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PROCEEDINGS

# HERITAGE, DIGITAL TECHNOLOGIES AND TOURISM MANAGEMENT

M.J. Viñals & C. López González (Eds.)

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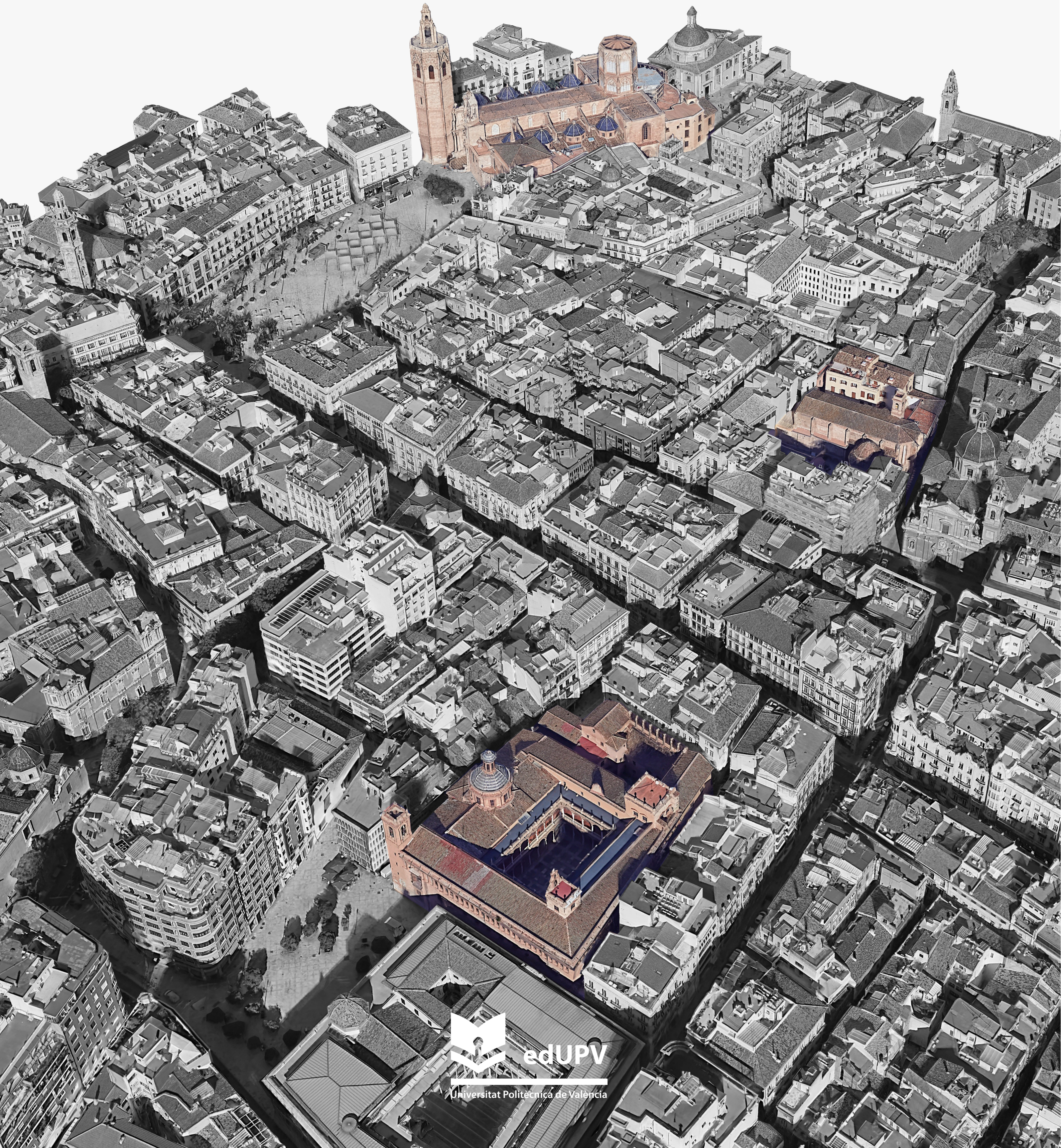

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**Scientific Editors:**

**María José Viñals**

**Concepción López González**

***Universitat Politècnica de València***



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**Valencia, 2024**

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# HERITAGE, DIGITAL TECHNOLOGIES AND TOURISM MANAGEMENT

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# FOREWORD

Architectural heritage assets and their urban environment strongly define the cultural identity of the societies in which they are, and additionally are a key driver of the local economies. Their conservation and proper management are therefore essential to ensure their long-term preservation and to pass them on to future generations in good condition.

The Universitat Politècnica de Valencia (UPV), within the framework of the R&D project 'Analysis and development of HBIM integration in GIS for the creation of a tourism planning protocol for the cultural heritage of a destination (PID2020-119088RB-I00)' funded by the Ministry of Science and Innovation, has set out to address this challenge and to share knowledge and debate on this topic with other academic institutions. For this reason, the research team decided to organise the International Congress on Heritage, Digital Technologies and Tourism Management - HEDIT 2024, which took place in Valencia in 2024.

Within this framework, aspects related to the urgent need to digitally document heritage elements, the use of detection systems and sensors for preventive conservation, and the use of new technologies for the planning and management of public use, especially the tourist use of heritage, were discussed.

This book gathers the scientific papers presented by the participating researchers that were accepted by the Scientific Committee after peer review. The contents are structured according to three topics. The first topic is devoted to contributions on *Digital Heritage Documentation;* the second one focuses on the study of *Digital tools for the conservation and enhancement of heritage*, third topic analyses *Smart technologies for heritage tourism planning and management*. The scientific papers present a wide range of interdisciplinary digital methodologies and technologies for researching, documenting, conserving and managing cultural heritage, as well as examples of notable case studies.

The editors are very grateful to the authors for the quality of the contributions and to the members of the International Scientific Committee for their help in reviewing and selecting the papers included in this publication.

**María José Viñals**
**Concepción López González**
*Valencia, 2024*

# TOPIC 1

*DIGITAL HERITAGE DOCUMENTATION*

International Congress for Heritage Digital Technologies and Tourism Management
June 20th – 21st, 2024. Valencia, Spain
Doi: https://doi.org/10.4995/HEDIT2024.2024.17727

# Integration of Historical Sources, HGIS and HBIM for Cultural Heritage Sites: The Digital Reconstruction of the Islands in the Venice Lagoon

**Federico Panarotto[a], Ludovica Galeazzo[b] and Gianlorenzo Dellabartola[c]**

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***Abstract***

*Starting from the 16th century, when the city of Venice began to systematically structure its water territory, the over sixty islands that shape the lagoon became an integral and fundamental component of its urban space. Today, much of this heritage site has disappeared or, in some cases, is in a state of complete abandonment. This situation prevents citizens or visitors from fully understanding the history and major events that characterised the lagoon's complex past, as well as the reasons for its current decline.* Venice's Nissology *(VeNiss) is a project aimed at representing this peculiar urban context through an interactive 3D web map in which users can virtually explore the water-bound settlements and their transformations over time, from the sixteenth century onwards. The development of this online geospatial platform involves an articulated methodological process that includes an heterogeneous group of scholars, such as architectural and art historians, as well as experts in digital surveying, GIS (Geographic Information System) and BIM (Building Information Modelling). Building on the analysis of historical documents – specifically maps, iconographic sources, and textual documents – alongside survey data, either already existing or newly obtained through measurement campaigns, the project aims to create interoperable bi- and three-dimensional digital models of thirty islands over the centuries, allowing for the visualisation of their urban and architectural transformations in relation to relevant historical information. 3D models are created through a process of data re-elaboration and interpretation aimed at vectorialising the considerable and varied amount of existing iconographic sources and visualising the relationships between them. The ultimate goal of the project is to implement these virtual models in a geospatial structure that ensures users can gain a conscious understanding of the events that involved these places and the transformations that led to their current state.*

***Keywords:*** *HBIM, HGIS, 3D models, Venetian lagoon, digital tools, VeNiss.*

## 1. Introduction

The ERC project *Venice's Nissology. Reframing the Lagoon City as an Archipelago* (VeNiss) digitally reconstructs the history and urban transformations of the hitherto neglected cluster of over sixty islands of varying sizes that, scattered across the Venetian lagoon, compose the archipelago of Venice. Today, this unique environment is in a state of severe disrepair, as most of its islands have been razed to the ground over the past two centuries and they now lie abandoned and detached – physically and conceptually – from the city centre (Galeazzo, 2024).

The origins of the gradual dissolution of the bond between Venice and its *aquascape* lie in the aftermath of the fall of the Republic in 1797. The suppression of ecclesiastical orders by Napoleon and the islands' conversion to accommodate warehouses, military hospitals, and barracks led to radical changes. These events not only transformed the islands' geography but also altered the perception of the articulated network of relationships that once sustained the archipelago's life. Nineteenth- and twentieth-century interventions erased the visual and historical memory of major buildings and architectural complexes, as well as an entire system of interdependent urban places that constituted the liquid outskirts of Venice, namely its whole periphery.

