H-GIS and Digital Strategies for the Documentation and Preservation of the Serenissima's Cultural Heritage: Spatio-Temporal Mapping of Itineraries along the Adriatic Coast

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Keywords: 3D Digital Survey, H-GIS, Cultural Heritage Routes, Venetian Serenissima Fortifications, Šibenik.

Abstract

The digitisation of Cultural Heritage through digital technologies and emerging technologies presents innovative opportunities for interpreting intangible values within immersive virtual environments. In the European context, the formal recognition of cultural routes has fostered integrated strategies aimed at safeguarding both tangible and intangible heritage assets.
This study explores the role of digital databases in the analysis of historical itineraries, underscoring the essential need for coherent, structured data frameworks to support long-term conservation and valorisation initiatives. Focusing on the Venetian Serenissima fortifications situated between Italy and Šibenik—strategic nodes within Adriatic trade networks and enduring symbols of Venetian maritime authority—the research employs advanced digital methodologies to map, document, and interpret these complex fortified landscapes.
By integrating high-resolution 3D surveying, archival investigation, and geospatial analysis, the project develops a comprehensive digital atlas, with the Šibenik case study serving as its core application. Conducted within an open-science paradigm, the initiative aims to enhance public engagement, cultivate cultural awareness, and promote sustainable approaches to heritage tourism.
Furthermore, the implementation of digital twins and Historical Geographic Information Systems (H-GIS) substantially deepens the preservation and interpretation of cultural routes by embedding spatial data within historically grounded narratives and multi-scalar analytical models.

1. Introduction

In recent decades, the documentation of cultural heritage has undergone a deep transformation, evolving from a practice focused solely on the three-dimensional reproduction of architectural forms into a complex, multidimensional approach. Today, it functions as a tool capable of encompassing, representing, and preserving not only the tangible components of heritage but also its intangible and symbolic dimensions. This transformation has been made possible by the integration of digital technologies, advanced geospatial tools, and interactive narrative approaches.

The digitisation of cultural assets is no longer limited to the mere physical replication of objects but also aims to enhance the intangible values that form the deepest and most identity-defining aspects of heritage (Shim et al., 2024). Within this context, digital storytelling plays a crucial role: it facilitates the dissemination of historical knowledge, cultural routes, and territorial stratifications within virtual environments, thereby enabling new forms of access to and understanding of historical landscapes. In Europe, the growing attention to cultural routes—understood as thematic networks of sites, architectures, and memories distributed across space and time—has led to the development of innovative strategies for the documentation and safeguarding of both tangible and intangible heritage (Lakoud et al., 2025). These routes represent not only physical paths but also complex narrative frameworks interwoven with cultural, political, economic, artistic, and religious dynamics. Their definition and valorisation thus require the adoption of advanced methodological protocols capable of integrating historical, topographic, architectural, and environmental data within dynamic and queryable models.

The concept of cultural heritage has undergone a substantial shift—from a static conception centred on isolated monuments to a dynamic and systemic vision encompassing landscapes, routes, and cultural networks (Parrinello, 2023). Within this framework, Cultural Heritage Routes (CHRs) constitute a qualitative evolution in the recognition, protection, and enhancement of heritage, as evidenced by their inclusion among the four official categories of World Heritage recognised by UNESCO (1).

This conceptual evolution began with the Council of Europe in the 1970s and 1980s and has been strengthened through the efforts of international organizations such as ICOMOS, IUCN, and UNESCO. The concept of a cultural route has emerged from the broader idea of a cultural landscape, emphasizing the connection between historical pathways, natural systems, and territorial identity.

The increasing focus on CHRs in Europe has led to the formulation of innovative strategies for documenting, digitising, and enhancing both tangible and intangible heritage (Pei-Lin, Lertcharnrit, and Smith, 2023). These routes are now acknowledged as fundamental tools not only for conservation but also for transmitting cultural values, promoting sustainable tourism, and fostering social cohesion (as indicated in the annual report of the Cultural Routes of the Council of Europe). However, despite the growing number of European cultural routes—such as the Fortified Towns of the Grande Region, the Liberation Route Europe, the Iron Age Danube Route, and the Women Writers Route—many sites remain poorly documented. Serious deficiencies persist in the conservation of structures, the architectural valorisation of sites, and the definition of effective maintenance, management, and promotional programmes (UNESCO, 2023).

