouraging residents and visitors to contribute environmental or site observations through citizen-science initiatives. These contributions will complement institutional datasets, strengthen local stewardship, and enhance adaptive management capacity. Together, these interconnected data streams create a comprehensive, multi-stakeholder evidence base for heritage protection, tourism sustainability, and climate adaptation, balancing open data principles with the safeguarding of sensitive cultural heritage information.

Mapping to tools / solutions

The HERIT ADAPT pilot at the Sanctuary of Apollo Hylates delivers a suite of digital outputs aimed at advancing both scientific preservation and public engagement. The primary outcome will be a high-resolution 3D model that precisely captures the temple's geometry and surface textures, including intricate carvings, fine architectural details, cracks, and other structural features. This high-fidelity model will support conservation experts in restoration planning, structural assessments, and long-term preservation strategies. Complementing this, a low-resolution 3D model is developed for educational and outreach purposes—optimized for accessibility and interactive use across platforms such as virtual tours, online exhibitions, and multimedia presentations, enabling broader public appreciation of the site.

Additionally, the project generates a comprehensive raw image data archive, comprising high-resolution aerial and terrestrial imagery collected during the pilot. This archive will not only ensure long-term digital preservation of the site's current condition but also provide a valuable resource for future research, reprocessing, and technological advancements in heritage documentation and analysis. The HERIT ADAPT pilot at the Temple of Apollo Hylates employs a sophisticated technological setup integrating both advanced hardware and software solutions to ensure the highest level of precision in heritage documentation. Using drones equipped with high-resolution cameras and GPS, the project captures detailed aerial imagery and terrain data, complemented by terrestrial laser scanning with sub-5 mm accuracy. A 360-degree camera mounted on the scanner produces high-quality photospheres through 5-bracket HDR imaging, enriching the visual dataset. The collected imagery and point-cloud data are processed through photogrammetry software such

as Agisoft Metashape or RealityCapture to reconstruct accurate 3D geometries, followed by refinement and texturing in Blender, MeshLab, or ZBrush.

The high-resolution 3D digital model of the Temple of Apollo Hylates, captures intricate architectural details, including carvings, surface textures, cracks, and other structural features, supporting long-term preservation, restoration planning, and scientific study.

Stakeholder engagement

At the local level, the HERIT ADAPT pilot at the Sanctuary of Apollo Hylates is strongly rooted in multi-stakeholder engagement through the Territorial Working Group (TWG) established in Limassol. This TWG brings together representatives from the Limassol Tourism Development and Promotion Company, the Cyprus Department of Antiquities, the Limassol Chamber of Commerce and Industry, local and national authorities, environmental NGOs, community representatives, and tourism sector stakeholders. Their collaboration ensures that decision-making reflects a quadruple-helix approach, integrating public institutions, academia, private entities, and citizens, to co-design sustainable management strategies for the site.

In terms of awareness and training, the pilot foresees workshops and community sessions focused on digital heritage, sustainable tourism principles, and climate adaptation awareness. Local guides, and small business owners are expected to receive orientation on how to use the 3D models, virtual materials, and interpretive tools for educational and visitor-management purposes.

Collaborative decision-making is a central mechanism in TWG's operation: stakeholders jointly identify site challenges and prioritize interventions based on sustainability and resilience criteria. The participatory nature of this process allows local communities to have a direct voice in tourism and conservation planning, ensuring alignment with both cultural preservation goals and climate adaptation strategies.

Ultimately, the actions undertaken at Apollo Hylates are designed not only to enhance heritage conservation but also to feed into sustainable tourism and climate adaptation planning for the wider Limassol region. By merging high-precision digital technologies with inclusive, community-based governance, the pilot establishes a model where citizens are not passive observers but active contributors to the long-term resilience and sustainability of their cultural landscape.

Outcomes and long-term benefits

Accessibility

The **Temple of Apollo Hylates**, situated near the ancient city of Kourion, presents several accessibility challenges that affect its overall visitor experience and tourism potential. Its **relatively remote and elevated location**, surrounded by natural terrain and limited infrastructure, makes it less accessible to the general public—particularly to visitors who rely on public transportation or organized tour routes. The **absence of a well-developed transport network**, including infrequent bus services and inadequate signage, restricts visitor mobility and makes reaching the site inconvenient for independent travelers.

Furthermore, the **lack of pedestrian-friendly pathways, shaded areas, and accessibility features for people with reduced mobility** diminishes the inclusiveness of the site. These conditions reduce its visibility within mainstream tourism itineraries and limit its potential as a key cultural attraction within the wider Limassol district. Addressing these issues through **improved transport connectivity, infrastructure upgrades, and inclusive design interventions** would significantly enhance both access and the overall visitor experience, contributing to the sustainable promotion of Cyprus's cultural heritage.

Diversification and De-seasonalization

A significant challenge for the Temple is the seasonal concentration of tourists in Cyprus, which often limits visits to the summer months. This seasonality constrains the economic and cultural benefits of heritage tourism and puts pressure on infrastructure during peak periods. The pilot can help by promoting off-season cultural tourism through thematic events, educational programs, and targeted marketing campaigns. For example, autumn or spring workshops, guided tours, or heritage festivals can attract diverse visitor groups beyond traditional high-season tourists, contributing to a more balanced and sustainable tourism flow.

Training and capacity building

Local stakeholders including site managers, tourism operators, and guides currently require enhanced knowledge in heritage interpretation, sustainable tourism practices, and digital promotion. Training and capacity building will equip them with the tools to improve visitor engagement, protect cultural value, and support responsible tourism development. Strengthening these skills also encourages cooperation between public authorities, tourism agencies, and the local community, helping ensure long-lasting positive impact beyond the pilot phase.

Description of Stakeholder upskilling activities during the pilot

During the pilot, stakeholders will participate in targeted workshops and practical training sessions focused on visitor management techniques, cultural storytelling, digital content creation, and accessibility best practices. These sessions are designed to improve how the Temple is presented and experienced by visitors, enabling stakeholders to create meaningful narratives, enhance promotional efforts, and manage tourism flows sustainably.

Strategy dimension

- **Problem Context:** The Sanctuary of Apollo Hylates suffers from limited accessibility and climate-related stressors like heat, erosion, and vegetation impact. These challenges restrict visitor engagement and sustainable management, while the site also needs improved interpretation to ensure tourism remains meaningful and heritage-friendly.

- **Strategy and Goals:** The pilot enhances the visitor experience by introducing new storytelling tools and collaborative stakeholder practices. The goal is to shift the site narrative toward cultural education and sustainability, ensuring that tourism development benefits both heritage preservation and the local community.
- **Tools and Methods:** The intervention includes the development and use of a 3D digital model of the Sanctuary, guided interpretation frameworks, co-creation workshops with local stakeholders, and capacity-building sessions on sustainable tourism practices and digital content creation.
- **Expected Outcomes and Impact:** The 3D model and enhanced interpretation are expected to increase visitor understanding and engagement, while the strengthened collaboration and training activities support improved destination stewardship. The pilot aims to create a consistent sustainable tourism model that continues beyond the project period and reinforces community and heritage value.

KPIs

KPIs applicable to the pilot site:

- Completion of a 3D model of the Temple of Apollon and creation of a digital media library
- Delivery of a descriptive report documenting the process, tools, and significance of the digital twin
- Number of local school students participating in climate adaptation and heritage awareness visits
- Change in knowledge/awareness among students pre- and post-educational site visit
- Number of maintenance logs, structural assessments, photographs, and environmental observations collected at the site
- Completion of a consolidated site condition report highlighting trends and conservation recommendations
- Number/percentage of community members surveyed regarding the Temple of Apollon and Herit Adapt initiative
- Change in community perception/satisfaction scores related to site preservation and project engagement
- Number of datasets and inputs consolidated from all project partners and stakeholders for final project insights
- Completion of a comprehensive final report summarizing economic, social, and replication potential outcomes

A set of general KPIs related to sustainable tourism.

Environmental and Socio-Cultural Sustainability KPIs:

- Measured reduction in erosion and wear-and-tear at the Temple of Apollon (Kourion, Limassol) following Heritage Adapt interventions
- Number of visitors and observed behavioral patterns at the Temple of Apollon
- Number of incidents, litter, or bottles recorded per unit area of the Temple site
- Cultural Heritage Preservation & Respect demonstrated by local community members and stakeholders at the Temple of Apollon
- Upskilling of students and younger generations through increased knowledge and awareness on Temple condition, conservation practices, and climate change impacts

Temple of Apollo Epicurius, Greece

The Temple of Apollo Epicurius, a UNESCO World Heritage site, is an ancient Greek temple located in Bassae, Peloponnese, Greece. Renowned for the unique combination of a variety of novel ideas both in its external appearance and in its internal arrangements, is dated to 420-400 BC and is believed to be the work of Iktinos, the architect of the Parthenon. Its remote mountainous settings and exceptional preservation make it a significant cultural heritage monument. A shelter, which will be removed at the end of the works, was erected in 1987 to protect the temple against the region's extreme weather conditions.

Specific Objectives

This pilot aims to leverage advanced 3D digitization and AI to serve two core goals: **precision conservation** and **sustainable development.**

1. Scientific & Restoration Objectives:

- Create a highly accurate 3D model of the temple driving towards its “Digital Twin” for archival, documentation purposes and analysis.
- Pilot AI tools to detect defects, virtually match and reassemble fragmented architectural elements (such as the temple frieze), directly aiding restoration.
- Use the high-resolution model with the ART3MIS annotation platform for detailed expert study and planning.

2. Public Engagement & Visibility Objectives:

- Develop a simplified, visually compelling 3D model offering adequate content for future development of digital applications and enhancement of the overall visitor experience.
- Dramatically increase global and local visibility of this remote UNESCO site.
- Enhance on-site and remote visitor understanding and interest.
- Promote citizen science practices by engaging local groups in the study and documentation of the site.

3. Environmental & Sustainability Objectives:

- **Monument Resilience:** Provide a crucial baseline to monitor structural impacts from climate and extreme weather, informing protective strategies.
- **Sustainable Tourism:** Enhance overall sustainability of the site enhancing its number of visitors while also offering rich digital alternatives, and promoting climate-friendly "value over volume" tourism.
- **Regional Sustainability:** Use the monument's enhanced digital profile to stimulate sustainable economic growth in the wider territory and surrounding municipalities, supporting local communities in a low-impact manner.

4. Methodological Objective:

- Establish a replicable best-practice workflow for digitizing and utilizing cultural heritage in covered, challenging environments.

Individual issues

The site of the Temple of Apollo Epicurius at Bassae experiences a number of individual challenges as categorized below:

A. Environmental & Structural Challenges

1. **Material Degradation:** The limestone structure is highly vulnerable to **freeze-thaw cycles** and **thermoclasty** (cracking from sudden temperature swings), exacerbated by high moisture.
2. **Extreme Climate:** Located in a mountainous zone at an altitude of 1,131m the monument faces challenges due to adverse weather conditions mitigated by the installation of a shelter tent.
3. **Wildfire Risk:** Location in a forested area increases susceptibility to forest fires.
4. **Ongoing preservation and restoration:** Part of the monument has been successfully restored by the Ephorate of Antiquities of Ileia having established a pipeline for its full restoration which is still pending.

B. Accessibility & Infrastructure Challenges

4. **Physical Remoteness:** Difficult, time-consuming access due to mountainous terrain, far from major urban centers and coastal tourist hubs.
5. **Inadequate Visitor Infrastructure:** Lack of on-site visitor center, insufficient signage, and limited amenities, reducing the overall quality of the visitor experience.
6. **Seasonality & Flow:** Tourism is highly seasonal, with winter weather severely limiting access. There is no system to monitor or manage visitor flows.
7. **Accessibility & Inclusiveness:** Lack of adequate infrastructure for persons with reduced mobility.

C. Socio-Economic & Promotional Challenges

7. **Low Visibility & Promotion:** The site's significant architectural merits and overall importance are not widely known, and it is disconnected from main regional tourism circuits.
8. **Lack of Integrated Offerings:** Absence of packaged tourism products linking the temple to neighboring municipalities and attractions or special targets of tourism like schools.
9. **Weak Regional Integration:** Challenge to connect the site sustainably with nearby communities to foster shared economic benefits.

10. **Dependence on Protective Shelter:** While necessary, the installed shelter tent reduces the visitor experience and indicates ongoing vulnerability, while its future management is a long-term consideration.

HERIT ADAPT Sustainable Tourism Model Evaluation

Understanding Risks and impact

The Temple of Apollo Epicurius pilot site exemplifies the Herit Adapt Model's approach to revitalizing a remote and under-visited yet significant monument through integrated sustainability and digital innovation. To overcome its physical seclusion and lack of visibility within mainstream tourism circuits, the model applies advanced digital tools—such as high-resolution 3D documentation, drone-based photogrammetry, and AI-powered analysis—for precise conservation, restoration planning, and structural monitoring. These digital assets not only create a permanent record of the temple for future generations but also enable virtual accessibility and can be used for producing immersive educational experiences, enhancing its appeal and redirecting tourist flows from major tourist hubs like Ancient Olympia.

This strategic elevation of the site directly supports local sustainable development. By boosting the temple's profile through digital content, the model stimulates regional economic diversification, creating opportunities for local guides, artisans, and hospitality services. Crucially, the digital documentation serves a dual purpose: it is both a foundation for climate-resilient preservation, allowing for detailed risk assessment and targeted restoration, and a tool for community engagement and storytelling. Thus, the pilot demonstrates how the Herit Adapt Model transforms heritage conservation into a catalyst for resilient economic growth, balancing visitor engagement with the imperative of long-term preservation.

Infrastructure

No infrastructure has been planned to be installed in the pilot site. Yet, relevant infrastructure of the ATHENA Research Center for photogrammetry has been enhanced and used for the purposed of 3D modeling of the site.

Technology

The preservation and promotion of the Temple of Apollo Epicurius as a sustainable tourism asset within the HERIT ADAPT model is fundamentally supported by a suite of advanced digital technologies. This multi-layered technological approach drives towards the creation of a precise digital twin, facilitates sophisticated analysis for conservation, and overcomes significant physical and logistical challenges, such as the presence of modern scaffolding. The process integrates cutting-edge methods in data acquisition, artificial intelligence, and 3D reconstruction to produce a comprehensive and actionable digital record of this remote heritage site.