More than just an ornamental frame, from the early middle ages, the lagoon embodied an integrated system of calculated politic, socio-economic, and cultural interactions between the city and its water margins and islands functioned as capillary structures for the interests of the capital. Like pieces on a skilled player's chessboard, at various moments these urban settlements addressed the different needs of Venice's urban framework. Starting from the eighteenth century and for almost the entire following millennium, the lagoon islands opened their doors to almost all the main Christian religious orders, which played major roles as active patrons of pioneering works of art and architecture. These islands also served as connective centres called upon to sustain the social and economic life of Venice. In particular, they fulfilled the capital's need for food by producing, processing, and providing foodstuffs for their inhabitants as well as for the whole city. The tiny strips of lands were no less essential socially, as they housed infrastructures that served the daily needs of the larger Venetian community, such as public boathouses, guest houses, inns, and gunpowder magazines as well as a series of military structures that helped preserve the State's invulnerability over the centuries. Likewise, they proved to be crucial for the public health facilities of the city. Two islands – the Lazzaretto Vecchio and Lazzaretto Nuovo – were permanently used as lazarettos to quarantine people and goods during the plague, while a number of other sites operated as supplementary shelters in times of crisis. The aqueous environment was finally the stage set on which the Republic promoted the glory and power of the State through ostentatious ceremonies and events contested on water and offered bespoke state lodging services to visiting foreign dignitaries.

The assimilation of the many lagoon settlements into a single archipelagic network was the result of a complex socio-political but also conceptual construction process systematically developed by the Republic over the centuries, encapsulating the city's rising consciousness of its geographically and functionally granular identity. Their demolition irrevocably interrupted the centuries-old network of relationships that connected the islands with each other and with the city centre, transforming a robust and organic sprawling urban environment into a stark assemblage of isolated islands.

With a view of reconstructing the urban history of the lagoon and reassessing Venice as a whole archipelago, the project VeNiss aims to reconstruct the broader social and geographical inclusiveness of Venice's water landscape by visualising and interpreting the islands' transformations and their supporting functions for the capital in an interactive online platform. This combines digital reconstructions of almost thirty islands – out of sixty – over time with their pertinent historical data. This platform is meant to help users understand not only the lagoon's ancient morphology over the past five hundred years but also how this operated and conceived itself as an integrated network.

Developed at the Department of Cultural Heritage of the University of Padua in partnership with the Harvard University centre of I Tatti and the Department of Architecture of the University of Florence, this research was granted an ERC Starting Grant by the European Research Council for five years (2023-2027).

## 2. Reconceptualise Venice as an archipelago through a geospatial infrastructure

The demolition of entire lagoon complexes, monasteries, convents, and architectural monuments offers a compelling gauge for experimenting with new techniques of digital visualisation applied to urban history research. The first objective of the project Venice's Nissology is therefore the reconstruction of the ancient urban and architectural configuration of the Venetian archipelago throughout time in order to determine the nature and extent of its transformation, thus enabling the exploration of a nearly lost cultural heritage. In addition, VeNiss aims to delve into the social, political-economic, and cultural dynamics that shaped the historical organisation of the lagoon archipelago over the centuries.

To fill a crucial knowledge gap, the project proposes an online geospatial and time-based semantic infrastructure that allows users to digitally navigate the historic lagoon while discovering its ancient appearance and socio-urban framework. Leveraging on the capabilities of digital surveys, HGIS mapping, HBIM modelling, and semantic technologies, the infrastructure enables the intersection of 2D and 3D models of the many islands over time with pertaining historical data. These are disseminated across a profuse number of textual and iconographic documents, ranging from descriptions, rental contracts, and notarial deeds to maps and drawings, paintings and, for more recent times, accurate surveys, aerial photographs, and orthophotos. This extensive documentation, in myriad formats, is classified on the platform into four main categories or "entities": the sources (primary and secondary), the events recalled in the historical documentation, the actors involved in these sequences of actions, and the built works themselves, marked as buildings, islands, open spaces, and waterways (Galeazzo et al., 2024).

As a sort of "Google maps of the past", the geospatial infrastructure invites users on a journey through time and space, revealing the many urban processes that shaped Venice. The platform displays a map of the whole lagoon with overlaid two- or three-dimensional models – which are the results of HGIS and HBIM reconstructions – representing the water basin's ancient landscapes. These visualisations are superimposed on the base map and constrained by both a timeline and the zoom level. The time slider allows users to select a specific point in time, displaying the 2D or 3D historical features that correspond to that year. Thus, by moving across the decades and exploring different corners of the lagoon, the ancient islets come to life in their physical appearance and spatial arrangement. Additionally, the platform enables users to navigate between sources that served as the foundation of the research. All entities related to features displayed on the map at a specific time are listed on a sidebar, called the navigator. These include archival and iconographic sources, bibliographic items, but also actors, architectural and socio-economic events, and places that, at any time, can be filtered by type and displayed as either entry-level information or in-depth metadata (Figure 1).

To make the process of digital reconstruction visible to the public – and therefore open to discussion –, the infrastructure also allows the overlay of georeferenced images on the base map, which served as the basis for drawing the geospatial features. Users can drag and drop images or modify their transparency to compare different maps and their pertaining visualisations.

Robust search and faceting components also allow for fine-tuned visualisation of archival sources and geospatial features. By applying filters and manipulating features' colours and labels, users can effectively visualise information about the various functions (private/public), uses (religious, military, healthcare, etc), typologies (church, monastery, warehouse, gunpowder tower, etc), architects, patrons, owners, and tenants related to the many islands over the centuries.

These complex spatial analyses are intended to support the interpretation of the archipelago's changes over time in terms of urban space, social activities, state/private jurisdictions, and interactions between different actors involved in the place-making process. At the same time, the ability to navigate the ancient archipelago through 2D and 3D virtual models of disappeared places and visually contextualise historical documents allows comparisons of architectural solutions, spatial typologies, materials, and building techniques. This exploration reveals the agency of many actors in the circulation of architectural and artistic models between the islands, the city, and the Italian Peninsula.

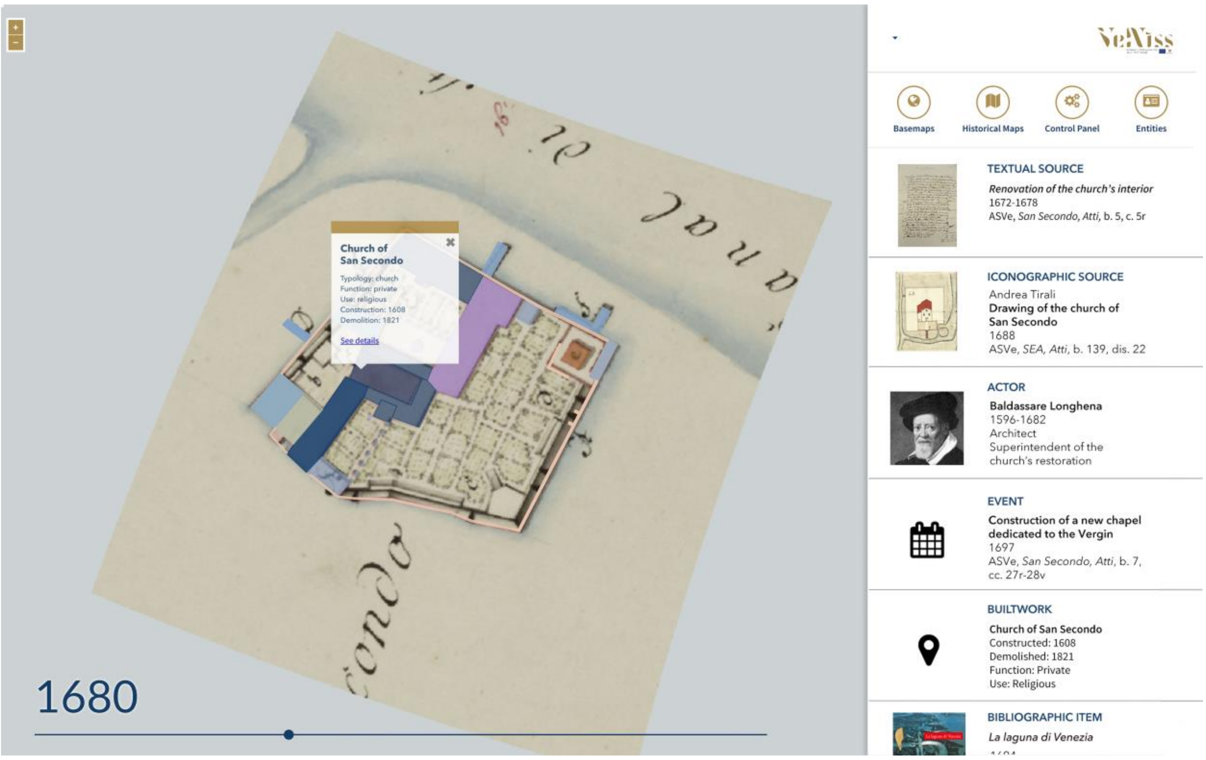


**Figure 1.** Layout of the VeNiss geospatial infrastructure.

By providing the possibility to visualise and interrogate historical information and archival data directly on the pertinent digital reconstructions, the infrastructure not only helps rediscover a cultural heritage that has almost completely disappeared but it also re-evaluates the city's borderlines as sites of incessant synergistic cultural, social, and economic dynamics, thus helping to move the discourse away from the typical schema of "centre-to-periphery".