Recent European policies, such as Recommendation 2011/711/EU and the European Agenda for Culture 2020–2030, have promoted the digitisation of cultural heritage by supporting and financing projects aimed at the creation of shared data spaces and the strengthening of digital skills, including partnerships between public institutions and private entities. The 2019 European Framework for Action on Cultural Heritage and the 2021 Recommendation on the Common

The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-M-9-2025
30th CIPA Symposium "Heritage Conservation from Bits:
From Digital Documentation to Data-driven Heritage Conservation", 25–29 August 2025, Seoul, Republic of Korea

European Data Space for Cultural Heritage set ambitious targets: to digitally document in 3D all at-risk monuments by 2030 and at least 50% of the most visited ones, with particular attention to assets with low levels of digital accessibility.

The research activities carried out by the DARWIN Laboratory of the Department of Architecture at the University of Florence (directed by Professor Sandro Parrinello), in collaboration with the DAda-LAB Laboratory of the Department of Civil Engineering and Architecture at the University of Pavia (directed by Professor Francesca Picchio), align with this direction. Both laboratories adopt a multidisciplinary approach oriented towards the experimentation of narrative and interactive interfaces based on immersive environments and 3D visualisation, aiming to facilitate access to cultural heritage. Projects such as 3D Sebenico (2), focused on documenting Venetian fortifications in the Dalmatian region, and EU MSCA HEPHAESTUS (3), which seeks to develop interoperable digital systems for architectural heritage, represent significant examples of the joint effort to promote the digitisation and enhancement of transnational cultural routes.

By integrating advanced survey technologies, parametric modelling, and geospatial information systems, these initiatives contribute to defining new paradigms for the representation, management, and narration of fortified heritage, with an emphasis on accessibility, openness, and research-driven practice.

2. Mapping Memory: Cultural Routes as Living System

Within the broader framework of digital experimentation promoted by the DARWIN and DAda-LAB laboratories, the Venetian defensive system in the Šibenik district emerges as a paradigmatic example of the interaction between military architecture, territorial control, and historical narrative. Distributed between coastal and inland areas, the fortified structures—castles, city walls, and bastions—formed a strategic network devised to monitor Adriatic maritime routes and counter Ottoman expansion. These constructions, still legible in the landscape today, not only reflect their military function but also express the visual and political ideology of the Serenissima, becoming integral to the cultural and symbolic identity of the "Stato da Mar" (Parrinello & La Placa, 2020).

The contemporary perception of these historical sites is the result of an overlapping of material traces and stratified cultural influences that have progressively altered their form and significance (D'Angelo, 2003). Consequently, the analysis of architectural heritage necessitates a systemic and interdisciplinary approach capable of integrating geometric, technological, historical, and symbolic data.

The consistency and interoperability of the data collected constitute essential prerequisites for implementing effective strategies of conservation and enhancement (Saygi et al., 2013). Within this study, digitisation emerges as a key instrument for cataloguing, analysing, and narrating the traces of Venetian presence in the Šibenik territory. The principal objective is the creation of a digital atlas of fortifications, resulting from the integration of high-resolution 3D surveys, georeferenced historical sources, and semantic models.

This atlas is not merely a cartographic product but a dynamic information system aimed at managing, interpreting, and disseminating cultural content related to fortified architecture.

The adopted methodological approach prioritises the development of complex models capable of rendering both the spatial and temporal dimensions of fortified landscapes.

The process starts with digitizing and georeferencing historical maps, which are often distorted and fragile due to their age. These maps are then analyzed and compared with high-resolution metric data obtained through techniques such as terrestrial laser scanning, UAV-based photogrammetry, and Structure from Motion (SfM). GPS systems are used throughout these operations to ensure accurate geolocation. (Parrinello, Picchio, & La Placa, 2024).

The incorporation of these datasets within GIS environments enables the correlation of historical maps and contemporary surveys, producing coherent, multi-scale, and multi-temporal geospatial representations.

These are fundamental for the evolutionary analysis of fortified systems and for constructing interoperable digital scenarios. This process facilitates the creation of H-GIS (Historical Geographic Information Systems) environments, in which the various levels of information are coherently anchored in both space and time.