The technological workflow for the temple is built upon three pillars: **Data Acquisition**, **AI-Powered Processing**, and **Advanced 3D Reconstruction**.

Data Acquisition relies primarily on **drone-based photogrammetry**. Unmanned Aerial Vehicles (UAVs), equipped with high-resolution cameras, RTK (Real-Time Kinematic) GPS for centimeter-

accurate positioning, were deployed to capture the temple from hundreds of unique angles and elevations. This method is crucial for accessing the full structure, especially its upper sections and precarious locations. Complementary **ground-level imaging** using high-resolution DSLR and 360-degree cameras ensures the capture of fine surface details, textures, carvings, and areas of erosion, providing the granular data necessary for detailed analysis and realistic texturing of the final 3D model.

AI-Powered Processing addresses a core challenge: the presence of temporary wooden and metal scaffolding essential for physical conservation but obstructive for digital documentation. To create a "clean" digital representation, a dual AI strategy was implemented. First, **semantic segmentation models**, specifically the **Segment Anything Model (SAM)**, were used to automatically identify and generate precise masks for the scaffolding in thousands of individual photographs. Second, **diffusion-based image inpainting models (e.g., Stable Diffusion)** were employed to realistically "erase" the masked scaffolding from each image, generating plausible background textures that match the surrounding stonework. This step is critical for producing imagery suitable for accurate 3D reconstruction without visual artifacts.

Advanced 3D Reconstruction moves beyond traditional photogrammetry. While standard **Structure-from-Motion (SfM)** and **Multi-View Stereo (MVS)** pipelines are used to generate initial dense point clouds and meshes from the original photographs, the project also leverages **3D Gaussian Splatting**. This modern technique is particularly robust for handling datasets where images have been edited (e.g., via inpainting), as it optimizes a volumetric representation directly from the images without relying on fragile feature point correspondences. The final output includes both a traditional high-resolution textured mesh and a photorealistic Gaussian splat model, serving different purposes from scientific analysis to immersive public engagement.

Mapping to tools / solutions

The technological pipeline is operationalized through specific software tools and frameworks developed or enhanced within HERIT ADAPT, forming a cohesive portfolio for heritage documentation.

The cornerstone tool for expert interaction with the 3D data is **ART3mis**. This web-based annotation platform, capitalized from the WARMEST[1] project, provides an intuitive interface for conservation specialists to manually or semi-automatically annotate the digital twin. Experts can mark regions of interest, document cracks, areas of erosion, or previous restoration work directly on the 3D model. ART3mis stores these annotations in the standardized **W3C Web Annotation (JSON-LD)** format, creating a structured, machine-readable record linked to specific 3D geometry. Its modular architecture allows for the integration of AI extensions, such as **CNN-based saliency detection** algorithms, which can automatically highlight protruding or damaged areas on the model, guiding experts to potential issues.

[1] WARMEST EU PROJECT – loW Altitude Remote sensing for the Monitoring of the state of cultural hEritage Sites: building an inTegrated model for maintenance

For the specific challenge of scaffold removal, a dedicated **AI Toolkit for Support Detection and Removal** was developed. This toolkit implements the two-pronged approach described in the Technology section:

1. **3D Geometric Analysis:** It uses both traditional **spectral saliency analysis** and a more efficient **CNN-based saliency extraction** method to identify non-heritage geometric features (scaffolds, beams) directly on the 3D mesh based on their protruding characteristics.
2. **Image-Based Restoration Pipeline:** This pipeline integrates **SAM** for automatic mask generation and **Stable Diffusion** for inpainting across the entire image dataset. The cleaned images are then fed into the **Gaussian Splatting** reconstruction pipeline to generate the final support-free 3D model.

These tools are not used in isolation but form an integrated workflow: data from drones and cameras feed into the AI toolkit for processing; the resulting clean 3D models are uploaded to ART3mis for expert annotation and analysis; and all generated data (models, annotations, saliency maps) contribute to the monument's long-term digital record.

Data Collection

The implementation of this technological framework at the Temple of Apollo Epicurius and its associated context has resulted in an extensive and rich dataset, forming the empirical foundation for all subsequent analysis and model development.

The primary effort focused on the temple itself. A comprehensive **drone and ground-based photogrammetry campaign** was executed, resulting in the capture of **over 6,500 high-resolution photographs**. This massive dataset provides exhaustive coverage of the temple's exterior from all angles and elevations, necessary for building a millimeter-accurate 3D model. The significant challenge was that these images inherently contained extensive views of the modern wooden scaffolding enveloping the structure. The successful combination of manual work and of the application of the AI removal toolkit to this dataset represents a major achievement, effectively separating the ancient monument from its contemporary supports in the digital domain.

To enrich the historical and contextual understanding of the site, data collection extended beyond the temple. A focused campaign was conducted at the **Andritsaina Library**, which houses a **replica of the temple's sculptural frieze**. **Over 2,000 photographs** were captured of this replica using similar photogrammetric techniques. The resulting **high-fidelity 3D model of the frieze** serves multiple purposes: it enables a virtual reunification of the monument as it was in antiquity, provides reference geometry for potential virtual reconstruction studies related to the temple, and offers an accessible digital asset for public education and exhibition, detached from the physical constraints of the remote temple site.

In summary, the data collection initiative produced two cornerstone assets: 1) A **scaffold-free 3D model of the Temple of Apollo Epicurius driving towards its Digital Twin**, created from 6,500+ processed images, and 2) A **detailed 3D model of the Andritsaina frieze replica** from 2,000+ images. This combined dataset unlocks new potentials for precise conservation planning, structural analysis, the development of immersive visitor experiences (e.g., VR/AR), and strategic

tourism promotion, directly supporting the HERIT ADAPT model's goals of sustainable preservation and adaptive reuse.

Stakeholder engagement

Stakeholder engagement for the Apollo Epicurius pilot has been systematically structured around a dedicated **Territorial Working Group** (TWG), ensuring a multi-level and inclusive governance approach. This TWG is anchored by a core partnership between the Region of Western Greece (RWG) as the political and strategic coordinator, the ATHENA Research Center as the scientific and technological lead, and the Ephorate of Antiquities of Ileia as the statutory management body responsible for the temple's conservation and restoration. This triad engaged in a series of targeted meetings to define the pilot's scope, objectives, and methodological framework, culminating in a formal **Memorandum of Understanding** (MoU) that solidified roles, data-sharing protocols, and joint commitments. HERIT ADAPT partner EPLO has also been engaged in the TWG right from the beginning contributing its strategy oriented expertise.

The group was strategically expanded to include the adjacent municipalities of Krestena-Andritsaina and Zacharo, integrating local governance and community interests into the project's planning. To further embed the initiative in the local socio-economic fabric and foster public participation, two broader Territorial Working Group meetings were convened in Andritsaina and Zacharo, engaging local authorities, tourism operators, cultural associations, and civil society representatives. These forums, attended by **influential policy makers** including a member of the Hellenic Parliament, several deputy regional governors of Western Greece, and the mayors of neighboring municipalities, facilitated dialogue on leveraging cultural heritage for sustainable regional development. The Territorial Working Group forums in Zacharo generated significant regional visibility, culminating in a dedicated **national television segment** that showcased the project to **an audience of over 500,000 viewers**, substantially amplifying public awareness and support for the temple's sustainable revitalization.

A key innovation in public engagement is the planned **citizen science initiative** led by ATHENA, specifically targeting **high school students** from the surrounding regions. This program will involve students in supervised, educational activities such as basic data collection, environmental monitoring around the site, or participatory annotation tasks using simplified digital tools, thereby building a sense of stewardship and connecting the younger generation directly to their cultural heritage.

Looking forward, engagement will transition into concrete collaboration: the Ephorate will utilize the high-resolution 3D model and AI-generated analyses for informing and planning the temple's physical restoration, while ATHENA will organize **capacity-building sessions** to upskill heritage professionals and local stakeholders in using the enhanced digital tools (e.g., ART3mis, the AI restoration toolkit).

This structured, phased engagement strategy—spanning formal agreements, policy dialogue, community forums, and educational citizen science—ensures that the pilot not only achieves its technical goals but also fosters **local ownership**, builds institutional and community **capacity**, and aligns heritage preservation with long-term socio-economic and educational **sustainability** for the wider area.

Outcomes and long-term benefits

Accessibility

The long-term impact of the pilot at the Temple of Apollo Epicurius centers on transforming the site's physical and perceptual accessibility through a dual strategy of **digital enhancement and territorial integration**. While the temple's remote mountainous location and underdeveloped infrastructure have historically limited physical visitation, the project's high-resolution 3D content—such as 3D models, and future material like virtual tours, and AI-restored visualizations—will dramatically increase its **digital visibility and accessibility** to global audiences, educators, and researchers. This digital layer effectively decouples cultural engagement from geographical constraints, allowing the monument to enter mainstream cultural and educational circuits even before physical upgrades are completed. Concurrently, targeted efforts to promote **school tourism** and structured educational exchanges will foster a steady flow of student groups, embedding the site into regional curricula and creating a sustainable, low-impact visitor base. Furthermore, by strengthening connectivity with adjacent municipalities like Krestena-Andritsaina and Zacharo—through integrated tourism routes, local guide training, and collaborative storytelling—the pilot ensures that physical visitors are better distributed across the territory, supporting local economies and encouraging longer stays. Thus, the long-term benefit lies not only in improved on-site infrastructure but in a redefined accessibility model: one that combines **digital outreach** to attract global interest, **educational programming** to ensure purposeful visitation, and **territorial networking** to embed the temple within a wider, resilient cultural landscape.

Diversification and De-seasonalization

The pilot presents a strategic opportunity for the Region of Western Greece to implement a model of tourism diversification and de-seasonalization, directly addressing the interrelated pressures of **climate change, environmental strain, and socio-economic vulnerability**. As rising temperatures and water scarcity increasingly burden coastal destinations during peak summer months, the Temple of Apollo Epicurius—nestled in the cooler, mountainous landscape of Bassae—offers a compelling alternative for **climate-aware cultural tourism**. By promoting the site as a nucleus for off-season and shoulder-season visitation, the region can shift tourist flows away from overburdened coastal zones, thereby alleviating local environmental stress. This diversification necessitates and simultaneously incentivizes the **enhancement of local tourism infrastructure**, including the development of small-scale, sustainable accommodations such as eco-lodges and guesthouses, as well as the expansion of authentic dining and service offerings in nearby villages. The growth in visitor interest, particularly beyond the summer season, creates a tangible **economic opportunity** for local entrepreneurs to invest in and upgrade these amenities, fostering a more robust and resilient hospitality sector. This approach is supported by **curating experiential offerings** that leverage the area's natural and cultural assets: guided thematic hikes, archaeological walking tours, gastronomy workshops in traditional mountain villages, and nature-based activities that are feasible across broader periods of the year. Such an integrated strategy not only extends the tourism season and distributes economic benefits more evenly, but also stimulates local entrepreneurship, creates year-round employment opportunities, and helps counteract rural depopulation by making the inland areas more attractive for investment and permanent residence. Ultimately, this fosters a **more resilient and balanced tourism economy**,

one that adapts to climatic realities while enriching and sustaining the region's unique cultural and natural heritage through improved infrastructure and community-led development.

Training and capacity building

The pilot includes a comprehensive, multi-tiered capacity-building strategy designed to empower all key stakeholders. **Primary upskilling** is directed towards the **Ephorate of Antiquities of Ileia**, where technical staff will receive hands-on training from the ATHENA Research Center on utilizing the project's advanced digital tools—such as the ART3mis annotation platform and the AI restoration toolkit—for practical applications in condition monitoring, restoration planning, and data-driven heritage management. Complementing this professional training, a **citizen science program** will engage high school students from neighboring municipalities in educational activities like environmental monitoring and participatory digital documentation, fostering early-stage technical literacy and cultivating a new generation of heritage stewards. Finally, **broader capacity-building sessions** within the **Territorial Working Group (TWG)** will ensure that regional authorities, local government officials, and tourism representatives gain a shared understanding of climate-resilient tourism management and sustainable heritage promotion, thereby institutionalizing innovative practices and ensuring cohesive, long-term strategy implementation across governance levels.

Strategy Dimension

Problem Context

The Temple of Apollo Epicurius, a UNESCO World Heritage site, is an architectural masterpiece of exceptional preservation and historical significance. Despite its outstanding value, the temple remains a peripheral destination within Western Greece's cultural tourism landscape due to its remote mountainous location and limited accessibility. This geographic isolation results in low visibility and under-visitation compared to major coastal sites like Ancient Olympia, depriving the region of the economic and cultural benefits associated with heritage tourism. Furthermore, the site faces environmental pressures from climate variability and risks being overlooked in mainstream tourism development, exacerbating regional disparities and limiting opportunities for sustainable local growth.

Strategy and Goals

The strategy for the Apollo Epicurius pilot is to transition the site from a secluded heritage asset into an integrated and resilient node within the regional tourism ecosystem. The primary goal is to strategically reposition the temple by enhancing its physical and digital accessibility, promoting it as a sustainable, climate-resilient alternative to overcrowded coastal destinations. This involves diversifying and de-seasonalizing tourism by leveraging the site's mountainous setting to attract visitors during off-peak periods, thereby redistributing tourist flows, alleviating pressure on saturated sites, and stimulating year-round economic activity in the surrounding municipalities of Krestena-Andritsaina and Zacharo. Ultimately, the strategy aims to embed the temple within mainstream cultural itineraries while fostering local socio-economic resilience and environmental sustainability.

Tools / Methods

To achieve these goals, the pilot employs a multi-layered technological and participatory

methodology. A core component is the creation of a **high-resolution digital twin** of the temple through drone-based photogrammetry and AI-assisted processing to remove modern scaffolding, providing a pristine model for conservation planning by the Ephorate of Antiquities. A **public-facing, low-resolution 3D model** and resulting digital content will be developed for educational dissemination in schools and online platforms. Additionally, the project utilizes the **ART3mis annotation platform** for expert analysis and a suite of **AI tools** for structural monitoring. Engagement is facilitated through the **Territorial Working Group (TWG)**, which orchestrates stakeholder collaboration, professional training for heritage managers, and citizen science programs targeting local high school students to foster community involvement and awareness.