## 3. Digital surveys for the definition of HGIS geospatial geometric references

A fundamental step in understanding the history and structure of the lagoon islands, with a particular reference to their current morphology and architectural condition, involves acquiring measurement data through digital surveys. These integrated surveys aim to provide reliable, georeferenced, and updated cartographic elaborations, which are crucial for georeferencing historical maps and drawings that describe the islets' former shapes. The newly acquired measurements are extremely significant as they constitute the base map for the georeferencing processes that complement outdated or often non-existent data.

The methodology adopted by the joint research teams of the University of Florence and Padua, responsible for the survey campaign, was highly sophisticated. Given the unconventional environments of the island settings, this involved using various types of instruments, preferring a static approach over a dynamic one according to need. It comprised fixed (TLS) and mobile (MLS) laser scanning systems for fast survey operations (Dell'Amico, 2021), integrated with photogrammetric databases from ground, drone (UAV), and underwater acquisitions. Additionally, spatial data were accompanied by morphological information expressed as GPS points, subsequently integrated into point clouds. The complexity of the selected case studies is evident from the need to use different survey instruments with the aim of collecting as much comprehensive data as possible. Equally complex was the data processing phase, which required the analysis and discretisation of a large amount of collected materials, subsequently uploaded into an integrated database. This database constitutes the indispensable basis for representing the current and historical configuration of the islands. To these extents, a new graphical language was defined through representation, in which reality is simplified in favour of selective information communication:

the drawing explicates descriptive needs operating through graphical synthesis and information transmission (Parrinello & Picchio, 2023).

To connect the information and graphical elaborations obtained from the digital surveys with both the database and the historical-archival documentation, the project VeNiss adopted a geographical information system for historical cartography (HGIS). This tool not only allows the acquisition, management, analysis, and visualisation of geospatial data, thus enriching the graphical data derived from the survey – vector drawings – with metadata, but it also enables the generation of dynamic and interoperable databases.

With the aim of representing the various transformative phases of the Venetian islands over the centuries, the process implies a backward reconstruction procedure. This begins with documenting the current state of the lagoon and then moves back in time to reconstruct changes through comparisons with historical maps and other archival materials (textual or iconographic). Within this methodology, historical documents – detailed maps, drawings, and large-scale plans – play an essential role in analysing spatial alterations, because they allow scholars to compare the current morphology of the lagoon settlements with numerous historical representations of ancient islands, thus facilitating the identification of urban and architectural transformations as well as the presence of buildings that have been modified over time (Galeazzo, 2024). This process of comparison involves identifying a series of reference points (ground control points) on historical maps that are still visible in the existing settlements and are necessary for georeferencing the iconographic documentation. These well-identifiable elements can be represented by geographic points, significant buildings, coastlines, or other urban and architectural components that scholars consider stable links between past and present environments (Picuno et al., 2019).

Once a series of ground control points is selected, historical maps are georeferenced through polynomial operations of roto-translation and scale variation, in order to adapt them to the current graphical elaborations. This process forms the foundation for the vectorisation activities that imply both drawing each urban and architectural element of a given island and reconstructing its many changes over time. In the GIS space, the resulting polygonal features are represented by four informational levels or "layers": canals, islands, open areas, and built works. These vector representations are integrated within the GIS environment with information regarding the temporal phase of each feature (namely its presence/absence in a given historical map) catalogued within specific attribute tables connected to the specific layers.

Both the georeferenced cartography and the vector features obtained in the GIS system are then implemented in the VeNiss online infrastructure. Here, they can be viewed and explored by users through a timeline and integrated into the BIM environment for constructing three-dimensional models that will also be loaded into the geospatial infrastructure.

## 4. From HGIS to HBIM: An interoperable methodology

The aim to describe an extensive area such as the Venetian lagoon through a sort of "4D geographic internet service" implies creating georeferenced graphical representations derived from the relationship between geographic/territorial data, managed within an HGIS system, and urban/architectural data, obtained within an HBIM (Historic Building Information Modeling) environment (Dore & Murphy, 2012). Additionally, the utilisation of extensive historical documents, crucial for depicting the islands' transformations spanning over more than five centuries, necessitates a robust management database.

In this framework, GIS serves primarily for georeferencing existing surveys or complex historical cartographic documentation in raster format, as well as for generating two-dimensional features associated with specific information. Building upon GIS features, the BIM methodology is employed to produce three-dimensional models using REVIT software. When focusing on built heritage, the term HBIM is certainly more appropriate (Murphy et al., 2009). This methodology, widely adopted in recent years, has significantly influenced the operations of documentation and monitoring of cultural assets (Diara, 2022) HBIM is in fact an advanced approach that combines the principles of Building Information Modelling with aspects related to the conservation and management of historic buildings and cultural heritage. This approach involves a series of specific activities aimed at creating digital models of historic buildings to enable a better understanding, conservation, and management of transformations of a given building throughout its whole lifecycle. In the VeNiss project, these capabilities are even more evident as we are dealing with a nearly lost cultural heritage site, where integrated 3D models serve as the only means to uncover the appearance and intricate history of significant ancient buildings and architectural complexes.

The creation of three-dimensional models in this research relies on close and continuous collaboration between architectural/art historians and BIM operators, but this is also greatly facilitated by the use of interoperable tools. To these extents, an elaborate protocol has been developed to manage information exchange among team members, outlined in a diagram known as Process Map (PM) (Figure 2). The PM, developed using the standard Business Process Modeling Notation (BPMN) approach (OMG, 2013), delineates all activities performed by the team, categorised by disciplines (referred to as Tasks), and the Exchange Requirements. These requirements are encapsulated in documents called Exchange Models, which define the information to be exchanged. This section highlights the activities undertaken by HBIM modellers and the corresponding data exchanged with GIS experts and art/architectural historians.

Drawing upon the conventional HBIM methodology integrated with customised processes tailored to the case study, the practice of constructing 3D models is structured into the following phases:

- Creation of the model representing the current building (Task 1.3);
- Definition of temporal phases and integration of historical data into the model (Task 2.2);
- Modelling of historical phases and assignment of temporal parameters (Task 3.2).

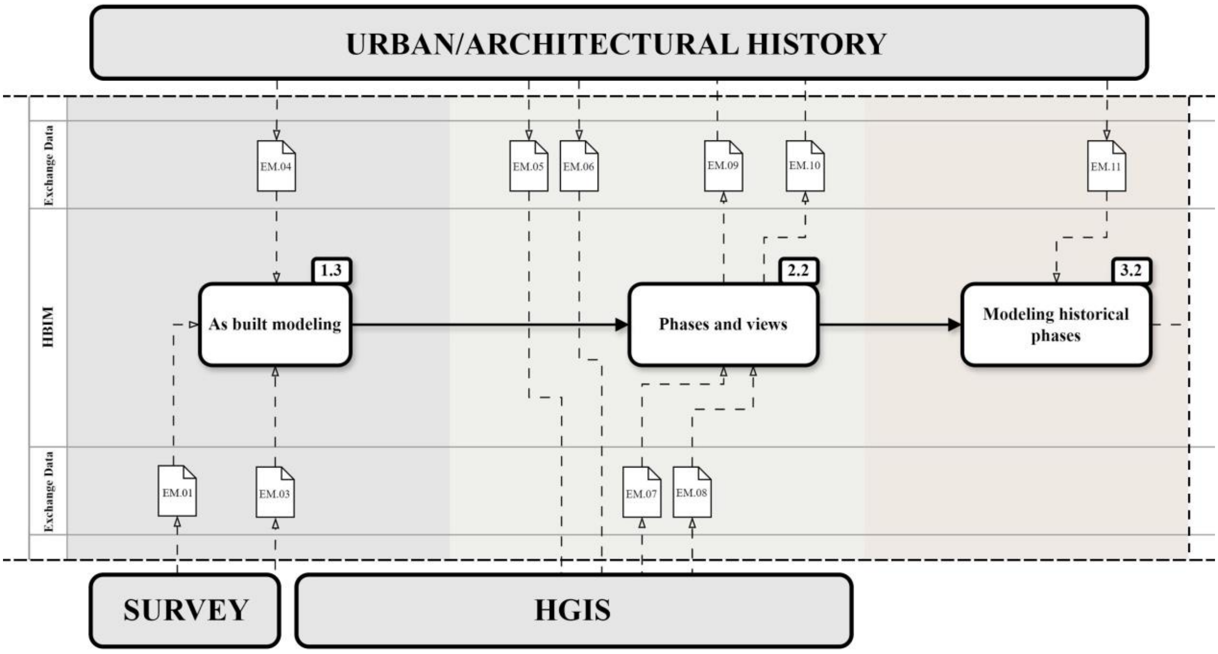


**Figure 2.** Process Map where the adopted workflow is schematically represented.

### 4.1. Creating as-built models

The initial phase of 3D reconstruction activities entails crafting BIM models reflecting the as-built state. Each building (or larger complex comprising multiple structures) is managed in separate files, which are then linked in a federated file based on a system of shared coordinates. The decision to divide the architectural space into multiple components is influenced by both constructional factors (such as the necessity to link specific parts of a building like common floor plans, etc.) and historical considerations (such as the uniformity of the construction period or functional relationships). In addition to the files representing architectural, construction, and civil works, a dedicated file for the topographic component of the island is created, which includes information about both its terrain and the vegetation.