The ability to overlay and compare historical geography with the contemporary landscape opens new avenues for the critical reconstruction of architectural and territorial transformations. The 3D models generated—constituting the foundation of digital twins—are not mere visual artefacts but data structures enriched with metadata and semantic associations (Galasso 2024). When properly organised, these digital twins support evolutionary simulations, risk assessments, visibility analyses, and scenarios for heritage tourism development (Parrinello & Picchio, 2024). A central element of this entire process lies in the ability to connect multiple scales—from micro-level architectural analysis to macro-level landscape contexts. Spatial segmentation of elements, morphological classification, and documentation of construction techniques and materials contribute to the construction of an articulated model in which each fortress is interpreted as a node within a broader network. The hierarchical and semantic organisation of the data is also intended to facilitate selective access to information, tailored to the needs of scholars, administrators, heritage professionals, and general users. From a theoretical perspective, this research is grounded in the belief that digitization is not just a technical process but also a cultural practice. It involves interpretative choices, cognitive models, and ethical values. To document is to select, represent, and communicate; each phase of the workflow contributes to the construction of meaning and influences the effectiveness of transmission (Parrinello, 2023).

For this reason, the entire project adheres to the principles of open-science, promoting methodological transparency, data accessibility, and the sharing of knowledge with both local and international communities. The introduction of standardised protocols and interoperable metadata systems ensures the scalability of the project and its integration with other archives, European projects, and heritage tourism platforms. In particular, the interoperability between GIS, HBIM, and narrative platforms represents one of the central challenges for the coming years, as highlighted in recent literature (Liu et al., 2024; Limongiello et al., 2025; Parrinello & Pettineo, 2025). Such integrations offer the potential to construct complex information ecosystems capable of conveying the richness and depth of European cultural heritage.

The proposed research is structured around three main methodological axes:

O1) architectural and territorial documentation, conducted through advanced survey techniques;

O2) digital modelling, aimed not only at graphical representation but also at the semantic definition of military fortifications through the identification of architectural components and the formalisation of reference glossaries;

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O3) the systematisation of spatial data within H-GIS environments, to construct multi-layered interpretative models that link geometry, historical geography, and collective memory. The actions are structured according to these objectives, including the reconnaissance and systematic mapping of sites, integration with 3D surveys, construction of high-fidelity information models (Digital Twins), definition of a shared semantics, and the scientific and outreach-oriented promotion of Venetian heritage within the Stato da Mar. The project adopts a replicable methodological protocol, tested on cross-border and maritime contexts, capable of evaluating each defensive element within its historical and evolutionary framework. Special focus is placed on developing strategies for the accurate representation of fortified systems via information models that express the complexity of cultural landscapes and their temporal evolution. This approach allows for spatial interpretations that are both multiscalar and multi-temporal. Previous experiences in digital mapping have shown the effectiveness of an integrated approach that combines metric surveying, geolocation, and digital storytelling. Specifically, applying GIS systems to historical cartography allows for the georeferencing of historical maps and their integration with contemporary spatial data, resulting in highly accessible cognitive tools (Galeazzo, 2024). This synergy not only facilitates a multi-temporal reading of cultural landscapes but also activates interpretative models that enhance the evolutionary and narrative aspects of historical itineraries.

3. Reconstructing History with Digital Atlases: Echoes of Venetian Defense Fortresses of the Sebenik district

Despite the undisputed historical, cultural, and strategic significance of the Venetian fortification system along the Adriatic coast, much of the defensive architecture in the Dalmatian region remains relatively unknown, poorly documented, and lacking a coherent systematisation.

The historical context of this area—shaped by successive regimes, from the late Roman Empire to the Hungarian Kingdom, from the Venetian Republic to the Ottoman presence, and finally the Austro-Hungarian Empire—has resulted in a layered assemblage of construction techniques, technological solutions, and architectural typologies. These are often difficult to interpret without a robust methodological framework.

Within this context, the Šibenik territory offers a privileged case study for the analysis and digital reconstruction of fortified landscapes.

his research pursues a dual objective: firstly, to initiate a systematic process of cataloguing defensive sites; secondly, to construct a digital atlas capable that conveys the morphological, spatial, and material characteristics of the fortifications, contextualised within the surrounding landscape and supported by available historical sources.

The investigation is grounded in the development of a replicable methodology for the integrated interpretation of architectural traces, with a particular focus on defensive components, settlement patterns, and the temporal dynamics of territorial transformation.

The case studies have been categorised according to typological and functional criteria. Along the coastline, one finds stone curtain walls fortifying promontories—as at Oštrica, Capocesto, and Mandalina—while the inland regions are characterised by noble-founded castles, such as Castel Andreis, Rakitnica, and Verpoglie, conceived as outposts guarding the northern and southern perimeters of the district (Parrinello & Dell'Amico, 2025).