Expected Outcomes & Impact

The pilot is expected to yield measurable and transformative outcomes: a significant **increase in visitor numbers** to the temple and the wider region, achieved through improved accessibility, targeted marketing, and digital visibility. The site's **inclusion in mainstream cultural routes** will reposition it as an important destination, while the promotion of off-season and experiential tourism will **alleviate pressure on coastal sites** or **mainstream sites** like Ancient Olympia. Socio-economically, the initiative will stimulate local development through the growth of small businesses, hospitality services, and job creation, helping to counteract rural depopulation. Environmentally, it promotes a climate-resilient tourism model. Institutionally, it will build lasting capacity within the Ephorate and local authorities, and foster a deeper sense of community stewardship, ensuring the temple's preservation and sustainable valorization for future generations.

KPIs

- Number of conservation actions initiated based on data from the Digital Twin or IoT monitoring – baseline % of the temple already restored
- % increase in staff/management who report a "good" or "very good" understanding of site-specific climate vulnerabilities after using the tools
- Number of events/ exhibitions participated – baseline 1
- Number of visitors participating in exhibitions or other events (e.g. Philoxenia) where pilot work on the monument is disseminated.
- Number of visitors from educational school trips
- Number of concrete actions or strategies co-created and approved by the Territorial Working Groups (TWGs) using data from the pilots
- Number of authorities and Institutions interested in replicating the pilot methodology – baseline 0

Roman Houses of Celio Hill, Rome, Italy

The Roman Houses of the Celio Hill are an underground archaeological complex located near the Colosseum in Rome. Discovered in the late 19th century, the site preserves a group of richly

decorated residential spaces dating from the 2nd to 4th centuries CE. The houses are renowned for their extensive wall paintings, mosaics, and architectural remains, which provide rare insight into the domestic and social life of late imperial Rome. Today, the site is managed as a museum space, offering visitors a unique opportunity to explore the everyday environments of ancient Roman elites in one of the city's most historically significant areas.

Specific Objectives

The pilot experimentation at the Roman Houses of Celio Hill was designed to explore how innovative digital technologies could address the challenges of under-visitation, conservation, and sustainable site management. The objectives were defined in close alignment with the broader goals of HERIT-ADAPT and can be summarized as follows.

The first objective is to *enhance the visitor experience* by introducing immersive and educational tools that make the site's cultural and historical significance more tangible. Through XR applications visitors gain access to reconstructions that enrich understanding and offer interpretive value to spaces that otherwise appear empty or inaccessible.

The second objective is to *manage tourist flows* more effectively by redirecting part of the pressure away from heavily visited landmarks, such as the Colosseum, towards the Roman Houses. This creates opportunities for more balanced itineraries across the Celio Hill area and helps mitigate the negative effects of overcrowding in nearby attractions.

Another important goal is to *promote accessibility and inclusion*. Through XR technologies, visitors can virtually access areas that may be restricted due to conservation needs or physical barriers. This ensures that individuals with mobility challenges or other limitations can still experience the site fully and inclusively. To further enhance accessibility, we also support multiple languages and provide subtitles.

The fourth objective is to *support conservation and climate resilience*. By shifting interpretation into digital formats, the pilot reduces direct contact with fragile artifacts and structures. At the same time, the use of energy-efficient devices ensures a reduced environmental footprint.

The experimentation also seeks to *generate socio-economic value*. By increasing the visibility of the Roman Houses, the pilot contributes to higher site revenues, which can be reinvested into preservation and excavation. In parallel, visitors are encouraged to explore the wider Celio Hill neighborhood, stimulating local businesses and creating synergies between heritage and community.

Finally, the pilot is designed *to test transferable methodologies*. By applying photogrammetry, 3D modeling, XR applications, and non-invasive installations, the project develops workflows that can be codified into open-source toolkits. This ensures that the results are scalable and replicable in other heritage contexts across the HERIT-ADAPT network.

The HERIT-ADAPT sustainable tourism model is built on principles of environmental responsibility, economic viability, social and cultural respect, high-quality visitor experience, resource efficiency,

and resilience to climate change. The pilot experimentation at the Roman Houses directly contributes to these pillars.

In terms of environmental responsibility, the XR applications reduce the need for invasive interventions, limit physical wear on fragile remains, and rely on energy-efficient technologies that minimize the site's ecological footprint. About economic viability, the pilot increases the attractiveness of a site that is often overlooked, generating new revenue streams for conservation while also supporting small businesses and services in the Celio Hill area.

From the perspective of social and cultural respect, the solutions adopted are non-invasive, preserve the integrity of the archaeological record, and reinforce authentic storytelling about the lived experiences of ancient Rome. The pilot also advances the visitor experience and education by offering accessible and immersive interpretations that foster cultural appreciation and raise awareness of conservation challenges. On the dimension of resource efficiency, the technologies applied are lightweight, cost-effective, and easy to maintain, making them suitable for replication in sites with limited budgets or staff.

Finally, the pilot strengthens resilience to climate change by reducing physical pressure on vulnerable environments, attempting to redistribute visitor flows across the city, and promoting sustainable patterns of exploration that extend beyond overburdened landmarks.

Individual issues related to each pilot

The Roman Houses of the Celio Hill are a remarkable underground complex of late imperial residences, located in the very heart of Rome, only a few steps away from the Colosseum. Despite their extraordinary historical and artistic value, the Houses remain one of the least visited cultural sites in the area. This paradox, being situated in one of the most touristic districts of the city while simultaneously suffering from invisibility, was one of the central issues the pilot project set out to address.

The Roman Houses are frequently bypassed by tourists who, drawn by the Colosseum and the Roman Forum, do not venture into the Celio Hill area. Visitor flows are inconsistent, and the site lacks integration into larger cultural itineraries. Stakeholders repeatedly pointed out during the meetings that although the Roman Houses are surrounded by world-famous monuments, they fail to capture the attention of the millions of visitors who pass nearby every year. This lack of visibility has direct repercussions not only on revenues but also on the long-term sustainability of the site.

Accessibility posed another major obstacle. The steep slopes of the Celio Hill, uneven pathways, and the hypogeal nature of the archaeological remains make visits difficult for people with reduced mobility. Many of the rooms are narrow and fragile, meaning access must be limited to protect the ancient structures and wall paintings. The site's physical characteristics therefore impose natural barriers to inclusivity. From the perspective of HERIT-ADAPT's sustainable tourism model, this represents a key issue: if heritage is to be a shared resource, solutions must be devised to overcome such exclusion.

The under-communication of the site's heritage value was also identified as a weakness. Although the Roman Houses contain extraordinary frescoes, decorative elements, and evidence of late antique domestic life, these features are not effectively conveyed through current tour formats.

Guided visits rely heavily on spoken explanation, while autonomous visits provide little interactivity. As a result, the richness of the site remains underappreciated, and the visitor experience is comparatively less engaging than that of other Roman monuments.

Conservation risks and environmental vulnerabilities further complicate site management. The hypogeal environment is highly sensitive: water infiltration, microclimatic instability, and biodeterioration processes threaten the frescoes and architectural remains. Increasing visitor pressure in certain areas accelerates deterioration, forcing managers to restrict access to fragile spaces. This creates tension between the need to preserve the site and the need to offer meaningful access to the public. These vulnerabilities are exacerbated by broader climate change effects, such as fluctuations in humidity, rising temperatures, and extreme weather, all of which place additional stress on the structures.

Fragmented management and limited operational capacity constitute an additional layer of difficulty. The Roman Houses are managed through the cooperation of multiple stakeholders, including a religious institute, the heritage superintendency, and the cultural management company. This complex governance framework can slow decision-making and complicate the implementation of innovative initiatives. Moreover, staff resources are limited, meaning any technological intervention must be low-maintenance, user-friendly, and sustainable in the long run.

Finally, the Roman Houses face constant competition of globally renowned nearby attractions. The Colosseum, Roman Forum, and Palatine Hill dominate the cultural and tourist narrative of the area. In comparison, the Roman Houses remain relatively unknown, even though they offer unique insights into the domestic, social, and religious life of late antique Rome. This imbalance in promotion and visibility prevents the site from achieving its full potential as part of Rome's cultural landscape.

Taken together, these issues paint a complex picture: the Roman Houses are rich in heritage value yet constrained by low visibility, physical barriers, conservation fragility, and operational limitations. These very challenges, however, provided the opportunity for the pilot experimentation to demonstrate the potential of Extended Reality solutions. By creating non-invasive, accessible, and engaging XR tools, the project sought not only to enrich the visitor experience but also to redistribute tourist flows, reduce conservation pressures, and bring new socio-economic opportunities to the Celio Hill area. In this sense, the Roman Houses offered the perfect testing ground for advancing the objectives of HERIT-ADAPT's sustainable tourism model.

HERIT ADAPT Sustainable Tourism Model Evaluation per pilot

Understanding Risks and impact

Infrastructure

A major value of the proposed solution lies in its lightweight infrastructure. The applications do not require any permanent installation or invasive modification of the archaeological site; instead, they rely on a minimal setup of portable devices such as tablets, projectors, and custom stands that can be easily positioned on the floor and removed after use.

This approach ensures full respect for conservation requirements while allowing the system to be deployed and maintained with minimal effort. By avoiding complex infrastructure, the solution remains flexible, cost-effective, and sustainable, making it adaptable to different heritage contexts without compromising the integrity of the site.

Technology

The design and development of the XR applications relied on a combination of digital documentation, 3D reconstruction, software development, and user interface design. A strong emphasis was placed on accuracy, usability, and non-invasiveness to respect the archaeological context and respond to the requirements expressed by stakeholders.

Photography and Photogrammetry

The process began with systematic photographic campaigns and photogrammetric surveys. These methods made it possible to document the spaces in high detail, capturing both geometry and surface textures. Photogrammetry was particularly important for generating precise 3D references that informed the reconstructions of the Wine Cellar and Bottega, ensuring that proportions, alignments, and decorative elements were anchored in measurable data rather than purely interpretative models.

3D Modeling and Texturing

Based on photogrammetric outputs and archeological reviews, 3D modeling tools were used to reconstruct missing architectural elements, furniture, and decorative schemes. Texturing techniques were applied to reproduce wall paintings, flooring, and surfaces with a high level of realism. This step was essential for offering visitors a vivid impression of spaces that today appear fragmentary or empty.

Unity Engine

Unity served as the main environment for developing the applications. Unity allowed the integration of 3D reconstructions with interactive features designed for tablets. Visitors could explore reconstructions aligned with the physical environment, rotate their viewpoint, and access information in a way that was intuitive and immersive but still anchored to the real space around them. Unity also supported the inclusion of navigation aids, such as the digital compass in the Bottega application, which was introduced after stakeholder feedback to improve orientation and usability while assisting into materializing and controlling floor projections.

3D Printing

To ensure non-invasive integration of both the Tablet-based non-immersive panoramic VR reconstruction (Bottega) and Tablet-based non-immersive VR reconstruction (Wine Cellar) applications, a custom 3D-printed tablet stand was designed, using Autodesk Fusion 360, and printed using Bambulab A1 and PETG materials. This methodology eased the integration of a tablet inside the Wine Cellar and Bottega areas, while the latter can be also rotated in correspondence with the visitor's orientation, maintaining a direct relationship between the digital reconstruction and the

physical environment. The use of 3D printing made it possible to adapt the design precisely to the site's needs, while keeping the solution lightweight, flexible, and reversible.

Figma for UI/UX Design

The user interfaces were designed with Figma, enabling the team to prototype, test, and refine layouts and interaction flows before implementation. The design emphasized simplicity, accessibility, and clarity, with intuitive icons and minimal text to accommodate diverse audiences, including those without prior familiarity with digital applications. Iterative feedback from stakeholders informed adjustments, such as the integration of the compass in Bottega, to ensure that the final product was user-friendly and fully aligned with the expectations of both managers and visitors.

By combining these technologies, we created XR applications that were archaeologically accurate, technically robust, and operationally sustainable. The emphasis on non-invasiveness, ease of use, and visual clarity ensured that the solutions could enrich the visitor experience without imposing additional burdens on site management or compromising the integrity of the heritage.

Data collection

Following the completion of the development phase and stakeholder validation, the next step is to carry out structured user testing on site with real visitors. The purpose of this evaluation is twofold: first, to verify that the applications are usable, intuitive, and engaging for diverse audiences; and second, to collect evidence on how effectively they contribute to the objectives of sustainable tourism.

The evaluation will be conducted directly in the Roman Houses during regular visits, ensuring that the applications are tested under realistic conditions. A representative sample of visitors, including tourists, residents, and different age groups, will be invited to interact with the Map Projection, the Bottega, and the Wine Cellar applications. Data will be collected through a combination of methods:

- Observation of how visitors interact with the tools, including ease of navigation, group dynamics, and time spent at each station.
- Questionnaires and interviews gather feedback on usability, clarity of content, and overall satisfaction.
- Comparative analysis of guided versus autonomous visits to understand how the applications integrate into different tour formats.

Particular attention will be given to aspects identified during the design phase, such as whether the floor projection enhances group orientation and autonomous visitors' engagement, and whether the applications integrated with the Bottega and Wine Cellar areas ensure intuitive use for both individuals and groups while establishing a strong linkage between virtual reconstructions and physical artifacts. Feedback will also be sought on accessibility, with the aim of ensuring that the applications add value for visitors with different levels of familiarity with XR technologies.

The results of this testing will inform further refinements before full-scale dissemination. Adjustments may include improvements to interface elements, pacing of information, or additional orientation aids. Beyond usability, the testing will also assess the broader impact on visitor

experience and site perception, helping to measure whether the tools encourage longer engagement, greater cultural appreciation, and interest in exploring the wider Celio Hill area.

By grounding development in real visitor feedback, the user testing will provide the final step to ensure that the applications are not only technically robust but also genuinely enhance cultural interpretation, visitor satisfaction, and the sustainable management of the Roman Houses of the Celio Hill.