3D models depicting the current state are developed by using input data derived from either existing surveys or new survey campaigns. In the first case, data typically consist of general floor plans, site maps, elevations, and sections, which, often not spatially located, require georeferencing in a GIS environment. Conversely, new digital surveys include georeferenced point clouds that, once processed, allow for the creation of BIM models using the standard Scan to BIM procedure (Banfi, 2020).

Given the multitude and heterogeneity of input data, harmonisation operations are necessary to ensure standardised modelling results. Regardless of the precision degree reported in available surveys (which is assigned a reliability score), the final result maintains a standardised level of detail. The Level of Information Need (LOIN) used during the modelling phase aligns with a Level of Detail (LOD) of 200/300 for the as-built state and 100/200 for historical phase modelling (Figure 3). Because the main purposes of the models are the visualisation and valorisation of the built heritage, the theme of LOD and Level of Reliability (Bianchini & Nicastro, 2018) is conditioned by the quality of the acquired original data. Models related to the current state may be reused for future purposes, necessitating increased level of detail. These purposes may include structural analysis, environmental simulations, surveys, assessments of degradation, etc., crucial for building conservation, maintenance, and restoration over time.

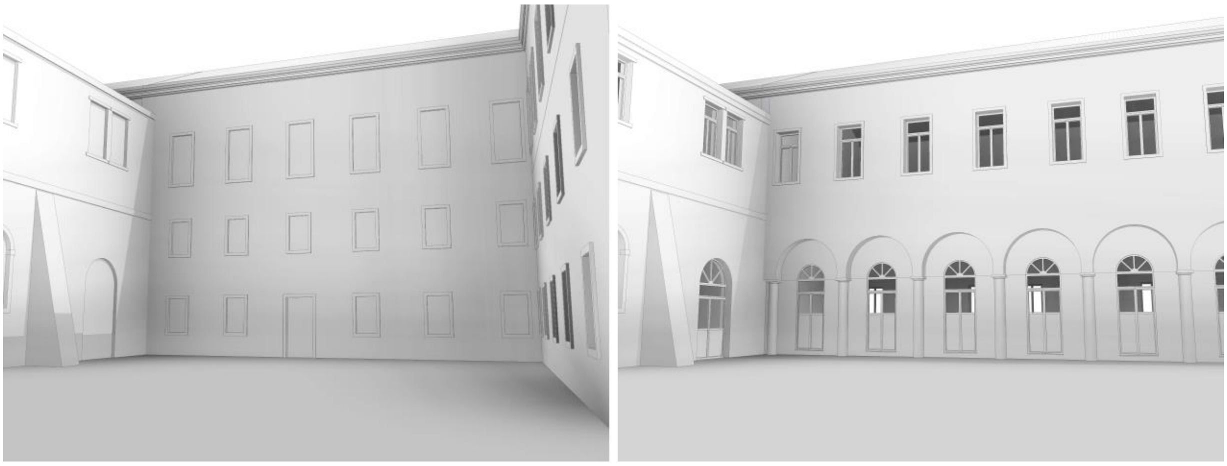

**Figure 3.** Image showing the difference, referred to the same portion of the building, that sometimes occurs between the level of detail of the as-built model (on the right) and the model representing historical phases (on the left).

### 4.2. Historical data integration

Mainly working on textual sources (both primary and secondary) and iconographic sources (historical maps, drawings, engravings, frescoes, paintings, views, and photographs), researchers of the VeNiss project need to constantly share historical information with GIS and 3D modelling experts. This approach requires a well-define and iterative collaboration process. Historical data comprise the number of "temporal phases" of a built work that need to be reconstructed (namely the temporal period located in between two starting/ending moments of a building structure) as well as iconographic sources that constitute the building blocks for the creation of the virtual instances. This material encompasses historical maps, plans, and drawings developed using GIS tools, along with other iconographic sources useful for HBIM model development. In this phase, HGIS is employed for the collection and integration of geographic data, but also because it stores drawn features in a PostgreSQL database running the PostGIS module (Galeazzo et al., 2024).

With regards to the GIS methodology, for each shapefile, an Identity number (ID) is assigned, and, using a boolean method (true/false), its presence or absence within the attribute table is indicated through a series of columns that refer to the dates of the historical maps used in the georeferencing process. The next step involves linking the historical metadata with the actual GIS functionalities. In order to implement this process, we decided that it was beneficial for scholars to integrate information about various aspects of a built work directly into the infrastructure so that they can work in a single environment and they do not need to access the GIS system. These include:

- Date parameters (construction / demolition);
- Functions (private / public);
- Uses (religious, military, healthcare, …);
- Typologies (church, guesthouse, refectory, …);
- People (architects, patrons, owners, …);
- Events (social, economic, urban, …);
- Artworks (paintings, sculptures, artefacts, …).

These data embedded in the platform, which consist of two-dimensional features and their associated attributes, are also transferred into the BIM modelling platform to create three-dimensional models (Figure 4). Additionally, all iconographic sources are integrated into the BIM environment through an XML (Extensible Markup Language) table. This contains the URLs (Uniform Resource Locators) of the original scanned documents gathered in a shared cloud storage.

To enhance interoperability between systems, each BIM object is assigned the same identifying code as the GIS features, enabling team members to easily identify the built work in both environments. Furthermore, the ID number is crucial as it ensures the subsequent transfer and management of 3D models within the VeNiss platform. Once GIS features, along with their pertinent temporal phases, are imported into the software REVIT, views are created and a display filter allows the visualisation of only BIM objects present in a given phase. These procedures are executed using scripts created with VPL (Visual Programming Language), which automate specific tasks that are not covered by the modelling software or would otherwise be repetitive.

### 4.3. Modelling the historical phases of a built work

Once the temporal phases of a historical building are defined and GIS data, including georeferenced historical maps, are imported into the REVIT environment, the process of modelling the historical phases can begin. This involves the creation or deletion of new buildings and the transformation or modification of existing units. During this phase, it is crucial to assign temporal parameters of construction and demolition to each individual BIM object, as the built works on the islands have been significantly transformed or altered over the centuries. As mentioned, the level of detail for 3D models representing historical transformations is LOD 100/200, where virtual instances are depicted with a depth of information related to the acquired historical data. Specifically, only documented historical evidence justifies the modelling of specific technical or decorative apparatuses; otherwise, a simplified schematic modelling approach is adopted (Giordano et al., 2023). The use of two different levels of details not only reflects the philological approach of the project but also enables users to understand the varying degrees of information derived from historical iconography (Bevilacqua et al., 2022).

Furthermore, we resolved to use parametric modelling procedures since BIM models, by their nature, allow for the agile update of object geometry directly through the modification of their dimensional attributes (Sacks et al., 2018). This capability is crucial as it facilitates the easy and rapid modification of 3D models in response to new discoveries or different interpretations developed by scholars during their research. To this extent, once produced, the models are shared in an online BIM management software, usBIM by ACCA Software, in which historians involved in the project can share their opinions and comments on the modelling results. In particular, through a user-friendly interface, they can explore the 3D models and provide feedback and annotations directly on them. This procedure creates an iterative process in which the BIM operator can incorporate changes and updates directly into the 3D reconstructions until a high-quality result is achieved. However, the use of this external platform is only temporary. In the future, when the VeNiss infrastructure is fully developed, this process will be carried out internally.