Although Šibenik was historically regarded as an impregnable stronghold, archival sources reveal widespread structural vulnerabilities that necessitated progressive adaptation over time, both in spatial configurations and construction techniques (Bilić, Krasanka Majer & Pavić, 2023). Within the broader programme of analysis and valorisation of the Venetian defence system in the Adriatic, this research undertakes a digital documentation campaign of the current state of fortified architecture distributed between the Italian and Croatian coasts, with a specific operational focus on the Šibenik district. The endeavour extends beyond the formal inventory of structures, aiming instead to re-establish a structured relationship between surviving material traces and the intricate historical and military fabric that shaped the coastal landscape over centuries.
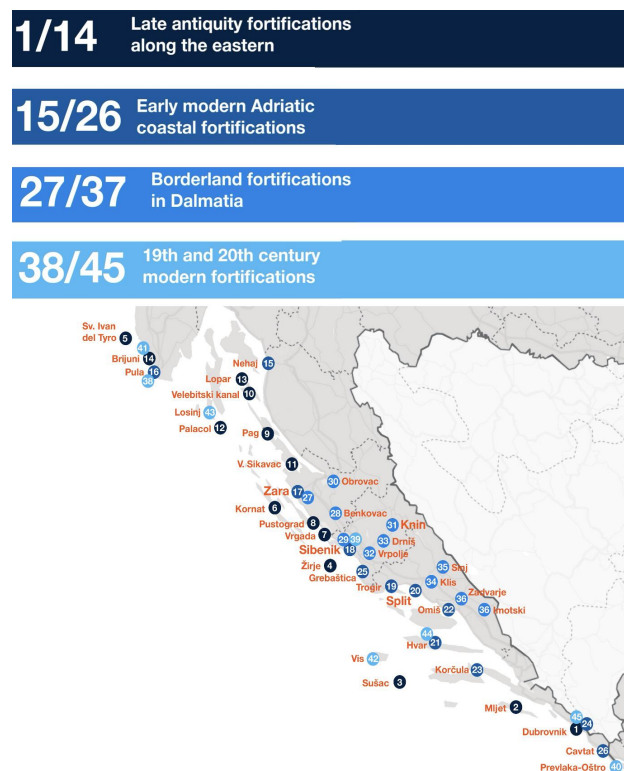

Figure 1. Preliminary Analysis and Inventory of Fortified Architecture along the Adriatic Route.

To enable the systematisation of data, the project began with a preliminary phase of reconnaissance and inventory of selected sites through field surveys, photographic documentation, archival research, and the creation of a structured database for site monitoring. A dedicated Excel spreadsheet was developed to standardise the recorded data and ensure consistency in cataloguing criteria. Each entry in the database includes:
- The name of the site in English, Croatian, and Italian, underscoring the historically multicultural nature of the Adriatic;
- An associated identification code (CHR Classification Code);
- Country;
- City (listed with both Croatian and Italian names);
- Description;
- Precise geographical coordinates, essential for geospatial mapping and GIS integration;
- Historical period of construction, categorised into four broad chronological phases (01_MEDIEVAL, 02_EARLY MODERN, 03_MODERN, 04_STRATIFIED—indicating multiple evident phases of development);
- Year of construction (where known);
- Inclusion in the Register of Cultural Goods (NB) (4);

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- Current state of conservation, assessed according to parameters of legibility, material integrity, and structural soundness;
- Level of public accessibility, classified as open, partially accessible, or inaccessible.

However, it is in the very act of "digitally mapping memory" that the project acquires a deeper significance. The defensive architectures scattered across the Stato da Mar are not merely military artefacts: they are living traces, deep imprints inscribed into the landscape—visual and symbolic echoes of a civilisation that built its power upon water and stone. Each bastion, tower, and city wall articulates a language of control and protection but also of aesthetics, representation, and endurance. In contemporary heritage discourse, the notion of the "trace" (Didi-Huberman, 2012) assumes an epistemological dimension: it does not simply denote what remains of the past, but rather that which continues to generate meaning—a living fragment that prompts inquiry and fosters relationships between space, time, and identity. From this perspective, Venetian fortifications are not only material constructs but complex cultural devices capable of crystallising collective memories, articulating systems of power, and narrating—through stone and space—the deep history of a territory. Their presence along the eastern Adriatic, today part of Croatia, evokes an entire geopolitical and symbolic vision: the Serenissima's intention to project itself across time and space, establishing an architectural continuum—a connective line between Venice and its eastern shores (Parrinello et al., 2024). This may be interpreted as an "aesthetics of defence" wherein military function is transmuted into formal and cultural codes recognisable and embedded within the landscape. From this standpoint, digitisation is not merely a technical exercise but an interpretative act: to survey and model these traces is to render them newly legible, re-embedding them into an accessible and shareable semantic and communicative system (Hutson, 2024).