Mapping to tools / solutions

The HERIT-ADAPT pilot at the Roman Houses of the Celio Hill tested a set of lightweight XR tools designed to enhance visitor engagement while respecting conservation constraints. These included a floor-based animated map projection for group orientation (solution 1), a Tablet-based panoramic AR-like environment reconstruction (solution 2) of the Bottega that visualizes it as a Roman wine shop, and a tablet-based VR reconstruction (solution 3) of the Wine Cellar connecting virtual environments with physical artifacts. All applications were deliberately designed to be non-invasive, intuitive, and accessible for both individuals and groups.

Beyond their site-specific use, these tools were developed as replicable templates that can be adapted to other heritage contexts. Packaged with tutorials and simple instructions, they allow institutions with limited resources to experiment with XR without major infrastructural investment. This modular approach ensures that the value of the pilot extends beyond the Roman Houses, contributing to a wider portfolio of accessible, low-cost XR solutions for sustainable cultural heritage tourism.

Stakeholder engagement

From the outset, the pilot at the Roman Houses of the Celio Hill was developed through active engagement with site stakeholders. In the initial stage, we presented a holistic vision of how XR technologies could be used to enhance the visitor experience, redistribute flows, and address the site's visibility and accessibility challenges. Stakeholders were not passive observers; they were invited into collaborative decision-making processes that shaped the direction of the intervention. Importantly, they played a central role in deciding which applications would be developed, ensuring that the chosen solutions aligned with both operational needs and long-term management strategies.

This dialogue continued into the final stage of development. Once the applications had been prototyped, stakeholders were invited to review them, confirm the integrity of the content, and evaluate their usability. Their feedback directly influenced refinement, such as the integration of a digital compass in the Bottega application to improve orientation. By involving stakeholders at both the initial and final phases, the project ensured that the outcomes were not only technically robust but also locally accepted and operationally feasible.

These collaborative choices directly supported the adaptation of tourism at the site. Instead of relying solely on traditional tours, the applications provided new ways of experiencing the Roman

Houses, making them more attractive and accessible without compromising conservation requirements. The interventions are fully consistent with sustainable tourism principles:

- They are energy-efficient, running on low-consumption tablets and projection systems.
- They avoid any physical interventions in the archaeological spaces, ensuring complete reversibility and respect for the fabric of the site.
- They are designed for minimal staff involvement, with automated systems and intuitive interfaces that can be operated by visitors themselves.

In this way, stakeholder engagement was not simply a consultative exercise but the foundation for creating solutions that are practical, sustainable, and adaptive. The result is a set of XR applications that enrich the visitor journey, respect the heritage context, and contribute to a model of tourism that is both resilient and future oriented.

Outcomes and long-term benefits

Accessibility

The development of the XR applications for the Roman Houses of the Celio Hill had to contend with several constraints specific to the heritage context and the way the site is managed. These challenges significantly shaped the design process and the final choices that were made.

One of the most critical issues was the prohibition of physical interventions within archaeological spaces. Because the Roman Houses are fragile and strictly protected, no permanent installations, alterations to the structure, or invasive technical equipment could be introduced. This ruled out many common XR solutions such as projection mapping with ceiling-mounted equipment or fixed interactive displays embedded in the walls. As a result, the applications had to be designed around reversible, lightweight, and non-invasive devices that could be placed in the rooms without altering or damaging the archaeological fabric.

Another central issue was the need to respect the already established visitor pathways. The Roman Houses are visited through carefully designed itineraries that balance conservation needs with visitor access. Any technological solution had to fit seamlessly into these routes, without disrupting visitor circulation or requiring new infrastructure. This required the applications to be designed as “add-on” interpretive layers that support, rather than alter, the existing flow of visits.

The site also accommodates both guided and non-guided tours, which introduced additional complexity. Guided tours are led by expert mediators and represent an important revenue stream, while non-guided visits rely on audio guides or autonomous exploration. The XR solutions had to be flexible enough to work in both contexts. For guided tours, they had to function as tools that enhanced the guide’s storytelling rather than replacing it. For autonomous visits, they needed to provide sufficient orientation and interpretive depth to engage visitors independently. Balancing these different modes of use was a constant challenge in the design process.

Accessibility was another key requirement. To ensure inclusivity, the applications had to integrate multiple languages along with subtitles and captions, making the content available to hearing-impaired visitors and non-native speakers. Visual contrast and readability were carefully considered

to ensure that the content was legible in the site's low-light conditions and on the stone floor of the projection area. Devices had to be easy to use, with intuitive interfaces designed for visitors of all ages and levels of digital familiarity. Tablets were chosen for their familiarity and flexibility, while the interfaces were prototyped to minimize the learning curve and avoid staff intervention.

Together, these issues framed a demanding design context: the solutions had to be non-invasive, seamlessly integrated into existing visitor flows, adaptable to both guided and autonomous tours, and accessible to all audiences. Far from being obstacles, these challenges ensured that the final applications were not only technologically sound but also respectful of the heritage context and fully aligned with principles of sustainable and inclusive tourism.

Diversification and De-seasonalization

A key principle behind the Celio applications was the creation of different kinds of visitor experiences. By diversifying the offer, the site avoids over-reliance on a single type of activity or visitor profile, making it possible to attract broader audiences and build greater resilience. Visitors with varying interests, whether focused on guided interpretation, autonomous exploration, or technology-enhanced discovery, can all find an experience tailored to their preferences.

This diversification also supports the seasonal and spatial redistribution of visitor flows. By offering engaging attractions and interactive content throughout the year, the site reduces reliance on peak tourist seasons and helps spread visitor traffic more evenly across months. In high season, this strategy mitigates overcrowding by distributing flows across different experiences, while in low season it ensures that the site remains attractive and animated.

The approach also considers the wider urban context. By integrating with existing pathways around the Colosseum and Celio Hill, the applications encourage visitors to explore beyond the most congested landmarks. Related areas are presented during the map projection and further showcased through the narration of the two XR applications, contributing to a more balanced tourism ecosystem and fostering deeper connections between the archaeological site and its surrounding urban area.

Looking ahead, the project also provides a long-term benefit through the creation of a reusable toolkit in Unity. This toolkit is designed to facilitate the development of 360° VR applications by cultural institutions, enabling them to replicate or adapt the methods tested at the Roman Houses. By making workflows, templates, and assets available, the toolkit will allow other heritage sites to quickly and cost-effectively implement their own XR experiences. In this way, the pilot not only strengthens the Roman Houses themselves but also contributes to broader capacity-building within the HERIT-ADAPT framework, promoting sustainable digital innovation across the cultural heritage sector.

Training and capacity building

During the pilot, upskilling activities focused on preparing staff and guides to effectively support and integrate the XR application into the visitor experience. Training sessions are organized to:

- Introducing staff and guides to the application: Demonstrating its features, functions, and interaction methods, with emphasis on smooth operation during guided and autonomous tours.
- Ensure confidence in using XR technologies: Practical, hands-on workshops help reduce hesitation and improved staff readiness to troubleshooting basic issues.
- Minimize supervision needs: The application was designed with intuitive, user-friendly interfaces, allowing visitors to explore autonomously and reducing staff workload.

Although training is an important aspect of the pilot, the emphasis was deliberately kept light. The strength of the intervention lay in designing applications that were intuitive and required minimal supervision. As a result, training efforts focused more on familiarization and confidence-building rather than in-depth technical instruction.

Strategy dimension

— **Problem Context:**
The Roman Houses suffer from extremely low visibility despite being located next to Rome's most visited monuments, resulting in under-visitation and reduced economic sustainability. At the same time, physical fragility, accessibility constraints, and conservation-sensitive underground environments limit normal tourist access and heighten vulnerability to climate-related risks.

— **Strategy & Goals:**
The pilot uses immersive XR tools to enrich interpretation, improve accessibility, and redistribute visitor flows from overcrowded landmarks toward lesser-known but high-value heritage assets. It directly supports sustainable tourism goals by enhancing cultural understanding, reducing physical impact on fragile remains, and fostering more balanced, climate-aware mobility across the Celio Hill area.

— **Tools/Methods:**
The experimentation introduces non-invasive XR applications, including tablet-based panoramic VR, 3D reconstructions, floor-aligned projections, and custom 3D-printed supports, that allow visitors to virtually access reconstructed spaces. These tools are developed through photogrammetry, 3D modeling, Unity-based app development, and iterative co-design with stakeholders to maximize usability and sustainability.

— **Expected Outcomes & Impact:**
The pilot aims to increase visitor engagement, diversify flows in the Colosseum area, and create inclusive access pathways for audiences who experience fragile heritage spaces. It also supports long-term conservation by reducing physical pressures, generating new economic value for the Celio Hill district, and establishing a replicable digital methodology for other European heritage sites.

KPIs

KPIs for Pilot Outputs (The "What" - Direct Results of the Experimentation)

Category	KPI	Measurement method and Target
XR/AR Deployment	Number of functional XR/AR experiences deployed	Live deployment records and user accessibility ≥3
	Number of languages/ accessibility features integrated	Feature list; target: ≥2 languages + WCAG 2.1 AA compliance
	XR intervention interaction rate (% of visitors)	On-site analytics; target: ≥60%
Data Collection & Reporting	Number of datasets consolidated from all partners	Datasets ≥2 Final project repository inventory

KPIs for Short-to-Medium Term Outcomes (The "So What" - Changes in Behavior & Conditions)

Category	KPI	Measurement method and Target
Visitor Engagement & Experience	Visitor interaction with digital tools (% who report enhanced understanding)	Post-visit surveys; target: ≥75%
	Average visit duration vs. baseline/control	Visitor tracking and ticket data analysis; target: +10%
	% change in off-season/shoulder-season visitation	Official statistics; target: +5–10%
Stakeholder & Community Engagement	Number of TWG actions/strategies co-created and approved	TWG meeting minutes and action plans ≥ 2
Capacity Building & Training	Number of training/workshop participants	Attendance lists and feedback forms; target: ≥ 20

KPIs for Long-Term Strategic Impacts (The "What Ultimately Changes")

Category	KPI	Measurement method and Target
	Economic diversification through tourism	Local employment and revenue tracking

Sustainable Regional Development	Accessibility improvements implemented (multilingual, inclusive design)	Accessibility audit and user feedback
Transferability & Model Success	Number of non-pilot sites adopting HERIT ADAPT tools/methodologies	Replication agreements and adoption reports
	Amount of additional funding secured for scaling solutions	Financial reports and grant applications

Rector's Palace, Dubrovnik, Croatia

Rector's Palace in Dubrovnik was built as the seat of government and residence of the rector, the highest political function in the Republic of Dubrovnik. The first mention of the building dates back to the 13th century . The palace houses the halls of the Great and Small Councils, state offices, courtroom, prison, armory, and powder magazine. Today, the Rector's Palace is a historical museum within the Dubrovnik Museums. It is furnished with period furniture from the 19th century, collected from old Dubrovnik palaces and summer residences.

Specific Objectives

The pilot experimentation at the Rector's Palace in Dubrovnik aimed to integrate innovative technologies and collaborative management practices to enhance the sustainability, resilience, and conservation of this key cultural heritage site. The specific objectives were closely aligned with the HERIT ADAPT Sustainable Tourism Model, focusing on balancing heritage preservation with responsible tourism management.

Digital Preservation through 3D Photogrammetry

To create high-resolution 3D digital models of selected sections of the Rector's Palace using photogrammetry techniques. These models supported long-term conservation, facilitated restoration planning.

Environmental Monitoring and Risk Prevention

To install and operate humidity and temperature sensors for continuous monitoring of environmental conditions affecting the building's structural integrity. The collected data supported predictive maintenance through Machine Learning analysis, allowing for data-driven, preventive conservation actions that strengthen the site's resilience to climate change and environmental pressures.

Community and Stakeholder Engagement

To engage local citizens, schools, academic institutions, and heritage organizations through participatory workshops and lectures. These activities increased public awareness of cultural heritage protection and promoted inclusive governance and social responsibility as key pillars of sustainable tourism.

Knowledge Transfer and Capacity Building

To strengthen the capacity of local heritage professionals, researchers, and municipal stakeholders through training and TWG cooperation, ensuring the transferability and replicability of the HERIT ADAPT model to other heritage sites in Croatia and beyond.

In summary, the pilot's objectives directly supported the HERIT ADAPT Sustainable Tourism Model by demonstrating how technology, stakeholder collaboration, and community engagement can

together foster the preservation of heritage assets while ensuring their responsible and resilient use within the tourism sector.

Individual issues related to each pilot

Heritage Conservation Challenges

The Rector's Palace had a long history of damage from earthquakes and environmental wear, making precise conservation critical.

The complex architectural structure, with Gothic, Renaissance, and Baroque elements, required careful monitoring to prevent deterioration while implementing new technologies.

Environmental Risks

The proximity to the Adriatic Sea exposed the building to high humidity, salt infiltration, and seasonal temperature fluctuations, affecting materials and finishes.

Microclimatic conditions within different sections of the palace varied significantly, creating challenges for preventive conservation.

Visitor Pressure and Tourism Impact

High annual visitor numbers (over 400,000 in 2023) posed risks of physical wear, overcrowding, and strain on infrastructure. Sustainable tourism needed balance between accessibility and preservation, motivating the use of digital tools to reduce physical impact.

Data Management and Sharing

Managing the large volume of sensor readings, 3D models, and analytics outputs required secure storage, backup, and controlled access.

Stakeholder Coordination and Governance

Coordination among multiple stakeholders (DURA, Dubrovnik Museums, Institute for Restoration, City of Dubrovnik, schools, universities, and citizens) demanded structured communication, TWG participation, and alignment on objectives.

Balancing technical, educational, and participatory activities with conservation requirements required continuous monitoring and adaptation.

HERIT ADAPT Sustainable Tourism Model Evaluation per pilot

Understanding Risks and impact

Infrastructure

The pilot at the Rector's Palace primarily leveraged existing infrastructure for environmental monitoring and heritage preservation, rather than constructing new physical facilities.

Existing Sensor Equipment:

The palace was already equipped with humidity, temperature sensors distributed throughout key areas. These sensors continuously collected microclimatic data, which served as the foundation for Machine Learning algorithms to predict potential risks related to humidity fluctuations, sea salt infiltration, and other environmental factors affecting the building's structural integrity.