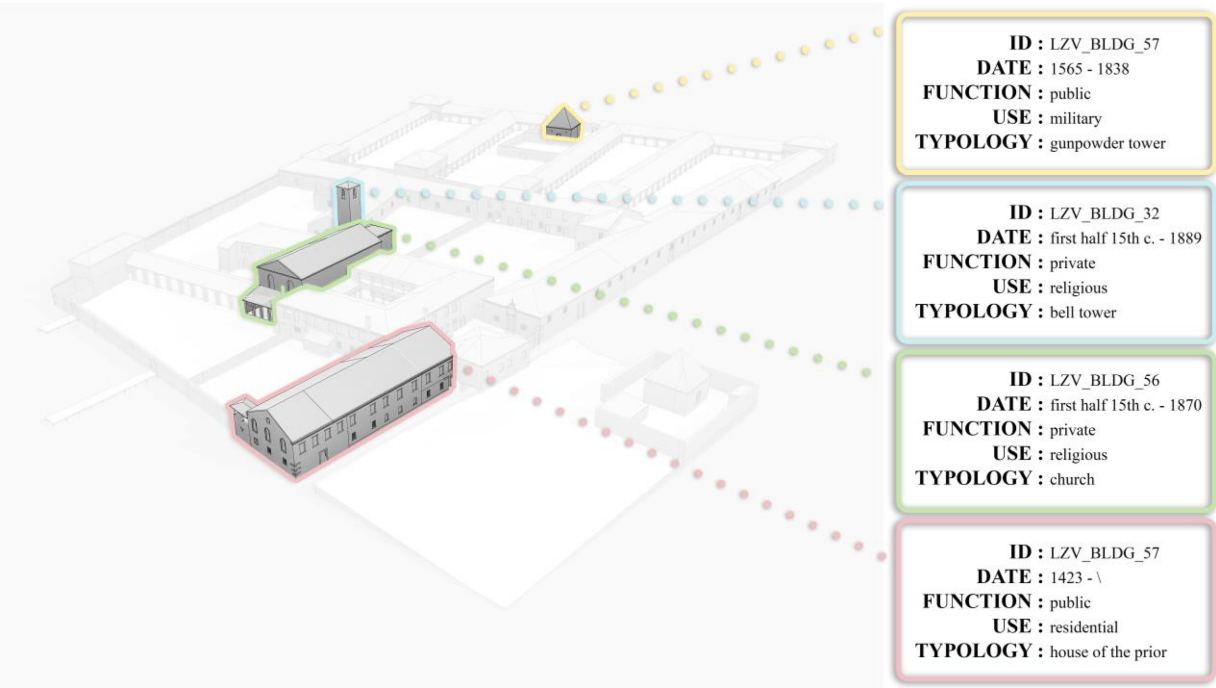


**Figure 4.** In the image, some of the data associated with building entities are graphically represented.

## 5. Results

The described process has been applied to two initial case studies: the islands of San Servolo and the Lazzaretto Vecchio. Both located a few hundred metres south of St Mark's basin, they were chosen for the immediate availability of existing surveys and for their complexity. Following the typical BIM methodological process, 3D models were created and organised in complex hierarchical structures. At the top of this hierarchy is the Project entity, followed by, in progressive order: Site, Building, Level, Room, BIM object. Models are linked in a federated coordination file that coincides with the export model in the Industry Foundation Classes format (IFC), which allows the transfer of file into the VeNiss platform (Figure 5). Each file is identified by a specific name consisting of:

- Project code (VNS);
- Island identification code (SSV, LZV, …);
- Model type (M, T o F);
- Unique code (001, 002, … , 00N);
- Level (GF, 01, 02, ZZ, …);
- File type (M3 = 3D Model);
- Discipline (A, S, E, … ).

According to this schema, for instance, a file containing a 3D model of a building located on the island of the Lazzaretto Vecchio, comprising multiple levels and referring to a given architectural feature, would be named VNS_LZV_M_003_ZZ_M3_A. The same coding is applied to other related entities, such as Level, Room, and BIM objects. Virtual models are created starting from the current state and then, moving backward in time, they extend to the 16th century to reconstruct the more ancient phases based on large-scale maps or detailed historical drawings. Planimetric documents are also integrated with other types of sources that describe the buildings' heights, such as sections and elevations. However, these documents are quite rare, especially for peripheral urban contexts like Venice's lagoon. Consequently, it is often necessary to refer to other kinds of sources, including engravings, views, paintings, and photographs. These documents are processed using perspective restitution techniques that allow for the internal and absolute orientation of the pictorial or photographic frame. In this process, the necessary condition for absolute orientation is that the depicted scenario shows a demolished building along with still-existing architectural structures, or at least a portion of the building needs to still be standing (Panarotto, in press).

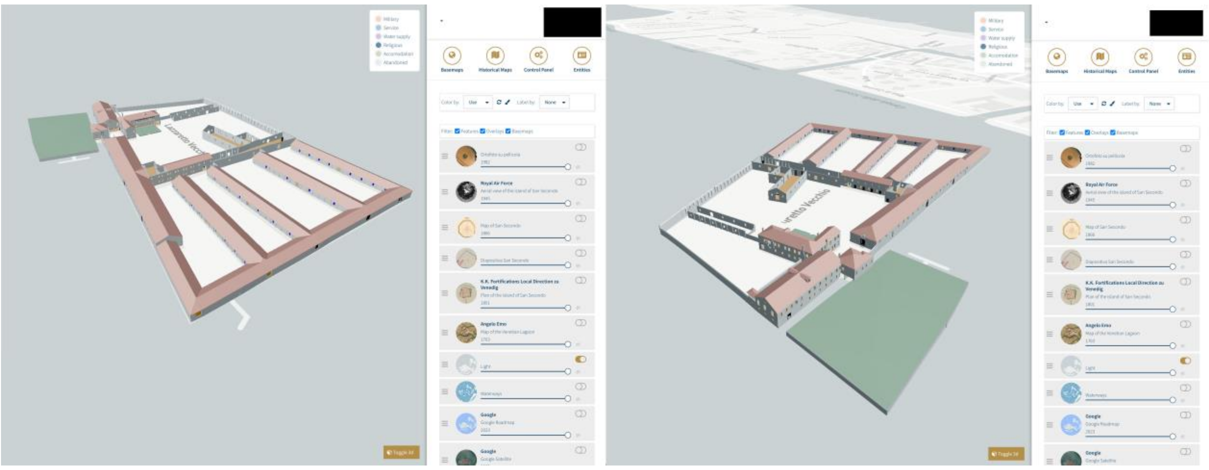

**Figure 5.** The image shows the initial approaches to integrating IFC files within the platform.

The operations described above have enabled the creation of HBIM models for the two islands under consideration. In summary, the virtual model of San Servolo consists of 78 entities, divided into 16 files, spanning from 1809 to the present day (Figure 6). The HBIM model for the Lazzaretto Vecchio, on the other hand, consists of 106 entities divided into 15 files, covering a temporal period from 1737 to the present day (Figure 7).