The construction of the digital atlas begins with the study and analysis of historical maps at various scales. In this initial phase, materials from the Archivio di Stato di Venezia, the Biblioteca Correr Museum, and the Biblioteca Nazionale Marciana were examined (Galeazzo, 2024). These sources, part of the principal documentary collections relating to the design and transformation of Venetian defensive works, form the foundation for a systematic integration of historical representations with contemporary spatial data. The process involves a comparative analysis of ancient cartographies and contemporary orthophotos, utilising the capabilities of H-GIS systems to integrate distorted historical depictions with recent metric data derived from photogrammetric and LiDAR surveys. Accordingly, the atlas constitutes not only a cartographic repository but a multi-scalar, multi-layered semantic platform in which each fortification is documented through structured metadata, 3D models, historical references, and topological relationships. In line with the most current approaches to the valorisation of cultural networks, the system enables the interpretation of fortified heritage not as a disconnected collection of isolated structures but as a structured and interconnected network—deeply rooted in its geographical and landscape context, and representative of both historical defence frameworks and the symbolic and visual identity of the territory. The digital atlas is thus not merely an updated map of architectural assets but a critical tool capable of generating new narratives and integrated territorial visions. As a dynamic archive and narrative platform, it restores to the fortifications their original role—not only as defensive bulwarks but as markers of civilisation and foundational elements of a transnational landscape of identity. In this sense, the digital atlas becomes an instrument for looking beyond the stone—for grasping what endures as cultural echo and as the structure of shared memory.

4. Reconstructing History with Digital Atlases: Echoes of Venetian Defense Fortresses of the Sebenik district

The digital acquisition and measurement process was developed through an operational strategy tailored to the specific morphological, historical, and environmental characteristics of the investigated contexts while also considering the available operational timelines. The adopted methodological approach involved the selective and combined use of advanced survey technologies calibrated according to territorial scale and epistemological objectives. At a broader scale, mobile laser scanning systems and aerial photogrammetric surveys using remotely piloted drones were employed to reconstruct extensive urban fabrics and landscape areas (Picchio & Parrinello, 2024). The primary aim was to identify correspondences between historical sources and extant material remains—such as towers, ruins, and civil and military architecture—and to reconstruct their spatial relationships within the site. To obtain localized insights and detailed analyses, we used high-resolution survey tools, including fixed-station terrestrial laser scanners and high-definition digital cameras. These operations necessitated the formulation and application of a methodological protocol for data integration aimed at producing high-fidelity graphical outputs and three-dimensional models that convey both the geometric and material characteristics of the surveyed architectural elements. Specifically, the protocol facilitated an accurate depiction of the relationships between the built structures and their surrounding environments. It highlighted the unique morphological features of each structure and improved our understanding of their environmental and landscape relationships.

The entire survey process was organised according to a logic of environmental segmentation, designed to optimise operational management based on the morphological and spatial complexity of the sites. Aerial photogrammetry played a strategic role, particularly in contexts where accessibility and visibility constraints limited the effectiveness of terrestrial surveys. The adoption of a UAV system equipped with RTK technology (DJI Phantom RTK), connected to GNSS networks for real-time georeferencing, allowed the generation of highly accurate digital models, significantly reducing subsequent data processing phases. Flight missions were manually planned and conducted to ensure direct and precise control over image acquisition. This approach allowed for real-time adjustments to flight paths and camera angles based on the site's morphological and architectural features. The strategy included both general views, useful for documenting the broader landscape and urban context, and low-altitude flights aimed at detailed recording of specific architectural elements. The flight altitude was carefully adjusted to address any gaps in the terrestrial survey and to achieve a comprehensive view of the site. Additionally, the flight plan was designed to ensure continuous visual contact between the operator and the drone, in accordance with safety regulations.

It also maintained a 70% overlap in images, which is essential for accurate photogrammetric reconstruction. The aerial photogrammetric dataset was integrated with terrestrial data, especially in areas where vegetation obstructed direct observation or where internal spaces were difficult to access. This combined approach allowed for the creation of a comprehensive three-dimensional representation. This representation is valuable not only for documenting the current state but also for comparative analysis with historical sources and for interpreting settlement dynamics, particularly in

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locations with complex terrains, such as slopes or ridges.The intervention areas were divided into functional sectors, and survey paths were planned to optimize operational efficiency, reduce acquisition time, and ensure uniform coverage.