Digital and Network Infrastructure:

The existing local network within the museum, including servers and virtual machines, was utilized to store, process, and visualize the collected sensor data.

Use in Pilot Activities:

By building on the pre-existing sensor network, the pilot was able to implement microclimate prediction models without the need for extensive new installations. This approach ensured non-intrusive monitoring, maintained compliance with heritage preservation standards, and reduced additional costs or structural interventions.

Overall, the pilot effectively demonstrated how existing technological infrastructure could be optimized for sustainable heritage management and predictive conservation, forming a core component of the HERIT ADAPT sustainable tourism model.

Technology

The pilot at the Rector's Palace employed a combination of advanced technologies to support heritage conservation, microclimatic monitoring, and sustainable tourism management:

Photogrammetry and 3D Modelling
High-resolution photogrammetry techniques were used to capture detailed images of the palace from multiple angles.LIDAR scanners and drones equipped with high-precision cameras complemented photogrammetry to create accurate, high-detail 3D digital models of the interior and exterior sections.

Machine Learning Algorithms

Predictive algorithms analyzed data collected from environmental sensors to forecast microclimatic risks, such as humidity fluctuations and temperature variations, which could affect the building's structure and materials.

Machine Learning enabled proactive conservation strategies, optimizing preventive measures and supporting evidence-based decision-making.

Databases and Digital Integration

Collected sensor data and 3D models were stored in databases. Data management systems allowed historical trend analysis, and secure sharing with stakeholders. Integration of 3D models with environmental data enabled comprehensive visualization and analysis for conservation, education, and tourism planning purposes.

Through the combined use of photogrammetry, LIDAR, drones, Machine Learning, and centralized databases, the pilot demonstrated a data-driven, technology-supported approach to heritage protection and sustainable tourism, aligning with the objectives of the HERIT ADAPT project.

Data collection

During the pilot at the Rector's Palace, several types of data were collected to support heritage conservation, sustainable tourism, and stakeholder decision-making:

Environmental and Microclimatic Data

Collected Data: Humidity, temperature readings from existing sensors within the palace. Dubrovnik Museums use the data to monitor environmental conditions, detect microclimatic risks, and inform preventive conservation measures, adjusting climate control systems to protect sensitive materials, supporting proactive maintenance schedules.

3D Digital Models and Photogrammetry Data

Collected Data: High-resolution 3D models of the palace interior and exterior created using photogrammetry, LIDAR, and drone imagery.

The Institute for the Restoration of Dubrovnik and the City of Dubrovnik will use the data for guiding restoration and conservation interventions with precise structural and architectural data, planning urban and heritage management strategies, including visitor flow and tourism infrastructure.

Through this approach, the collected data supported sustainable and resilient heritage management, informed tourism planning, and enhanced community engagement by providing accessible insights into the palace's condition and preservation needs.

Mapping to tools / solutions

A custom predictive tool was developed specifically for the palace, integrating environmental sensor data (humidity, temperature) with Machine Learning algorithms to forecast potential risks to the building.

Purpose: To support preventive conservation measures, risk management, and proactive maintenance planning.

Users: Dubrovnik Museums for operational decision-making and conservation planning.

Stakeholder engagement

The pilot at the Rector's Palace actively engaged multiple local stakeholders through the Territorial Working Groups (TWGs), ensuring collaborative decision-making and co-creation of solutions.

TWG Participation: Representatives from Dubrovnik Museums, the City of Dubrovnik, and the Institute for the Restoration of Dubrovnik were involved in TWG meetings, providing expertise, monitoring pilot activities, and brainstorming technical solutions. TWG discussions facilitated joint

planning for heritage protection, sustainable tourism management, and climate adaptation strategies.

Citizen Involvement: Local residents and community groups participated in interactive workshops, presentations, and open events organized by DURA and the museums. Activities included demonstrations of 3D modelling, environmental sensors, and dashboards, as well as opportunities for citizens to provide feedback on sustainable tourism practices. This engagement fostered awareness of heritage protection and responsible tourism behavior.

Educational and Training Activities: Schools, universities, and research institutions were involved through hands-on workshops and lectures focused on heritage protection, 3D scanning, photogrammetry, and microclimate monitoring. These activities enhanced local knowledge and skills, particularly among students and strengthened the community's capacity to participate in heritage conservation.

Collaborative Decision-Making: TWG coordination enabled evidence-based decisions regarding conservation interventions, preventive measures, and visitor management. Stakeholders jointly analyzed sensor data, predictive models, and 3D digital outputs to inform both tourism planning and climate adaptation measures.

Citizen Science Aspects: Citizens indirectly contributed to the pilot through observations, participatory workshops, and interaction with visualized data. While the project did not deploy mass sensor networks for citizen-led data collection, public engagement in understanding environmental risks and preservation strategies represents a citizen science component, fostering community ownership of heritage management outcomes.

Through these activities, the pilot strengthened local engagement, capacity building, and participatory governance, demonstrating how technology, education, and citizen involvement can contribute to sustainable heritage conservation and resilient tourism planning.

Outcomes and long-term benefits

Accessibility

The pilot at the Rector's Palace addressed several key challenges related to heritage preservation, sustainable tourism, and climate adaptation:

Environmental and Microclimatic Risks:

The palace is exposed to humidity fluctuations, sea salt infiltration, and temperature changes, which can accelerate structural and material deterioration.

Pilot Contribution: The installation and use of existing environmental sensors, combined with Machine Learning predictive models, enabled proactive monitoring and early warning of potential damage, supporting preventive conservation strategies.

High Visitor Pressure:

Annual visitor numbers exceeded 400,000, creating risks of physical wear, overcrowding, and strain on infrastructure.

Pilot Contribution: The creation of 3D digital models will help create interactive experiences, and educational applications, reducing physical pressure on the site while maintaining high-quality visitor engagement.

Complex Conservation Needs:

The palace's intricate Gothic, Renaissance, and Baroque architecture, combined with previous damage from earthquakes and explosions, made interventions delicate and technically challenging.

Pilot Contribution: Detailed 3D modelling and sensor-based data provided precise information for restoration and preventive measures, enabling evidence-based decisions by conservation professionals.

Stakeholder Coordination and Knowledge Gaps:

Multiple stakeholders, including museums, city authorities, and restoration experts, needed to align on conservation priorities, sustainable tourism management, and climate adaptation measures.

Pilot Contribution: TWG meetings, participatory workshops, and citizen engagement activities facilitated collaborative decision-making, awareness raising, and knowledge transfer, ensuring that interventions were both scientifically informed and socially accepted.

Data Management and Predictive Capacity:

Effective use of environmental and heritage data required integration, analysis, and secure sharing among stakeholders.

Pilot Contribution: Databases, dashboards, and predictive tools enabled real-time monitoring, scenario planning, and data-driven interventions, directly supporting resilient tourism management and heritage protection.

Through these interventions, the pilot helped overcome existing challenges by combining technological innovation, stakeholder collaboration, and participatory engagement, contributing to the long-term sustainable management of the Rector's Palace and providing a model applicable to other heritage sites.

Diversification and De-seasonalization

Dubrovnik experiences high tourist concentration during peak summer months, leading to overcrowding at the Rector's Palace and pressure on local infrastructure, while visitor numbers drop significantly in off-peak seasons. Limited year-round engagement with the site reduces opportunities for education, community involvement, and consistent revenue streams for heritage

management. Traditional tourism experiences focus mainly on physical visits, restricting access for audiences unable to travel during peak season.

Pilot Contribution:

The 3D digital models can foster development of virtual tours and off-season access to the Rector's Palace, providing a diversified visitor experience that extends beyond physical presence.

Educational workshops, citizen engagement events, and interactive digital content were organized throughout the year, fostering continuous community involvement and knowledge transfer independent of the tourist season.

The integration of environmental monitoring and predictive tools allowed staff to plan conservation interventions and visitor management more effectively, enabling balanced tourism flows across the year.

Training and capacity building

During the pilot at the Rector's Palace, stakeholders participated in hands-on workshops, lectures, and demonstrations focused on heritage protection, 3D scanning, photogrammetry, and microclimate monitoring. Museum staff, restoration experts, students, and local authorities were trained to use digital tools, interpret environmental data, and apply predictive models, enhancing their technical skills and decision-making capacity for sustainable heritage management and resilient tourism planning.

Strategy dimension

1. Problem Context:

The pilot targeted heritage preservation under environmental stress and overcrowding of visitors, addressing risks from humidity, sea salt, temperature fluctuations, and high seasonal tourist flows.

2. Strategy & Goals:

The strategy combined digital monitoring and predictive analysis with community and stakeholder engagement to support sustainable tourism, preventive conservation, and resilient heritage management. Goals included reducing physical wear on the site, enabling year-round engagement, and promoting evidence-based interventions.

3. Tools/Methods:

- 3D Photogrammetry Models for digital documentation and virtual tours.
- Environmental Sensors & Machine Learning Algorithms for microclimate monitoring and predictive conservation.
- Participatory Workshops & TWG Collaboration for stakeholder engagement and decision-making.

4. Expected Outcomes & Impact:

- High-resolution digital replicas enabling restoration planning and virtual visitor experiences.
- Predictive environmental insights supporting preventive conservation.
- Enhanced stakeholder capacity and community awareness.

KPIs

Key Performance Indicator (KPI)	**Measurement Method & Target**
Digital Twin Completion & Fidelity	% of the pilot site accurately modeled in 3D against project specifications (Target: 100% of defined area). Source: Project validation report.
Data Integration Platform Active	Successful connection of at least 3 different data sources (e.g., sensors, counting camera, weather) into a single dashboard. Source: Operational data platform.
Number of data logs received	Number of data logs received from Dubrovnik Museums to update the AI-based predictive application. Tracked through data log records; target is to ensure continuous, high-frequency updates from all installed sensors to maintain model accuracy and reliability. Source: Data logs
Climate Risk Awareness	Number of persons staff/management/public informed of site-specific climate vulnerabilities after being informed of and using the tools. Source: Workshop signature lists.
Digital Engagement & Reach	Number of online interactions Source: Web & social analytics.
TWG Activity & Collaboration	Development of a comprehensive action plan within the TWG, informed by insights from pilot data assessed through TWG documented action plans, and consensus approvals. Source: Action plan created
Leveraged Funding	Amount of additional funding (EU, national, private) secured by partners to scale up the solutions tested in the pilots. Source: Number of project applications.

Monumental Complex of Alhambra and Generalife, Granada, Spain

Patronato de la Alhambra y Generalife (Granada, Andalusia – Spain)

The pilot site focuses on the **Alhambra and Generalife complex**, one of Europe's most visited cultural heritage landmarks and a key testing ground for the HERIT ADAPT Sustainable Tourism Model. Within this framework, the **University of Granada (UGR)** collaborates with the **Patronato de la Alhambra y Generalife** as the primary pilot site, strategically linking it with the **Western Mountains territory** (Moclín, Montefrío, Íllora) and the **Vega Sierra Elvira Consortium**.

The approach connects the **over-visited heritage core** of the Alhambra with its **historical defensive landscape** of towers and fortresses scattered across nearby rural municipalities. This linkage enables the pilot to test **visitor-flow redistribution**, **emotional storytelling**, and **sustainable mobility strategies**, while reinforcing local economies, crafts, and gastronomy in the extended heritage corridor surrounding Granada.

Specific Objectives

The pilot aims to test the **HERIT ADAPT Sustainable Tourism Model** through the **Patronato de la Alhambra y Generalife**, addressing the challenge of overtourism while promoting new, resilient cultural experiences that extend beyond the monument itself.

Specific objectives include:

- **Testing a replicable model of visitor-flow redistribution**, using the Alhambra as the entry point to guide tourists towards less-visited but culturally connected rural heritage sites in the Western Mountains (Moclín, Montefrío, Íllora).
- **Enhancing the visitor experience through emotional storytelling**, linking the defensive system of the Alhambra with its historical network of watchtowers and fortifications across the Vega–Sierra Elvira territory.
- **Evaluating visitor perception and intention**, before and after exposure to the AI-generated audiovisual narratives presented on-site (via QR panels in the Alhambra) and online.
- **Measuring socio-economic and awareness impacts**, including local business engagement, stakeholder cooperation, and increased understanding of climate adaptation and sustainable tourism principles.
- **Validating the collaboration model** between a major World Heritage site and surrounding rural areas as a means to reduce environmental pressure while generating inclusive, long-term regional benefits.

Individual issues

- **Overtourism and visitor concentration** within the Alhambra and Generalife complex, producing environmental pressure and management challenges.
- **Lack of awareness** among visitors of the wider defensive and cultural landscape historically connected to the Alhambra, including the watchtowers and fortresses of the Western Mountains.
- **Need for visitor-flow diversification** towards rural heritage areas to reduce congestion, improve quality of visit, and extend economic benefits beyond the monument.
- **Fragmented cooperation** among local stakeholders and limited visibility of existing rural tourism assets.
- **Accessibility and inclusivity gaps**, including the lack of multilingual and inclusive interpretation tools.
- **Climate-related vulnerabilities**, such as water scarcity, temperature extremes, and erosion affecting both the Alhambra site and the surrounding rural environment.

HERIT ADAPT Sustainable Tourism Model Evaluation per pilot

Understanding Risks and impact

The Alhambra pilot provides a unique opportunity to evaluate **how sustainable tourism principles can be applied within a major World Heritage site** while contributing to the socio-economic revitalization of its surrounding rural landscape.

The pilot addresses:

- **Environmental and management risks** caused by excessive visitor flows within the Alhambra complex.
- **Socio-economic imbalance** between an over-visited monument and under-visited rural areas located within its historical defensive network.
- **Cultural continuity and landscape integrity**, reconnecting the monument to its territorial context.
- **Climate adaptation challenges**, by integrating narratives about historical water management, heat mitigation, and resource efficiency into the visitor experience.

Through this approach, the Alhambra becomes both a **laboratory for sustainable visitor management** and a **gateway for redistributing tourism benefits** across the Western Mountains of Granada, fostering a balanced, resilient, and climate-aware cultural tourism model.