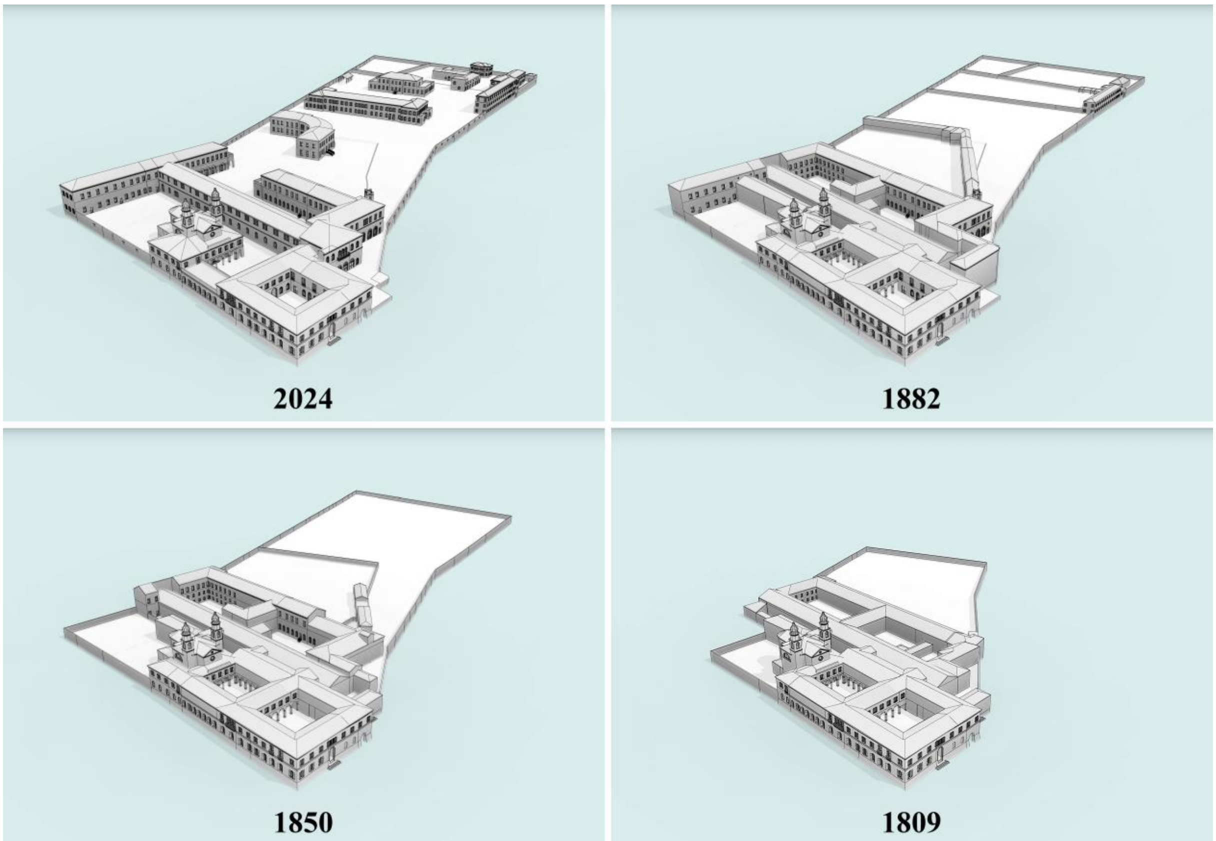


**Figure 6.** The image illustrates some of the main phases related to the San Servolo model.

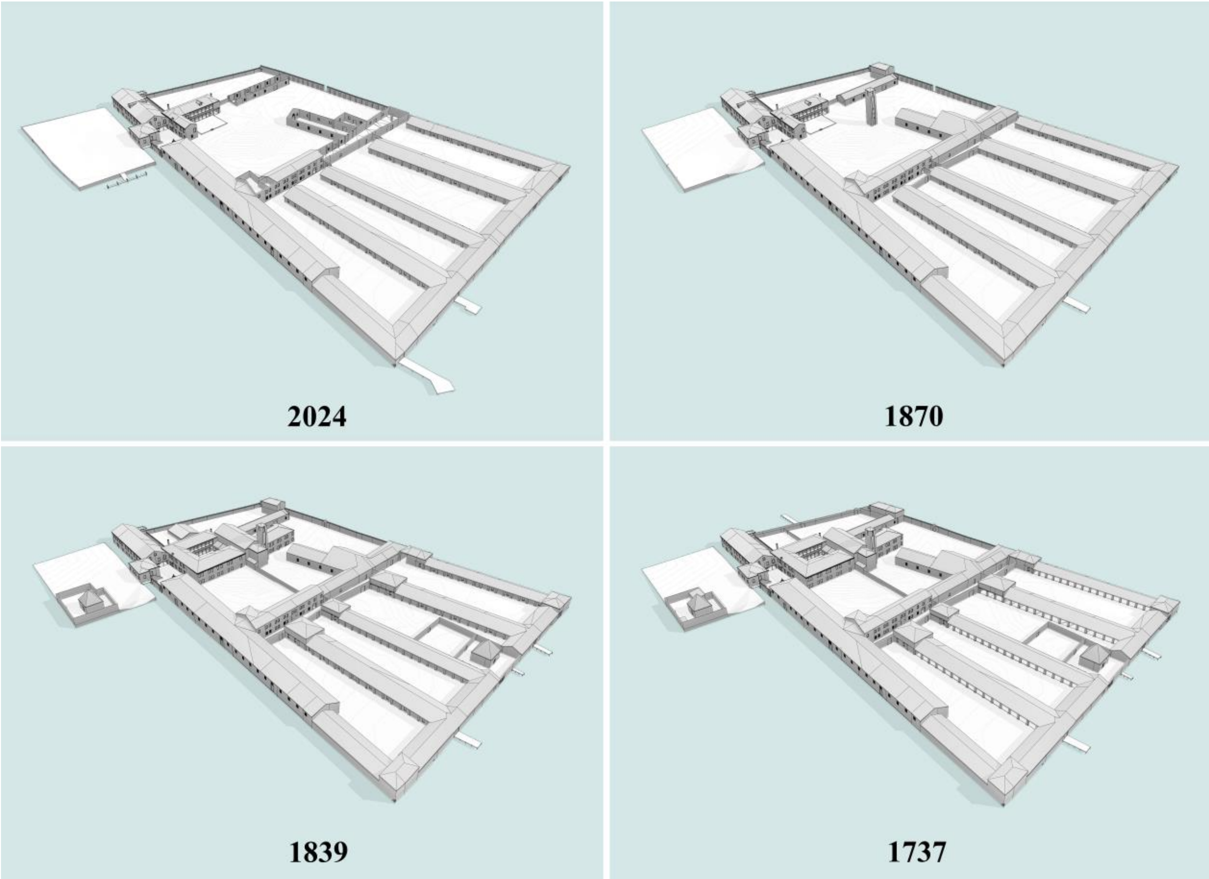


**Figure 7.** The image illustrates some of the main phases related to the Lazzaretto Vecchio model.

## 6. Conclusions

Given the interdisciplinary nature of the project, the methodological approach adopted was developed to address the specific needs of different professionals involved in the research, focusing on the peculiarities of the two pilot cases treated during the first year. The data refer to the results obtained through a study and in-depth analysis based on philological interpretations of certain and indisputable documents. The immediate future goal of the project is to focus on historical documents related to more ancient temporal phases, which are not only fewer in quantity but also less accurate graphically. This requires a stronger effort of interpretation and, conversely, a higher level of simplification of details in the modelling procedure. For this purpose, the 3D model representing the oldest version of a building or complex serves as a critical investigative basis through which various interpretative hypotheses related to earlier phases can be examined.

The VeNiss platform is designed to explore the historical lagoon backwards in time, covering a temporal range from the 16th century to the present day, with a granularity of a single year. On the contrary, in the BIM modelling software, objects are embedded in a specific temporal phase that is determined by the available cartography, representing a snapshot of a particular moment in time. To allow scholars to refine the granularity of the temporal range by assigning specific dates of construction or demolition to each built work, 3D BIM models are exported as single architectural-territorial entities. This enables scholars to attribute individual date parameters to each entity, transitioning from a "layers" structure to a time-based geospatial reconstruction. The described methodology allows historians to update by themselves temporal data directly within the VeNiss platform according to their discoveries based on new documents and sources, thus increasing their autonomy.

Another crucial aspect we are currently considering and plan to further develop in the next steps of the project is the representation of vegetation. Greenery is not only a fundamental component of today's lagoon environment due to the state of disrepair of the current islands, but it was also an integral element of the societal framework of the ancient islands, whose spaces were largely used for agricultural activities. This condition is particularly important in a series of cases that will be addressed in the near future, such as the islands of San Secondo, Poveglia, and San Giorgio in Alga. Accurately representing greenery will provide users with a more realistic depiction of the complexity of the Venetian islands' framework over time.

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# Results of the joint reading of the Windmills of the Region of Murcia and their context

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### *Abstract*

*The use of GIS tools in the preparation of the Master Plan for the Region of Murcia's Windmills has facilitated the documentation work, study and analysis of the complex context in which these heritage elements are inserted, considered B.I.C. (Bien de Interés Cultural - Asset of Cultural Interest) with monument category and therefore subject to unique protection and tutelage.*

*The GIS analysis allows the integration of information from different sources that respond, among others, to variables such as the territorial variables that link the windmills to a system of corridors of cattle trails and wadis, those of a productive nature associated with their functionality in milling processes or water extraction in agricultural and salt exploitation processes, etc.; those related to landscape values and their impact on the construction and characterisation of the different landscapes. In this way, a model is generated that, by combining or discriminating the different variables, makes it possible to specify relationships between individual elements, identify settlement patterns, or recognise singularities.*

*The joint vision of all these aspects enables a reading beyond the current situation of the windmills as isolated pieces subject to recovery as unique elements of the landscape but also enables a different way of thinking about the windmill complex, as a whole, as a system. Nodes in an ecosystemic network or, in other words, elements that can become part of a large green network as cultural services associated with nature.*

***Keywords:*** *Windmills, GIS, Master Plan for the Windmills of the Region of Murcia*

## 1. Introduction

The Master Plan for the Windmills of the Region of Murcia[1] (PDMVRM) is the result of a contract tendered by the "Consejería de Turismo y Cultura" in 2019 and awarded to the Temporary Business Association: ZIMA Desarrollos Integrales S.L., Enrique de Andrés Rodríguez and Fernando de Retes Aparicio. The plan goal is *"to establish the general conditions that must govern the conservation and enhancement of this Asset of Cultural Interest (B.I.C.) and their associated landscape to establish a tool that determines their constituent values and serves as a basis for the planning of future actions, from a perspective of preservation of authenticity.*" (de Andrés, 2020).

The PDMVRM is developed by a first phase of documentation, a second phase of analysis and diagnosis, and a third phase of a propositional nature based on the previous ones. Geographic Information Systems (GIS) are incorporated from the outset as a project to establish the territorial context in which to dump different levels of information and facilitate its analysis based on the cartographies generated. Participation in the PDMVRM has been carried out by a multidisciplinary team that collaborates and supports the different demands required in each phase.