Figure 2. The database's morphometric quality allows for analyses of the structures' state of conservation, serving as a foundation for subsequent studies.

Figure 3. The remains of the towers, which are still preserved today, in contrast with the surrounding urban development.

Special care was taken to maintain consistency across data collected using different technologies, ensuring adequate overlap between datasets and managing informational redundancy. The diverse expertise of the research team, which includes specialists in digital surveying, architectural history, geography, and heritage sciences, greatly enhanced the integrated analysis of the collected data. The interaction between morphometric analysis and historiographical investigation enabled a deeper interpretation of the material traces, thereby contributing to the construction of a scientifically sound and culturally significant narrative of the architectural heritage under examination (Parrinello, 2024b).

5. H-GIS: Bridging Past and Present Landscapes

Understanding the current morphological and architectural configuration of sites along the studied route is fundamentally rooted in data derived from integrated digital surveys. These surveys not only provide an up-to-date representation of the current condition but also constitute a georeferenced cartographic base essential for the geolocation of historical maps and the subsequent construction of Historical Geographic Information Systems (H-GIS) dedicated to the historical memory of places. In this regard, the cartographic outputs generated from survey datasets play a pivotal role in addressing documentation gaps caused by the obsolescence or absence of earlier maps, offering a solid and updated base map for the analysis and interpretation of historical sources. The survey activity, conducted in environments characterised by non-conventional and often difficult-to-access conditions, was supplemented by a geospatial acquisition campaign using GPS points. These were subsequently integrated into point clouds generated through LiDAR and photogrammetric technologies. The heterogeneity of the surveyed contexts necessitated the use of a diverse range of instruments aimed at collecting multidimensional and as comprehensive as possible data, which served as the foundation for an articulated and selective processing workflow. The material gathered was subjected to a process of analysis, classification, and discretisation, culminating in an integrated database serving as a cornerstone for both synchronic and diachronic representations of the studied sites.

The graphical outputs derived from digital survey processes are configured as a synthetic and selective visual language, capable of articulating and transmitting information through simplified representations of reality (Parrinello, 2024a). Technical drawing thus becomes an interpretative and communicative tool, operating through abstraction to convey the morphological, historical, and typological characteristics of architectural entities.

To render survey data interoperable with historical and archival documentary sources, a Historical Geographic Information System (H-GIS) was implemented. This system is designed to manage, analyse, and visualise geospatial data connected to historical cartography. It enables the enrichment of vector data derived from surveys with descriptive metadata, generating a dynamic and accessible database that supports the consultation, comparison, and analysis of historical-architectural heritage over time.

The case studies selected for methodological testing demonstrate significant differences in terms of location, morphology, and historical development. Two specific case studies—Castel Andreis and Verpoglie—were chosen along the route to investigate distinct aspects relating to urban configuration, historical evolution, and topographic placement. The site of Castel Andreis is characterised by a compact settlement structure integrated into the current urban fabric. Morphotypological analysis revealed a strong correspondence between the layout documented in historical sources and its present configuration. The ancient defensive wall is today legible as a continuous alignment of residential buildings connecting two still-extant towers—one square and the other semi-circular in plan—both of which have been reduced in height yet remain recognisable within the built environment. The original access gate is also partially visible, now embedded within private architectural structures (Glavas, 2015). For this site, a three-dimensional H-GIS system was implemented using ArcGIS, within which a distinction was made between original structures and reconstructed elements.

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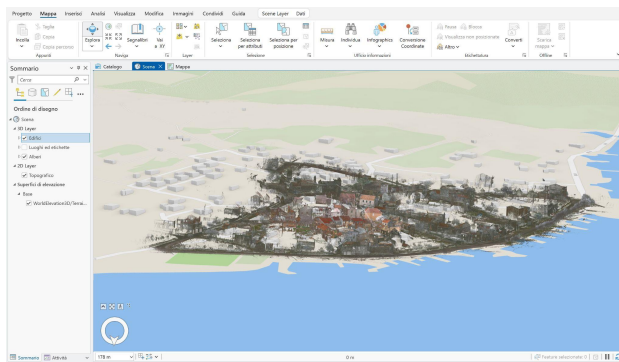
Figure 4. Integration of the point cloud of Castel Andreis in the
GIS environment on ArcGIS software.