Infrastructure

The pilot combines **on-site and territorial infrastructures** to implement and test the HERIT ADAPT Sustainable Tourism Model through the Alhambra as the central node:

- **Installation of interpretive QR panels** and **information points** at the *Corral del Carbón* (the main ticketing area for Alhambra visitors) and in the *Alcazaba* defensive sector, linking the monument to the network of medieval watchtowers in the Western Mountains.
- **Deployment of complementary signage and QR codes** in the municipalities of Moclín, Montefrío and Íllora, coordinated by the **Granada Provincial Council** and **Consorcio Vega Sierra Elvira**, establishing the Alhambra–Western Mountains as a continuous cultural route.
- **Integration with the official Alhambra and municipal tourism websites**, offering downloadable **GPX/KML routes**, background videos, and gastronomic/craft itineraries.
- **Potential development of Augmented Reality (AR) content** to visualize historical connections between the Alhambra's fortifications and the rural towers visible from its ramparts.

Future feasibility studies will assess the installation of **non-invasive environmental sensors** near the towers and defensive sites, in collaboration with atmospheric physics experts, ensuring compliance with **BIC (Bien de Interés Cultural)** protection regulations.

Technology

The pilot relies on a combination of **AI-based, GIS-based, and immersive technologies** to enhance visitor interpretation and monitor sustainable tourism indicators:

- **AI-assisted audiovisual storytelling**: creation of hyper-realistic short films generated with Kling, Adobe Creative Cloud, Gemini, ChatGPT and Krita, narrating the historical and climatic links between the Alhambra and the Western Mountains.
- **Web integration and GIS mapping**: WordPress-based platform embedding interactive **Mapbox maps**, routes exported in **GPX/KML**, and QR-linked narratives for mobile users.
- **Analytics infrastructure**: QR and video tracking via **Google Analytics / Tag Manager**, enabling data collection on visitor engagement, origin, and post-visit interest in rural sites.

- **Survey and feedback tools**: digital forms (Google Forms, LimeSurvey) for measuring perception, satisfaction, and behavioral changes before and after exposure to storytelling content.
- **(Optional pilot expansion)** Integration of **IoT micro-sensors** for real-time monitoring of microclimate and visitor impact in selected rural towers, providing complementary environmental data to the pilot.

The technological configuration ensures full **interoperability** with the HERIT ADAPT portfolio and prioritizes **low-impact, accessible digital solutions**, scalable to other MED heritage sites

Data collection

The pilot generates and collects a variety of **quantitative and qualitative data** to evaluate the effectiveness of the HERIT ADAPT Sustainable Tourism Model within the Alhambra and its connected rural network.

Data types and collection methods:

- **Visitor analytics** gathered through **QR scans and video plays** at the *Corral del Carbón* and the *Alcazaba*, providing metrics on user engagement, dwell time, and interaction with the Western Mountains narratives.
- **Geospatial and route data**, including downloads of GPX/KML itineraries, mapping visitor interest across the Alhambra–Moclín–Montefrío–Íllora axis.
- **Perception and satisfaction surveys,** distributed both digitally (via QR codes) and through field testing with tourists, local guides, and residents, to assess awareness and behavioural change.
- **Local economic indicators**, such as the number of businesses and cultural operators participating in the tourism product (crafts, gastronomy, rural lodging).
- **Environmental and climatic data**, potentially integrated from non-invasive micro-sensors located near watchtowers, to correlate visitor activity with climatic variables.

Data management and sharing:

All data will be **anonymized and aggregated**.

They will be shared among HERIT ADAPT partners through the project's common repository and made accessible to local stakeholders, including the **Patronato de la Alhambra y Generalife**, **Diputación de Granada**, and **Consorcio Vega Sierra Elvira**, for monitoring and evaluation purposes.
Results will also contribute to the definition of **transferable sustainability indicators** for other heritage sites across the MED area.

Mapping to tools / solutions

The Alhambra pilot applies and validates the HERIT ADAPT tool developed under **Activity 2.1**, titled: **Emotionally Intelligent Destinations (EID) — AI-Generated Storytelling for Andalusian Watchtowers.**

Through the installation of interactive QR points and AI-based audiovisual narratives, the tool:

- **Links the Alhambra's defensive heritage** with the wider territorial system of fortresses and watchtowers in the Western Mountains.
- **Demonstrates scalability** of AI-generated storytelling as a visitor management and interpretation method adaptable to other Mediterranean heritage contexts.
- **Integrates seamlessly** with existing digital infrastructures of the Patronato de la Alhambra and municipal tourism offices, contributing to a shared sustainable tourism framework.
- **Provides measurable outputs** (views, scans, engagement rates) aligned with the HERIT ADAPT monitoring methodology and the common indicator system.

The pilot thus transforms the Alhambra from a static attraction into an **active gateway for sustainable tourism innovation**, using emotional storytelling and data-driven insights to redistribute cultural, environmental, and economic value across its surrounding territory.

Stakeholder engagement

The pilot benefits from an extensive **multi-level stakeholder network** connecting the **Patronato de la Alhambra y Generalife** with regional and local partners in the Western Mountains of Granada.

1. **Institutional stakeholders:**

- *Patronato de la Alhambra y Generalife* — Pilot site and leading institution in sustainable visitor management.
- *Diputación de Granada* — Support for regional coordination and signage infrastructure.
- *Consorcio Vega Sierra Elvira* — Territorial coordination and stakeholder integration.
- *University of Granada (UGR)* — Methodological design, technical development, and evaluation of the pilot.
- *Asociación para el Desarrollo Sostenible del Poniente Granadino* — Liaison with local businesses and community actors.

2. **Local stakeholders and associations:**
   Municipalities of Moclín, Montefrío and Íllora; local NGOs such as *Gallipatos*, *La Pileta*, *Almenara*; *Amnistía Internacional – Granada Chapter*; *Granada Tourist Guides Association*; *CADEs* (Villanueva de Mesía, Íllora, Montefrío); local schools, artisans, and cultural agents.
3. **Citizen involvement:**
   Visitors and residents participate in the testing of QR codes and audiovisual materials. Initial surveys are being circulated via mobile devices and social networks to capture perception and behavioural changes.
4. **Training and awareness actions:**

A second-phase **capacity-building programme** will involve local librarians, tourist guides, and municipal culture officers.

Training will focus on:

- Using AI and storytelling for heritage interpretation.
- Managing and promoting sustainable itineraries.
- Monitoring visitor engagement through the digital dashboard.

5. **Feasible and low-cost activities:**

- "*Local Heritage Ambassadors*" initiative to empower youth and librarians as promoters of the pilot routes.
- Short workshops for municipal staff on inclusive communication and sustainable tourism.

- On-site demonstrations showing how QR systems and dashboards operate.

These activities strengthen local ownership of the HERIT ADAPT methodology and ensure long-term transferability beyond the project's lifetime.

Outcomes and long-term benefits

Accessibility

The pilot directly addresses accessibility gaps by introducing **multilingual signage (ES/EN/FR/DE)** and **inclusive interpretive materials** (audio description, simplified texts, subtitles, and high-contrast visuals).

Both physical and digital components are designed following **WCAG 2.1 AA** standards.

Special consideration is given to **neurodiverse visitors** (e.g. autistic spectrum) and those with **hearing or mobility impairments**.

Diversification and De-seasonalization

The Alhambra pilot contributes to **temporal and spatial diversification** by:

- Encouraging visitors to explore connected routes and rural experiences throughout the year, reducing pressure on peak seasons.
- Promoting **off-season cultural events** and gastronomy workshops in the Western Mountains.
- Supporting **cycling and hiking tourism**, activities less dependent on traditional high-season visitation patterns.
- Generating **new narrative-based products** that allow repeat visitation and year-round engagement.

Training and capacity building

The pilot strengthens local competencies through structured **training and mentoring** actions:

- **Workshops and practical sessions** on managing sustainable tourism data and digital storytelling tools.
- **Upskilling of local personnel** (guides, municipal staff, tourism technicians) in accessibility, heritage communication, and climate adaptation messaging.
- **Peer-learning exchanges** between the Alhambra and rural municipalities, ensuring shared governance and continuity of practices after project completion.

Together, these outcomes enhance the **social resilience and adaptive management capacity** of both the Alhambra and its surrounding heritage territories, setting a precedent for **integrated, climate-conscious tourism models** across the Mediterranean.

Strategy dimension

Element	Description
Problem Context	The Alhambra and Generalife face high visitor density and environmental pressure resulting from overtourism. In contrast, nearby rural areas with direct historical links—such as Moclín, Montefrío and Íllora—remain under-visited and economically fragile.
Strategy & Goals	To transform the Alhambra into a **gateway for sustainable tourism redistribution**, connecting it with the Western Mountains through AI-generated emotional storytelling, itineraries, and community participation. The goal is to promote sustainable tourism development in the municipalities of the Western Mountains, which have attractive tourism potential based on the cultural heritage of the fortresses and watchtowers linked to the historical development of the Nasrid Kingdom, connecting the rural areas of the Western Mountains with the Alhambra through the **creation of a tourism product that focuses on the role played by the defensive watchtowers**, with the aim of redistributing some of the visitors to the Alhambra to these territories.
Tools / Methods	Implementation of the **Emotionally Intelligent Destinations (EID)** tool developed under Activity 2.1: AI-generated short films, QR interpretation panels at the Alhambra, GIS-based rural routes, online platform, and stakeholder co-creation workshops.
Expected Outcomes & Impact	Diversified visitor flows from the Alhambra toward rural heritage areas; improved perception of sustainability and heritage cohesion; empowerment of local actors (including women and young professionals); increased adaptive management capacity for climate-aware tourism.

KPIs

Tool-specific and Behavioural Indicators

1. UC3: AI Storytelling. KPIs for Pilot Outputs (The "What" - Direct Results of the Experimentation)

These measure the successful development and deployment of the technological solutions

Key Performance Indicator (KPI)	Target 2026	Measurement Method

AI-Narrative Content Developed	5	Number of episodes narrated or personalized narratives generated and integrated using AI tools.
Total video views (AI short films)	≥5,000	YouTube/Vimeo analytics
QR code scans at Alhambra + rural sites	≥1,000	Google Analytics / Tag Manager
Post-visit satisfaction rate	≥50%	Online survey (Google Forms / LimeSurvey)
Visitors reporting intention to visit rural areas after exposure	≥15%	Post-exposure survey
Stakeholder Engagement	≥5	Number of activities co-created by TWG
Local businesses engaged in pilot itineraries	≥10	UGR & A.D. Poniente records
Participation of women in storytelling and guiding	≥30%	Workshop and training records

2. UC3: AI Storytelling. KPIs for Short-to-Medium Term Outcomes (The "So What" - Changes in Behavior & Conditions)

These measure the successful development and deployment of the technological solutions

Key Performance Indicator (KPI)	**Target 2027**	**Measurement Method**
Total video views - interactions (AI short films)	≥10,000	YouTube/Vimeo analytics
QR code scans at Alhambra + rural sites	≥2,500	Google Analytics / Tag Manager
Post-visit satisfaction rate	≥75%	Online survey (Google Forms / LimeSurvey)
Visitors reporting intention to visit rural areas after exposure	≥25%	Post-exposure survey

Alhambra visitors aware of Western Mountains heritage	≥15%	Field survey at Alhambra exits

3. UC3: AI Storytelling. KPIs for Long-Term Strategic Impacts (The "What Ultimately Changes")

Strategic Goal	**Key Performance Indicator (KPI)**	**Measurement Method**
Sustainable Regional Develpment	New local tourism businesses created	Institutional Regional Database
Increase in businesses started by women	Women's entrepreneurship in local businesses related to the tourism product created	Institutional Regional Database
Transferability & Model Success	Adoption by other sites	Number of non-pilot sites (within or outside the consortium) that formally adopt tools or methodologies from the HERIT ADAPT model

SUSTAINABILITY INDICATORS:

DIMENSION	**INDICATOR**	**TARGET**	**SOURCE**
A. Environmental	— Increase in rural site visits	+15%	QR and survey data
B. Socio-Cultural	● Number of active local stakeholders ● Accessibility improvements (signage, audio, multilingual)	≥50 ≥15 new elements	UGR records Signage audit

C. Economic & Operational	● New local products (crafts, gastronomy) linked to pilot routes	≥5	Business registry
D. Behavioural Change	Visitors reporting improved awareness of sustainability	≥20%	Post-visit surveys

Žabljak Crnojevića Fortress, Montenegro

Žabljak Crnojevića is an abandoned medieval fortress in Montenegro. It is located on the confluence of the Morača river in Lake Skadar.

Specific Objectives

The main objectives of the pilot are:

- To promote the Fortress as a tourist destination and a central attraction for the entire surrounding area, in the context of thematic experiences
- To enhance visibility of the monument online via the Virtual Tour
- To act as a starting point for the valorization of other monuments and the entire surrounding area

Individual issues

- The access road to the Fortress is seasonally cut off due to water rising
- inadequate protection of the fortress from deterioration
- Water Fluctuation: Rising water levels at mostly winter and early spring, making it difficult for tourists to visit the fortress

HERIT ADAPT Sustainable Tourism Model Evaluation

Understanding Risks and impact

The Fortress is an under-utilized monument that is vulnerable to climate change. Despite its significance, lack of access during several seasons reduces its potential and makes preservation efforts harder. This pilot aims to promote the monument as a central attraction for the surrounding area, positively impacting the local population and economy, while helping with the preservation tasks of the Fortress.

Infrastructure

Photogrammetry related infrastructure has been created in the Old Royal Capital Cetinje.

Technology

Drones with LIDAR technology have been utilized to create the 3D model of the Fortress.

Mapping to tools / solutions

This pilot applies the 3D model solution developed in the HERIT ADAPT project. This solution is used both for scientific purposes, to aid preservation experts, and to promote the monument together with the developed Virtual Tour.

Stakeholder engagement

- Local authorities
- Local public
- Tourism stakeholders
- Local businesses

Outcomes and long-term benefits

Accessibility

The development of a virtual tool of the fortress for those who suffer from a disability that prevents them from visiting the site in person.

Strategy Dimension

Problem Context

The Fortress is an under-visited monument despite its historical significance. Lack of year round access due to rising water makes the monument inaccessible to tourists and hard to preserve.

Strategy & Goals

A 3D model of the monument is used to promote visibility and make the Fortress a central attraction for the entire region, attracting tourist flows and enhancing the tourist product of the surrounding area.