It is necessary to highlight the scope of the information to be processed; the PDMVRM deals with the 224 windmills included in the list of properties listed as Assets of Cultural Interest (Bien de Interés Cultural, BIC), a document available on the Cultural Heritage Portal of the Region of Murcia (PATRIMUR, 2019), all of them declared BIC by the first transitory provision of the Law 4/2007, of Cultural Heritage of the Autonomous Community of the Region of Murcia, according to which *"…windmills located in the territory of the Autonomous Community of the Region of Murcia are considered to be assets of cultural interest by operation of Law, with the category of monuments."* As shown in Figure 1, windmills are distributed heterogeneously throughout the Region of Murcia, meaning they cover a territorial extension of over 11.000 km$^2$ and use information of very different origins and formats. Thus, using GIS tools is necessary to compose a model on which to document and identify the windmills, analyse the dialogue of these elements with their environment and each other, and provide the basis for devising a maintenance and recovery strategy.

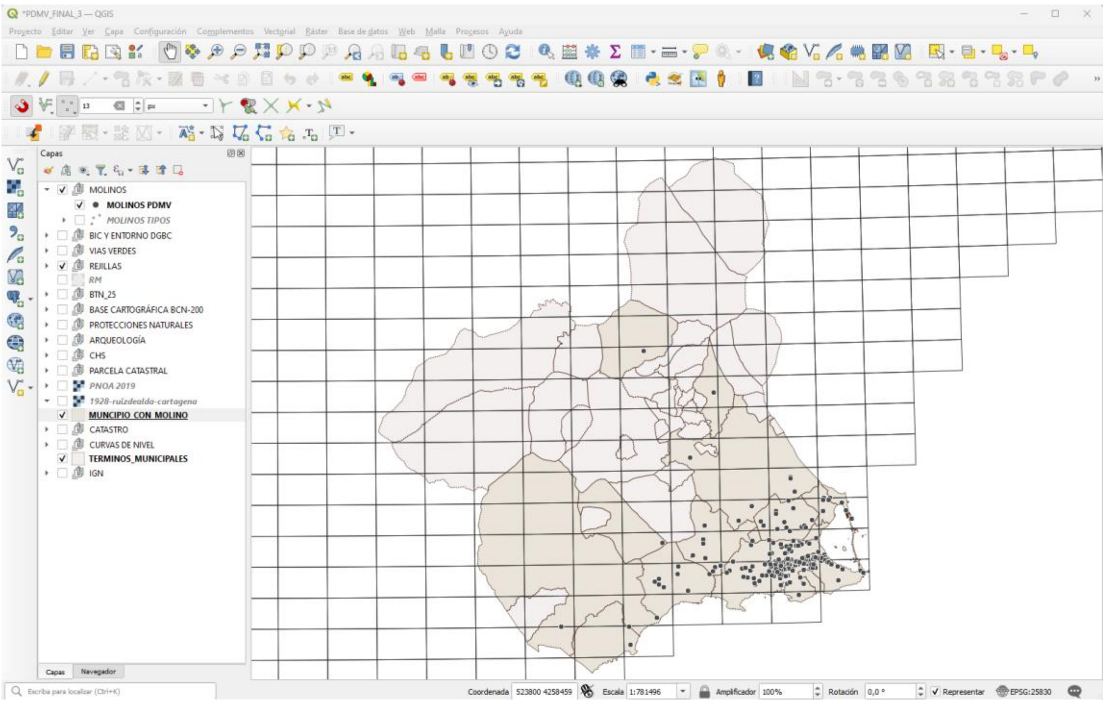



**Figure 1.** QGIS Base Project. Territorial scope: Region of Murcia. Source: Author's elaboration.

[1] The document can be found at https://www.patrimur.es/web/patrimonio-cultural/plan-director-molinos-de-viento

## 2. Aims and objectives

The specific objectives of the Master Plan are divided into three distinct phases: Phase I, Preliminary studies and documentation; Phase II, Current situation and diagnosis. Specific collection of information, analysis of such information, and diagnosis of the current state. Phase III Conclusions and proposal for conserving and enhancing the Region of Murcia's Windmills. This communication aims to identify the scope of GIS in each of the phases and the importance of the cumulative generation of information in successive decisions and phases.

The GIS tool is particularly useful in Phase I, which includes aspects such as the georeferencing of the property and its surroundings and the establishment of a precise planimetry for the description of both; the incorporation of administrative data that allows the identification of data relating to address, owner, as well as those corresponding to the plot on which it is located and that of its boundaries; the historical study carried out based on historical orthophotographs in which it is possible to recognise related constructions and their transformation; the urban analysis in which situations and conditions are identified by existing regulations.

Phase II, although it involves the detailed analysis of each of the windmills, also refers to aspects that can be incorporated into the GIS project, such as the environmental and territorial studies of the landscape, which involves the analysis of environmental variables, existing vegetation, orography, water resources, climatic conditions, land use, links with the territory and the relationship with the natural environment, among others.

Phase III, of a propositional nature, is based on the graphic documentation obtained in the previous phases and the results of the previous analyses to generate management and improvement proposals for conserving the windmills. The current state of most of the mills and the transformation their restoration implies can be seen in Figure 2 through the example of the windmill n.115 and its situation in 2014 and 2024.

Determining the environment affected by the declaration of the BIC is one of the objectives of Phase I of the PDMVRM. However, it is considered that an in-depth study is necessary for its definition. Therefore, a first approximation is proposed for this phase, followed by a revision in subsequent phases based on greater knowledge.

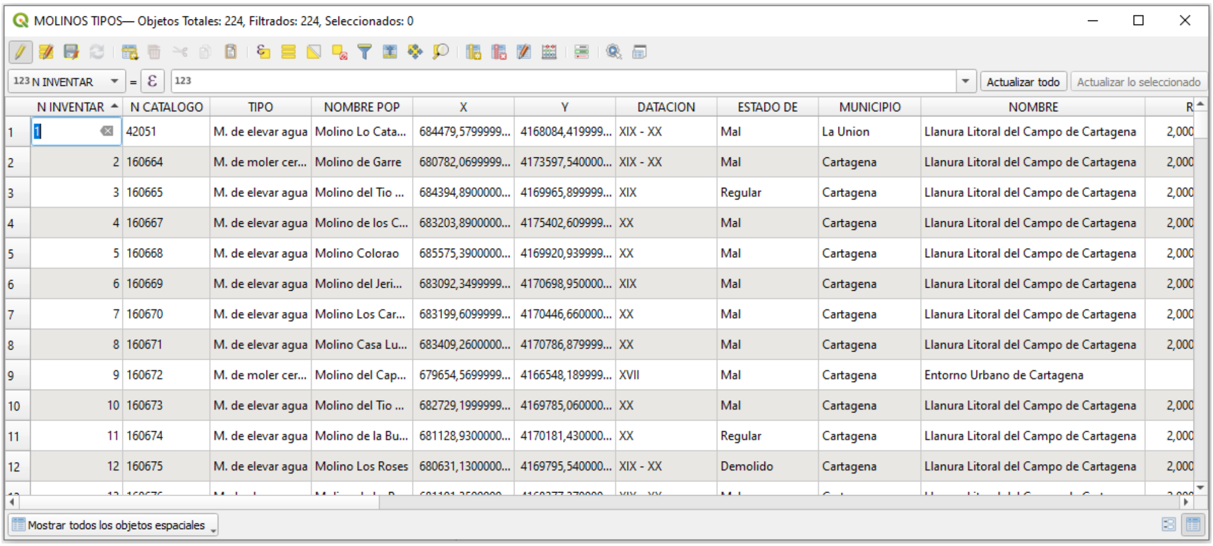

**Figure 2.** Windmill n. One hundred fifteen in the years 2014 and 2024.
Source: De Andrés et al. (2020) and Author's elaboration.

## 3. Methods and procedure

Based on the objectives set out for Phase I, the premise is the generation of cartographies using GIS that should serve as a basis for identifying and characterising the windmills and for the analyses and studies corresponding to the subsequent phases. Phase II, referring to the analysis and diagnosis of the current situation of the different elements, involves the location and incorporation of thematic cartography according to the object of analysis. The combination of the different levels of information reveals similarities and homogeneous groupings from which group maps will be generated for the intervention proposals expected in Phase III.

### 3.1 Cartographic basis for Phase I Preliminary studies and documentation

The generation of the GIS project begins by establishing the territorial scope of the study based on the cartography of the Autonomous Community of the Region of Murcia with the identification of its municipalities and the incorporation of the 224 windmills, which is done as a .csv text file obtained from the tables in which the data compiled in the individual files prepared for each of the windmills are synthesised. In this way, based on the UTM ETRS89 coordinates of the windmills, they are transferred to the project as a layer of points that also contain associated information related to their type, state of conservation, etc. The attribute table corresponding to this layer is shown in Figure 3.