Each building was categorised through descriptive queries regarding its original and current form, historical function, and present use. This process facilitated a stratigraphic analysis of the context, aiding in the understanding of settlement evolution and structural transformations over time. Each building was categorised through descriptive queries regarding its original and current form, historical function, and present use. This process facilitated a stratigraphic analysis of the context, aiding in the understanding of settlement evolution and structural transformations over time. This approach has proven effective not only for documentation purposes but also for generating critical interpretative hypotheses on the site's architectural and historical development. In contrast, the site of Verpoglie exhibits an isolated settlement structure and pronounced topographical features. Situated atop the hill of San Giovanni, at 175 metres above sea level, the castle constitutes a true defensive acropolis, likely in use since the medieval period for visual control over the southern approaches to the city of Šibenik.

Figure 5. Map showing the surviving elements of the former
castle of Verpoglie: 1. Northern guard tower; 2. Western tower
with adjoining residential quarters and barracks; 3. Rainwater
cistern; 4. South-eastern tower; 5. Church of St John.

The historical investigation made use of relevant documentary sources, including a site plan by Agostino Alberti (1626) and a reconstruction proposal by architect De Boucaut (1686) (Bilić, 2018). The current state of conservation at the site is limited: apart from the still-active church of San Giovanni, only fragmented walls and cornerstones remain. In this context of low material density, the implementation of the H-GIS system enabled the valorisation of documentary heritage and its use as a basis for reconstructive hypotheses. The historical plan was georeferenced against the current survey through a critical process of adaptation aimed at identifying and repositioning lost elements while analysing original spatial relationships and their evolution over time.
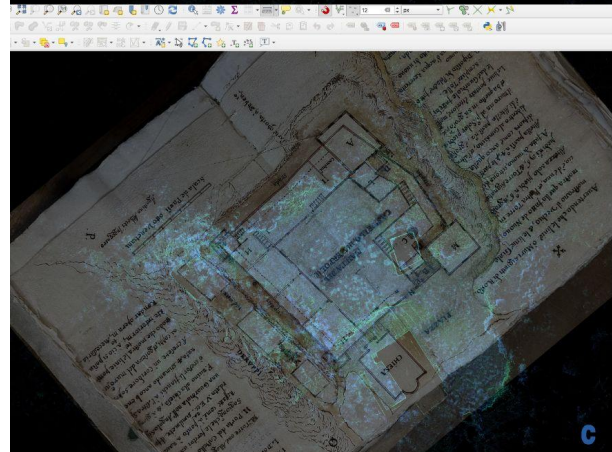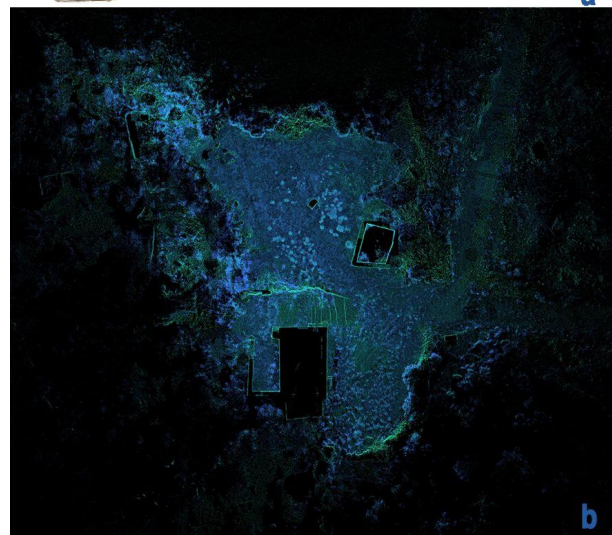

Figure 6. The image above compares Agostino Alberti's map
with the 3D point cloud. Below, Agostino Alberti's map is
superimposed on the base map using an H-GIS method.

The integration of georeferenced historical cartography with three-dimensional point cloud models enables the formulation of hypotheses regarding the site's original configuration. It opens the way for comparative modelling between historical and current states.

The development of 3D models in both historical and present-day phases serves as an effective tool for analysing temporal transformations, identifying significantly altered components, and reflecting on the dynamic evolution of spatial configurations. This comparative approach, grounded in the integration of historical sources and digital surveys, provides a

robust interpretative framework for critically engaging with heritage stratification. The effectiveness of this methodology invites the possibility of its replication and adaptation across other sites along the route, modulating the intensity and type of integration according to the availability and richness of documentation.