Tools / Methods

Drones with LIDAR technology have been used to create an accurate 3D model of the Fortress complex.

Expected Outcomes & Impact

An immersive digital recreation of the Fortress will be used to engage local and remote audiences, highlighting the significance of the monument and attracting more visitors for an enhanced tourist experience.

KPIs

- % of the pilot site accurately modeled in 3D against project specifications
- Number of conservation actions initiated based on data from the Digital Twin or IoT monitoring
- Number of online interactions
- % change in visitor numbers to promoted, lesser-visited areas within or near the pilot site
- % change in visitor numbers during shoulder/low seasons compared to baseline
- Number of concrete actions or strategies co-created and approved by the Territorial Working Groups
- Heritage Preservation Index
- % of visitor spending occurring in local businesses (accommodation, artisans, restaurants) in neighboring municipalities.
- % of local residents who believe tourism is well-managed and has a positive impact on their quality of life.
- Number of non-pilot sites (within or outside the consortium) that formally adopt tools or methodologies from the HERIT ADAPT model.
- Amount of additional funding (EU, national, private) secured by partners to scale up the solutions tested in the pilots.

Site of Genoa: "Museo Chiossone"

Pilot Testing implementation methodology

Pilot summary. The Museo Chiossone pilot focuses on improving the accessibility, visibility, and sustainable enjoyment of the Museo d'Arte Orientale "E. Chiossone" and its surrounding Villetta Di Negro Park. The intervention aims to balance cultural valorization with tourism flow redistribution, enhancing visitors' experience through targeted signage and integrated digital communication tools. Furthermore, the intervention focus on heat islands issues by redirecting tourism flow to a "cooler" route (the Chiossone Museum is located within an urban park).

Objectives

- Strengthen the museum's accessibility and legibility within the urban and park context;
- Support the decentralization of tourist flows from the UNESCO core area toward under-visited cultural sites;
- Focusing on heat island issues, redirecting tourism flow to a "cooler" route.
- Promote sustainable tourism practices and awareness through improved information and visitor orientation;
- Test adaptive communication and monitoring tools in line with HERIT ADAPT principles.
- Use of 3D techniques for: conservation and research, virtual access, educational use e improvement of accessibility and visibility.

Stakeholders

- Comune di Genova – project coordination and implementation support;
- Università di Genova (DICCA) – methodological guidance, coordinator of participatory activities, monitoring, and data analysis;
- Museo d'Arte Orientale "E. Chiossone" – site management and cultural mediation;
- Regional and local heritage authorities – supervision and alignment with preservation policies (UNESCO Steering Committee);
- Local community and visitors – active participants in feedback and co-design.

Tools to be tested (from HERIT ADAPT portfolio).

- UC1: Digital Twin & 3D Modeling – 3D scanning and photogrammetric reconstruction of selected museum artefacts (e.g., samurai armours) to create accurate digital replicas for conservation, virtual access, and educational use. These assets will be integrated into the museum's digital archive to support conservation, research, and virtual accessibility.
- UC2: XR/AR for Enhanced Visibility - Deployment of immersive digital content linked to the 3D models published on the museum's website. The experience will enable online exploration (virtual tours, interactive model views) and AR-based storytelling. Enhanced visibility through implementation of vertical/horizontal signage and improvement communication.

- UC3: AI-Enabled Storytelling – Testing of AI-driven narrative tools to generate personalized descriptions and thematic stories for the scanned artefacts, enriching the museum's digital platform and enhancing user engagement.
- UC4: Big Data & IoT Integration – Collection and management of site data (visitor flows, accessibility, environmental parameters) through digital dashboards and participatory mapping tools (e.g., MyMaps).

Method.

— *Phase 1 – Pre-Testing Preparation & Baseline Establishment:* The Territorial Working Group _TWG of Genoa identified the Chiossone Museum and Villetta Di Negro Park as a pilot site to test adaptive tourism measures. A baseline analysis was conducted through field visits, stakeholder meetings, and data collection on accessibility, visitor flows, and signage conditions.
As part of the preliminary digital documentation, a 3D scanning campaign of the museum's samurai armours and selected artworks was carried out. This activity aimed to support the creation of high-fidelity digital replicas and to test the potential of photogrammetry within the HERIT ADAPT framework (UC1 – Digital Twin & 3D Modeling).
The diagnostic phase defined the main challenges: poor visibility, limited orientation tools, and underutilization of the park's cultural and climate potential.

— *Phase 2 – Testing & Monitoring:* The pilot intervention involved the design and installation of new vertical signage within the park and adjacent streets, alongside the continuation of the 3D scanning process and metadata organization of the museum's artefacts. Continuous monitoring was carried out through site observations, photographic documentation, and stakeholder feedback. Data collection focused on visitor behavior, wayfinding effectiveness, and public perception of both the physical signage and the potential use of digital assets for storytelling and educational purposes. ON GOING

— *Phase 3 – Mid-term Adaptation:* ON GOING

— *Phase 4 – Final Evaluation & Reporting:* ON GOING

— *Phase 5 – Learning & Knowledge Transfer:* ON GOING

Data collected

- Baseline opinions of accessibility and signage conditions.
- Visitor flow observations and photographic documentation before and after intervention.
- Stakeholder feedback (museum staff, municipality, TWG members, tourists).
- Quantitative and qualitative assessment of visitor orientation and satisfaction.
- Georeferenced data from the MyMaps participatory mapping activity.

KPIs

- Number of high-resolution 2D/3D digital assets (models, textures, point clouds) created and archived [Baseline: 3/12]
- Number of vertical/horizontal signage installed. [Baseline: 1]
- % increase in staff/management who report a "good" or "very good" understanding of site-specific climate vulnerabilities after using the tools. [Baseline: 25%]
- Number of online interactions (virtual tours, model views, social media shares of AR content). [Baseline: 0 interactions/year]
- % change in visitor numbers to promoted, lesser-visited areas within or near the pilot site. [Baseline: Visitor numbers Nov 24]
- % change in visitor numbers during shoulder/low seasons compared to baseline. [Baseline: Visitor number Nov 24 – Feb 25]
- Number of concrete actions or strategies co-created and approved by the Territorial Working Groups (TWGs) using data from the pilots. [Baseline: 0]
- Number of non-pilot sites (within or outside the consortium) that formally adopt tools or methodologies from the HERIT ADAPT model. [Baseline: 0]
- Amount of additional funding (EU, national, private) secured by partners to scale up the solutions tested in the pilots. [Baseline: 0]

Mausoleum–Ossuary, Koprivshtitsa, Bulgaria

The Mausoleum–Ossuary in Koprivshtitsa is a commemorative monument dedicated to the participants who fell during the April Uprising of 1876, a defining event in Bulgaria's national revival and struggle for liberation. The site forms part of a wider historic urban environment characterized by preserved National Revival architecture and a strong tradition of cultural tourism. Designed by architect Panteley Tsvetkov, construction began in 1926 and was carried out by local stonemasons using funds provided by the prominent local benefactor Nencho Palaveev. Although the mausoleum was officially opened in 1928, the monument was fully completed in 1930, standing today as a central symbol of the town's revolutionary spirit.

Specific Objectives

The HERIT ADAPT project is built around several core specific objectives aimed at creating a robust framework for sustainable heritage management. Key among these is the need to improve **understanding and management of visitor flows**, using data to ensure that tourism benefits sites without overwhelming them. Simultaneously, the project seeks to **strengthen climate resilience and preventive conservation**, implementing adaptive measures to protect physical structures from environmental degradation. A further goal is to **enhance interpretation and visitor experience**, leveraging digital tools like **3D modeling** and **360-degree virtual tour** that allows for detailed digital exploration of the monument's interior to make the rich history of these sites more engaging and accessible. These efforts are designed not just to preserve the monuments themselves, but to actively **support sustainable local development** by integrating heritage sites into the local economy. Ultimately, the project emphasizes the critical importance of **promote stakeholder collaboration and local ownership**, ensuring that conservation strategies are inclusive and have lasting community support.

Individual Issues Related to the Pilot

The individual issues related to the **Mausoleum–Ossuary in Koprivshtitsa** can be grouped into several general categories:

- **Environmental and climate-related risks** include the impact of rain, wind, extreme temperatures, humidity, and drought, which contribute to erosion and long-term deterioration of the monument;
- **Tourism pressure and visitor management challenges** arise from unrestricted access, high foot traffic, uneven visitor distribution, and seasonality, increasing the risk of physical damage;

- **Conservation and management limitations** are evident in the lack of clear regulations, insufficient preventive conservation measures, and limited financial and technical resources;
- **Environmental sustainability concerns** include inadequate waste management and the resulting negative impact on the surrounding area;
- **Awareness and governance challenges** stem from low public awareness of climate-related risks and fragmented coordination among stakeholders responsible for the site's protection.

HERIT ADAPT Sustainable Tourism Model Evaluation

Understanding Risks and impact

The evaluation of the HERIT ADAPT pilot for the Mausoleum–Ossuary in Koprivshtitsa highlights a promising approach to sustainable heritage management, though there are areas for improvement. Governance and stakeholder engagement show potential, with collaboration between local authorities, national agencies, and the Koprivshtitsa community, though coordination efforts could be further strengthened. The integration of digital tools is a key focus, with the development of a 3D model of the mausoleum and the introduction of a 360-degree virtual tour, showcasing advanced digital heritage practices and enhancing the visitor experience. However, while the pilot emphasizes climate resilience and preventive conservation, there is limited evidence of active environmental monitoring systems, leading to a moderate rating for heritage and environmental risk management. Tourism flow and sustainability have been conceptually addressed, but the lack of clear regulations and strategies for visitor management remains a challenge. Overall, the pilot demonstrates strong foundations in governance, technology, and digital heritage, with opportunities to improve real-time monitoring, manage visitor flows more effectively, and engage the local community more actively to ensure the long-term sustainability and resilience of the site.

Infrastructure

No infrastructure has been planned to be installed in the pilot site. Only two humidity and temperature sensors will be installed.

Technology

The Mausoleum–Ossuary in Koprivshtitsa has successfully integrated drone-based 3D model rendering and a 360-degree virtual tour to enhance both its preservation and visitor engagement.

Drone-Based 3D Model Rendering

Using high-resolution drones, a series of detailed aerial photographs were taken from multiple angles around the mausoleum. These images were processed using advanced photogrammetry software like Agisoft Metashape, which analyzed overlapping images to create a highly accurate 3D model of the site. The result was a point cloud that captured intricate details of the mausoleum's structure and surroundings. This point cloud was then transformed into a mesh, outlining the monument's surface in three dimensions.

High-resolution textures, based on the photos taken during the drone survey, were mapped onto the 3D mesh, creating a realistic digital twin of the mausoleum. The model was optimized for online and mobile viewing, allowing for easy access without sacrificing detail. This digital model now serves as a vital resource for monitoring the monument's condition, supporting preventive conservation efforts, and preserving its historical accuracy for future generations.

360-Degree Virtual Tour

Inside and around the mausoleum, 360-degree cameras captured immersive, panoramic images that provide a comprehensive view of the monument's interior and exterior. These photographs were stitched together seamlessly to form interactive panoramas that allow visitors to virtually walk through the site.

The 360-degree virtual tour is integrated with interactive elements that highlight key features of the mausoleum, such as historical inscriptions and architectural details. Visitors can navigate the site by clicking or dragging to move from one location to another, experiencing the monument as if they were physically there.

Integration of Technologies

The 360-degree virtual tour complements the drone-generated 3D model, allowing users to switch between an interactive, walkable experience and a detailed 3D view. This integration provides an even more comprehensive and engaging way to explore the mausoleum, with the ability to zoom in on specific architectural features or view the monument from different angles.

Accessibility and Impact

The virtual tour is available on a web platform, enabling global access to the Mausoleum–Ossuary in Koprivshtitsa. Whether through a desktop computer, smartphone, or virtual reality headset, users can explore the monument remotely. This not only helps to raise awareness about the historical significance of the site but also reduces the physical impact on the monument, promoting sustainable tourism practices.

Benefits for Preservation and Education

The integration of these technologies provides a digital archive that contributes to the ongoing preservation efforts for the mausoleum. The 3D model allows for precise monitoring of any structural changes or wear over time, aiding in preventive conservation. Additionally, the virtual tour makes the mausoleum more accessible to a wider audience, both locally and internationally, enhancing its role as an educational and cultural resource.

By offering a rich, interactive experience, these technologies promote engagement with the history of the April Uprising, ensuring that the monument remains a living, accessible piece of Bulgaria's heritage.

Mapping to tools / solutions

In addition to the drone-based **3D modeling and 360-degree virtual tour**, the **installation of humidity and temperature sensors** within the Mausoleum–Ossuary in Koprivshtitsa provides key benefits for its preservation. These sensors will monitor environmental conditions in real time, transmitting data that can be used to track fluctuations in temperature and humidity, which are critical factors in the monument's preservation. By collecting this data, the sensors help identify potential risks for material degradation, allowing for timely interventions to prevent damage. This integration enhances preventive conservation efforts, ensuring the mausoleum's physical integrity is maintained while offering data-driven insights for long-term protection.

Data Collection

The 3D model and virtual tour are **publicly available** on the internet and **can be embedded in websites**. In addition, they will be provided to any stakeholders involved in the project.

Humidity and temperature data will be collected in real time via an online application. As tourist access to the monument is free, **official data on tourist flows** is obtained from the National Statistical Institute of Bulgaria.

Stakeholder Engagement

Stakeholder engagement is vital for the sustainable development and promotion of the Mausoleum–Ossuary in Koprivshtitsa. Regular meetings of the Territorial Working Group, alongside broader stakeholder meetings, provide essential platforms for collaboration among municipal authorities, museums, cultural institutions, schools, tourism operators, and community representatives. These meetings allow stakeholders to discuss key issues related to site preservation, promotion, and

integration into educational and tourism programs. By fostering open communication and coordination, the group ensures a unified approach to safeguarding the Mausoleum–Ossuary while exploring opportunities for sustainable local development. These ongoing discussions enhance the site's visibility, encourage responsible tourism, and ensure that the cultural and economic benefits of the site are shared by the entire community.

Outcomes and Long-Term Benefits

Within the framework of the HeritAdapt project, the implementation of various measures at the Mausoleum-Ossuary in Koprivshtitsa has led to several significant outcomes and long-term benefits aimed at sustainable cultural heritage management and balanced tourism development.

Improved Interpretation and Awareness

The project aimed to enrich the visitor experience and raise awareness about the Mausoleum's historical significance and the 1876 April Uprising heroes it commemorates.

- **Enhanced Engagement:** Innovative approaches to presenting the heritage helped visitors connect more deeply with the site's history.
- **Increased Information Access:** Koprivshtitsa is bringing its heritage into the digital age as part of the project, including digital exhibits and information that improve the accessibility and understanding of the site.
- **Promoting Responsible Behavior:** A key goal of the improved interpretation is to inspire behavior among tourists that is mindful of the preservation of the cultural and natural environment.

More Balanced Tourism Flows

HeritAdapt focused on managing the impact of tourism activities on cultural heritage by leveraging technology and data exploitation.

- **Sustainable Tourism Model**: HeritAdapt aims to develop and implement a sustainable tourism model tailored to pilot areas like Koprivshtitsa. This model helps optimize visitor routes and manage demand to avoid overcrowding during peak times.
- **Mitigating Negative Impacts:** Better management of flows ensures a balance between using the site for tourism and its long-term preservation, which is crucial for its sustainability. The project helps regions adapt to the pressures of mass tourism.

Enhanced Local Capacity for Sustainable Heritage Management

The project reinforced the sustainability and resilience of the destination by increasing the adaptation capacity of its natural and cultural heritage assets.

- **Skill Development:** Participation in the project, including developing and applying policies and strategies, has improved the capacity of local authorities and experts in Koprivshtitsa to manage EU-funded projects and implement best European practices.
- **Strategic Planning:** The project has provided the municipality with a framework to develop its own visions and strategies that link cultural heritage protection with sustainable tourism development.
- **Stakeholder Engagement:** The activation of interdisciplinary Territorial Working Groups (TWGs) within the project has fostered collaboration among various local stakeholders, a key element for effective and inclusive heritage management.

Overall, HeritAdapt has contributed to making the Mausoleum-Ossuary a more sustainable and resilient destination by introducing innovative, data-based solutions and strengthening local governance.

KPIs

- *% of the pilot site accurately modeled in 3D against project specifications*
- *Number of high-resolution 2D/3D digital assets (models, textures, point clouds) created and archived*
- *Detailed 360° Virtual tour*
- *Two humidity and temperature sensors installed, with online real-time data monitoring and data Archiving*
- *Number of conservation measures planned based on visual analysis through the 3D model the sensors data*
- *% increase in understanding of climate risks through pre- and post-training surveys*
- *Number of joint actions with the municipality, museum, or schools*
- *Number of resilience and preservation actions integrated into the site management plan*
- *% Increase in the total number of visitors*
- *% of surveyed residents with a positive view of tourism impact*
- *Organization of cultural, sport and educational events*
- *Maintenance of terrain and green areas. Cleaning and waste management. Visitor awareness*

campaigns

- *Number of non-pilot sites (within or outside the consortium) that formally adopt tools or methodologies from the HERIT ADAPT model*

KPI Framework

The Key Performance Indicator (KPI) framework for the HERIT ADAPT project is structured to capture progress across three levels: Pilot Outputs, Short-to-Medium Term Outcomes, and Long-Term Strategic Impacts. This framework incorporates all KPIs proposed by individual pilots, organized thematically and aligned with the project's four main use cases:

UC1: Digital Twin & 3D Modeling

UC2: XR/AR for Enhanced Visibility

UC3: AI-Enabled Storytelling

UC4: Big Data & IoT Integration

Each KPI is mapped to the relevant pilot(s) where it is measured, ensuring a comprehensive and comparable monitoring approach across all sites.

KPIs for Pilot Outputs (The "What" - Direct Results of the Experimentation)

These KPIs measure the successful development, deployment, and immediate tangible results of technological and methodological interventions.

Category	KPI	Pilot(s)	Measurement method and Target
Digital Twin & 3D Modeling	% of pilot site accurately modeled in 3D	Limassol (CY), Western Greece (GR), Montenegro (ME), Genoa (IT), Dubrovnik (HR), Koprivshtitsa (BG)	Project validation report; target: 100% of defined area
	Number of high-resolution 2D/3D digital assets created/archived	Limassol, Western Greece, Montenegro, Genoa, Dubrovnik, Koprivshtitsa	Digital asset library count
	Completion of 3D model and digital media library	Limassol	Delivery confirmation and metadata catalog
	Completion of descriptive report documenting digital twin process	Limassol	Report submitted and approved
XR/AR Deployment	Number of functional XR/AR experiences deployed	Rome (IT), Genoa	Live deployment records and user accessibility
	Number of languages/ accessibility features integrated	Rome, Granada (ES), Genoa	Feature list; target: ≥3 languages + WCAG 2.1 AA compliance

	XR intervention interaction rate (% of visitors)	Rome	On-site analytics; target: ≥60%
AI & Storytelling	Number of AI-generated narrative contents developed	Granada	Content management system; target: 5 episodes
	Total video views (AI short films)	Granada	YouTube/Vimeo analytics; target: ≥5,000
IoT & Data Integration	IoT sensor network operational (%)	Dubrovnik, Occitanie (FR), Granada (potential), Koprivshtitsa (BG)	IoT platform dashboard
	Data integration platform active (≥3 sources)	Dubrovnik, Occitanie, Granada	Dashboard validation and data flow logs
	Number of data logs received from sensors	Dubrovnik	Data log records; continuous transmission
Infrastructure & Tools	Number of vertical/horizontal signage installed	Genoa, Granada	Installation audit and geolocation records
	Number of eco-counters/sensors installed	Occitanie (Villefranche de Conflent)	Installation report; target: 3 eco-counters
	QR code panels installed at key points	Granada, Genoa	Site audit and QR functionality test
Data Collection & Reporting	Number of datasets consolidated from all partners	All pilots	Final project repository inventory
	Completion of site condition/risk assessment reports	Limassol, Occitanie, Dubrovnik	Report delivery and stakeholder validation
	Number of maintenance logs/structural assessments collected	Limassol, Dubrovnik	Logbook entries and digital records

KPIs for Short-to-Medium Term Outcomes (The "So What" - Changes in Behavior & Conditions)

These KPIs assess changes in visitor behavior, stakeholder engagement, site management, and tourism flows during and shortly after pilot implementation.

Category	**KPI**	**Pilot(s)**	**Measurement method and Target**

Visitor Engagement & Experience	QR code scans at Alhambra + rural sites	Granada	Google Analytics/Tag Manager; target: ≥1,000 scans
	Visitor interaction with digital tools (% who report enhanced understanding)	Rome, Granada, Limassol, Dubrovnik, Genoa, Koprivshtitsa	Post-visit surveys; target: ≥75%
	Average visit duration vs. baseline/control	Occitanie, Rome, Granada, Limassol	Visitor tracking and ticket data analysis
	Number of online interactions (virtual tours, AR content)	Genoa, Dubrovnik, Montenegro, Granada	Web/social analytics; target: ≥10,000 engagements
Visitor Flow & Diversification	% change in visitor numbers to promoted lesser-visited areas	Granada, Genoa, Montenegro, Western Greece, Koprivshtitsa	Pedestrian counters/ticket data; target: +15%
	% change in off-season/shoulder-season visitation	All pilots	Official statistics; target: +5–10%
	Visitors reporting intention to visit rural areas after exposure	Granada	Post-exposure survey; target: ≥15%
	Number of visitors from educational/school trips	Western Greece, Limassol	School visit logs and booking records
Stakeholder & Community Engagement	Number of TWG actions/strategies co-created and approved	All pilots	TWG meeting minutes and action plans
	Number of local stakeholders/businesses engaged	Granada, Limassol, Dubrovnik, Western Greece, Occitanie	Stakeholder registries and participation logs
	Number of community members surveyed	Limassol, Dubrovnik, Granada, Occitanie	Survey records and response rates
	Stakeholder climate risk awareness increase (%)	Occitanie, Dubrovnik, Western Greece, Genoa	Pre- and post-workshop surveys
Capacity Building & Training	Number of training/workshop participants	Dubrovnik, Western Greece, Granada, Limassol, Rome	Attendance lists and feedback forms
	Number of students participating in climate/heritage visits	Limassol, Western Greece	School records and educational activity reports
	Upskilling of students/younger generations (knowledge gain)	Limassol	Pre- and post-educational visit assessments
Environmental & Heritage Monitoring	Number of conservation actions initiated based on digital data	Dubrovnik, Western Greece, Montenegro, Limassol, Koprivshtitsa	Maintenance logs and restoration reports

	Number of risks identified and solutions addressed	Occitanie	Risk assessment reports and action plans
	Reduction in erosion/wear-and-tear at site	Limassol	Site condition monitoring and comparative analysis
	Visitor flow density (ratio visitors/inhabitants)	Occitanie	Sensor data and local population data

KPIs for Long-Term Strategic Impacts (The "What Ultimately Changes")

These KPIs evaluate the lasting contributions to heritage resilience, sustainable regional development, social inclusion, and the transferability of the HERIT ADAPT model.

Category	**KPI**	**Pilot(s)**	**Measurement method and Target**
Heritage Resilience & Preservation	Heritage Preservation Index (composite metric)	Dubrovnik, Western Greece, Montenegro, Limassol	Periodic conservation audits and monitoring
	Number of climate adaptation measures integrated into management plans	Occitanie, Dubrovnik, Granada, Koprivshtitsa	Official management plan updates
	Measured reduction in environmental degradation	Limassol, Occitanie	Environmental monitoring reports
Sustainable Regional Development	% of visitor spending in local businesses	Montenegro, Granada, Western Greece, Limassol, Occitanie	Regional tourism spend surveys
	Number of new local tourism products/businesses created	Granada, Western Greece, Occitanie	Business registry and stakeholder reports
	% of local residents with positive perception of tourism	Montenegro, Dubrovnik, Granada, Limassol, Koprivshtitsa	Biannual community surveys
	Economic diversification through tourism	All pilots	Local employment and revenue tracking
Social & Economic Inclusion	Participation of women in storytelling/guiding activities	Granada	Workshop/training records; target: ≥30%
	Accessibility improvements implemented (multilingual, inclusive design)	Granada, Rome, Genoa	Accessibility audit and user feedback

	Number of local school students engaged in heritage activities	Limassol, Western Greece	School partnership records and activity reports
Transferability & Model Success	Number of non-pilot sites adopting HERIT ADAPT tools/methodologies	All pilots (knowledge transfer)	Replication agreements and adoption reports
	Amount of additional funding secured for scaling solutions	All pilots	Financial reports and grant applications
	Number of events/exhibitions participated in (dissemination)	Western Greece, Limassol, Dubrovnik, Granada	Event logs and participation records
	Number of authorities/institutions interested in replicating methodology	Western Greece, All pilots	Letters of interest and follow-up meetings

Conclusions

This deliverable, D.2.2.1, has presented a comprehensive, cyclical, and unifying implementation methodology for the pilot testing phase of the HERIT ADAPT project. Designed as a structured yet adaptable framework, the methodology provides all territorial partners with a clear roadmap to validate the project's Sustainable Tourism Model across a diverse range of geographical, climatic, and heritage contexts. The detailed testing approaches outlined for each pilot site demonstrate the model's inherent flexibility and its capacity to be tailored to address specific local challenges while maintaining a core of consistency, comparability, and replicability.

The pilot site analyses reveal a powerful collective narrative of innovation and adaptation. From the data-driven tourism intelligence of Villefranche-de-Conflent (Occitanie) to the digital twin creation for remote monuments in Cyprus, Greece, and Montenegro; from the immersive XR experiences in Rome and Genoa to the predictive conservation models in Dubrovnik and the emotional storytelling for visitor redistribution in Granada—each pilot applies the HERIT ADAPT pillars in a unique combination. This diversity is not a weakness but a core strength, proving that the model is not a rigid prescription but a versatile toolkit. Partners have adeptly selected and integrated specific technological solutions—3D modeling, AI, XR, IoT, and data analytics—to tackle pressing issues such as overtourism, physical degradation, climate vulnerability, low visibility, and socio-economic imbalances.

A critical success factor evident across all pilots is the central role of the **Territorial Working Groups (TWGs)**. These multi-helix forums have operationalized the principle of co-creation, ensuring that interventions are grounded in local reality, owned by local stakeholders, and aligned with long-term management strategies. The engagement of public authorities, private businesses, academic institutions, and local communities has been instrumental in transitioning from theoretical planning to practical, socially accepted action. Furthermore, the integrated **KPI Framework** established in this document provides a robust mechanism for evidence-based evaluation. By categorizing indicators into Outputs, Short-to-Medium Term Outcomes, and Long-Term Strategic Impacts, the framework ensures that success is measured not just by the deployment of technology, but by tangible changes in visitor behavior, stakeholder capacity, site resilience, and regional sustainability.

The ultimate validation of the HERIT ADAPT model lies in its **potential for transferability and scaling**. The pilots collectively serve as a living laboratory, generating a rich repository of validated tools, methods, and lessons learned. The documented workflows—from AI-assisted scaffold removal in 3D models to the development of low-cost, non-invasive XR applications—are designed to be replicated. The methodology's emphasis on phases like *Mid-Term Adaptive Management* and *Learning & Knowledge Transfer* ensures that insights are continuously captured and shared, transforming individual experiments into collective intelligence for the Euro-Mediterranean region and beyond.

In conclusion, the implementation methodology and the ensuing pilot activities confirm that the HERIT ADAPT Sustainable Tourism Model provides a viable and effective pathway for heritage destinations to navigate the dual challenges of climate change and tourism pressures. By synergizing **data-driven diagnosis**, **inclusive governance**, and **adaptive innovation**, the project equips sites with the strategies and tools needed to build resilience. The successful execution of this pilot testing phase lays a solid foundation for the next critical step: synthesizing these cross-site results into validated guidelines and policy recommendations, thereby enabling the widespread adoption of a sustainable, resilient, and future-proof model for cultural heritage tourism.