In contexts where documentary heritage is pervasive and complex, the integration of digital survey data and H-GIS emerges as a fundamental strategy for delivering a stratified, historicised, and dynamic interpretation of the cultural landscape—thus contributing to the development of an interoperable knowledge system for the valorisation of architectural and territorial heritage.

6. Conclusion and Future Development

The research undertaken represents a significant initial step towards the construction of a shared and structured body of knowledge concerning the Venetian defensive system in the Adriatic. Through the in-depth analysis of two case studies—Castel Andreis and Verpoglie—it has been possible to test an integrated methodology for the surveying, modelling, and digital representation of data. This methodology is grounded in the combination of geomatic technologies, historical archives, and GIS environments. In the case of Castel Andreis, the integration of UAV surveys and point cloud data enabled the accurate georeferencing of architectural elements and the construction of a queryable database, wherein each structure is contextualised according to its historical, functional, and constructive dimensions. For Verpoglie, the comparison between contemporary orthophotos and georeferenced historical cartography will serve as a critical component in the forthcoming phases of 3D modelling of the site's current state and the reconstruction of its successive phases of transformation—highlighting the stratifications and material continuities that characterise the site. The foundational element of this work lies not merely in the precise restitution of individual assets but in the articulation of a systemic vision: the ongoing inventory serves as the groundwork for the future development of an interconnected digital atlas. This atlas will establish relationships, on a transnational scale, between Venetian fortifications distributed across Italy and Croatia. The goal is to develop a shared platform that extends beyond the visualisation of data to enable processes of interpretation, comparison, and cultural valorisation. From this perspective, the atlas is conceived not as a static map but as a dynamic and narrative environment in which each site contributes to defining a coherent, interpretable, and accessible cultural network—one that, far from presenting a fixed view of history, returns to the territory its temporal depth and its character as an evolving landscape of identity (Baldacci, 2016, Hutson, 2024). In this light, fortified heritage is not to be regarded as a mere assemblage of isolated episodes but rather as a living cultural system deeply rooted in the landscape and reconfigurable through digital technologies. The digital atlas thus envisaged is intended as a tool for connection, interpretation, and remembrance—open to future developments in scientific, educational, and managerial domains and capable of guiding historical knowledge towards new forms of engagement and participation.

Footnotes

(1) Reference is made to the four official categories of World Heritage as recognised by UNESCO: cultural heritage, natural heritage, mixed heritage (combining both cultural and natural elements), and intangible cultural heritage. Source: https://www.unesco.it/it/iniziative-dellunesco/patrimonio-mondiale/.

(2) The research project *"3D SEBENICO"* is co-funded by the Veneto Region under the 2023 call for proposals titled *"Project for the Recovery, Conservation and Valorisation of the Cultural Heritage of the Republic of Venice in Istria, Dalmatia and the Mediterranean Area."* Activities undertaken in support of this objective involved collaboration among several institutions: the Department of Architecture at the University of Florence; the Department of Civil Engineering and Architecture at the University of Pavia; the Department of Cultural Heritage: Archaeology, Art History, Film and Music at the University of Padua; as well as researchers from the Istituto Veneto per i Beni Culturali, the Public Cultural Institution Fortress of Culture Šibenik, the Institute of Art History in Zagreb, the Municipality of Šibenik, the Municipality of Verona, and the Società Mutuo Soccorso di Porta Palio.

(3) The project "*HEPHAESTUS – HEritage Protocols for ArcHitecturAl European croSs-bordering siTes evalUationS"* is funded by the European Union's Horizon Europe Marie Skłodowska-Curie Research and Innovation Staff Exchange (RISE) programme, proposal number: 101182877. The project spans 48 months (2024–2028) and includes the participation of both academic and non-academic partners: Academic partners: Department of Architecture, University of Florence (Italy, project coordinator: Prof. Sandro Parrinello), Department of Civil Engineering and Architecture, University of Pavia (Italy), Gdańsk University of Technology (Poland), Bochum University of Applied Sciences (Germany). Non-academic partners: Metaheritage (Italy), Fundacja To Get There (Poland), Urban Culture Institute (Poland), Fortress of Culture Šibenik (Croatia), Institute of Art History (Croatia).

(4) The Register of Cultural Property of the Republic of Croatia is a public record of cultural property kept by the Ministry of Culture. It comprises three lists: The List of Cultural Goods, the List of Cultural Goods of National Significance and the List of the Cultural Goods under the Preventive Protection (Article 14 of the Act on the Protection and Preservation of Cultural Goods.

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