MOLINOS TIPOS— Objetos Totales: 224, Filtrados: 224, Seleccionados: 0

123 N INVENTAR = ε 123 Actualizar todo Actualizar lo seleccionado

| | N INVENTAR | N CATALOGO | TIPO | NOMBRE POP | X | Y | DATACION | ESTADO DE | MUNICIPIO | NOMBRE | R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 42051 | M. de elevar agua | Molino Lo Cata... | 684479,5799999... | 4168084,419999... | XIX - XX | Mal | La Union | Llanura Litoral del Campo de Cartagena | 2,000 |
| 2 | 2 | 160664 | M. de moler cer... | Molino de Garre | 680782,0699999... | 4173597,540000... | XIX - XX | Mal | Cartagena | Llanura Litoral del Campo de Cartagena | 2,000 |
| 3 | 3 | 160665 | M. de elevar agua | Molino del Tio ... | 684394,8900000... | 4169965,899999... | XIX | Regular | Cartagena | Llanura Litoral del Campo de Cartagena | 2,000 |
| 4 | 4 | 160667 | M. de elevar agua | Molino de los C... | 683203,8900000... | 4175402,609999... | XX | Mal | Cartagena | Llanura Litoral del Campo de Cartagena | 2,000 |
| 5 | 5 | 160668 | M. de elevar agua | Molino Colorao | 685575,3900000... | 4169920,939999... | XX | Mal | Cartagena | Llanura Litoral del Campo de Cartagena | 2,000 |
| 6 | 6 | 160669 | M. de elevar agua | Molino del Jeri... | 683092,3499999... | 4170698,950000... | XIX | Mal | Cartagena | Llanura Litoral del Campo de Cartagena | 2,000 |
| 7 | 7 | 160670 | M. de elevar agua | Molino Los Car... | 683199,6099999... | 4170446,660000... | XX | Mal | Cartagena | Llanura Litoral del Campo de Cartagena | 2,000 |
| 8 | 8 | 160671 | M. de elevar agua | Molino Casa Lu... | 683409,2600000... | 4170786,879999... | XX | Mal | Cartagena | Llanura Litoral del Campo de Cartagena | 2,000 |
| 9 | 9 | 160672 | M. de moler cer... | Molino del Cap... | 679654,5699999... | 4166548,189999... | XVII | Mal | Cartagena | Entorno Urbano de Cartagena | |
| 10 | 10 | 160673 | M. de elevar agua | Molino del Tio ... | 682729,1999999... | 4169785,060000... | XX | Mal | Cartagena | Llanura Litoral del Campo de Cartagena | 2,000 |
| 11 | 11 | 160674 | M. de elevar agua | Molino de la Bu... | 681128,9300000... | 4170181,430000... | XX | Regular | Cartagena | Llanura Litoral del Campo de Cartagena | 2,000 |
| 12 | 12 | 160675 | M. de elevar agua | Molino Los Roses | 680631,1300000... | 4169795,540000... | XIX - XX | Demolido | Cartagena | Llanura Litoral del Campo de Cartagena | 2,000 |

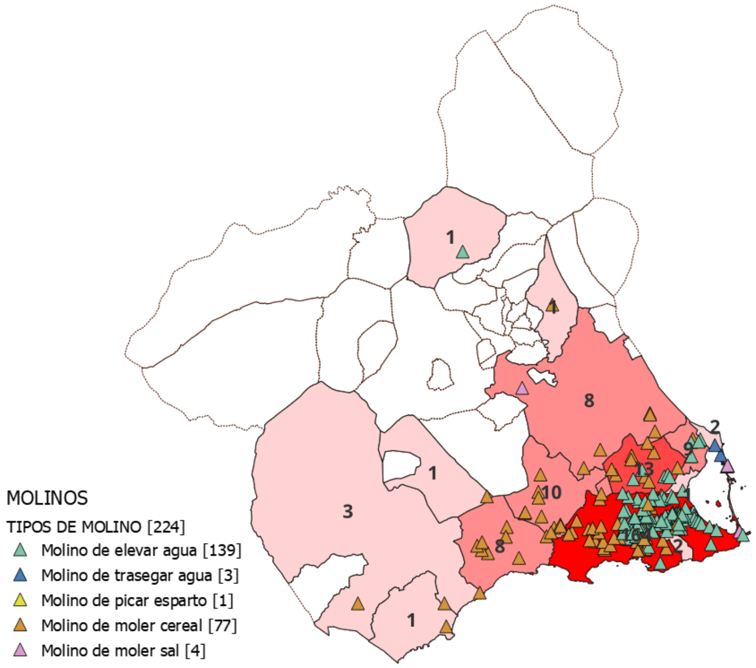
Mostrar todos los objetos espaciales

**Figure 3.** The attribute table of the point layer "Molinos. shp" is embedded as a delimited text file.
Source: Author's elaboration.

From these only two initial layers, it is possible to generate different levels of density, for example Figure 4, about the number of windmills per municipality, and to recognise a heterogeneous distribution in 14 of the 45 municipalities that make up the Region of Murcia, with a greater presence of these elements in the Campo de Cartagena region, or, in terms of type, the concentration of windmills for water extraction in this same area compared to the greater dispersion of windmills for grinding cereal.

This base cartography is supplemented by the battery of historical orthophotographs available on the Sitmurcia geoportal (SITMURCIA, 2019), from which a first reading of each element in its immediate surroundings and its historical evolution is possible, as well as the identification of related constructions.

The territorial characterisation is initially carried out by incorporating the National Topographic Base (BTN) available in the download centre of the website of the National Geographic Institute (IGN, 2019), which includes, among other territorial landmarks, the layers corresponding to roads, railway lines, population centres, watercourses and contour lines. The latter are considered to be of great importance in terms of the definition of altimetry and their graphic relevance in reading the maps. However, the contour lines of the BTN correspond to 10 m intervals, which is excessive for the area of work in which most of the windmills are located, the basin of the Mar Menor. This area is characterised by its flatness, and the definition of the territory requires smaller intervals to identify slopes and runoff directions. The contour lines are obtained at 1-metre intervals from the Digital Elevation Models, also available on the IGN website, which involves downloading the Digital Terrain Model - MDT05 and generating the contour lines using raster analysis.




| MUNICIPIO | |
|---|---|
| Águilas | 1 |
| Cartagena | 164 |
| Cieza | 1 |
| Fuente Álamo de Murcia | 10 |
| La Unión | 2 |
| Lorca | 3 |
| Los Alcázares | 1 |
| Mazarrón | 8 |
| Molina de Segura | 1 |
| Murcia | 8 |
| San Javier | 9 |
| San Pedro del Pinatar | 2 |
| Torre Pacheco | 13 |
| Totana | 1 |

**Figure 4.** Map of location, identification according to type and number of windmills by municipality. Source: Author´s elaboration based on Map De Andrés et al. (2020).

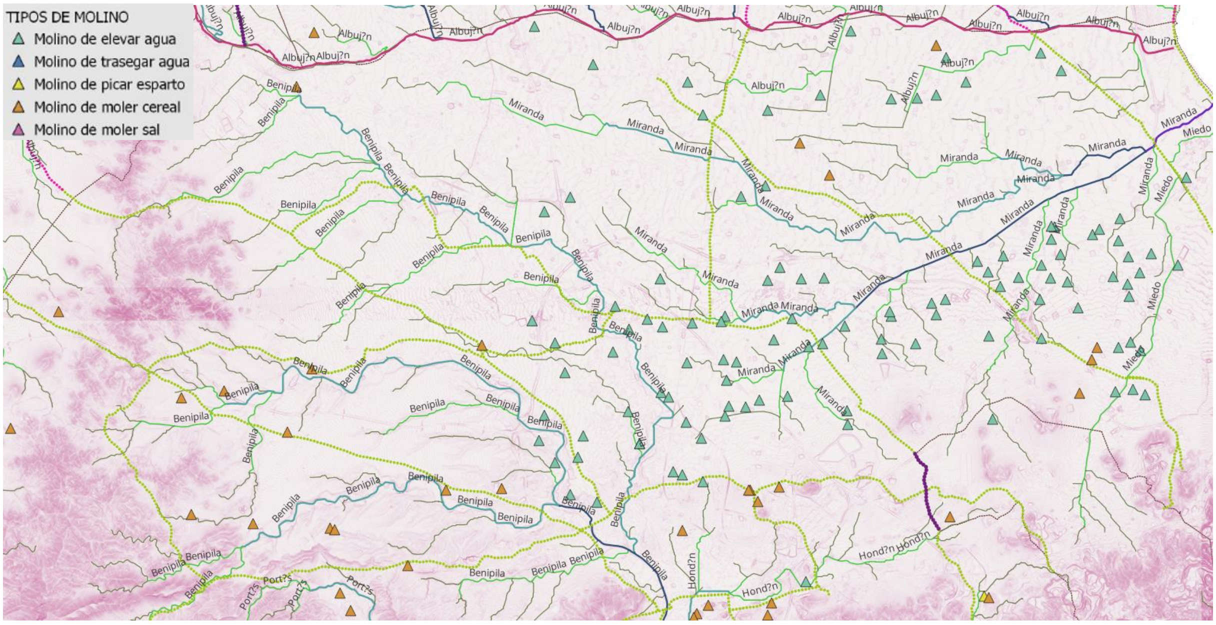



**Figure 5.** Correspondence of the location of the windmills concerning the orography, watercourses and cattle tracks. Source: Author´s elaboration based on Map De Andrés et al. (2020).

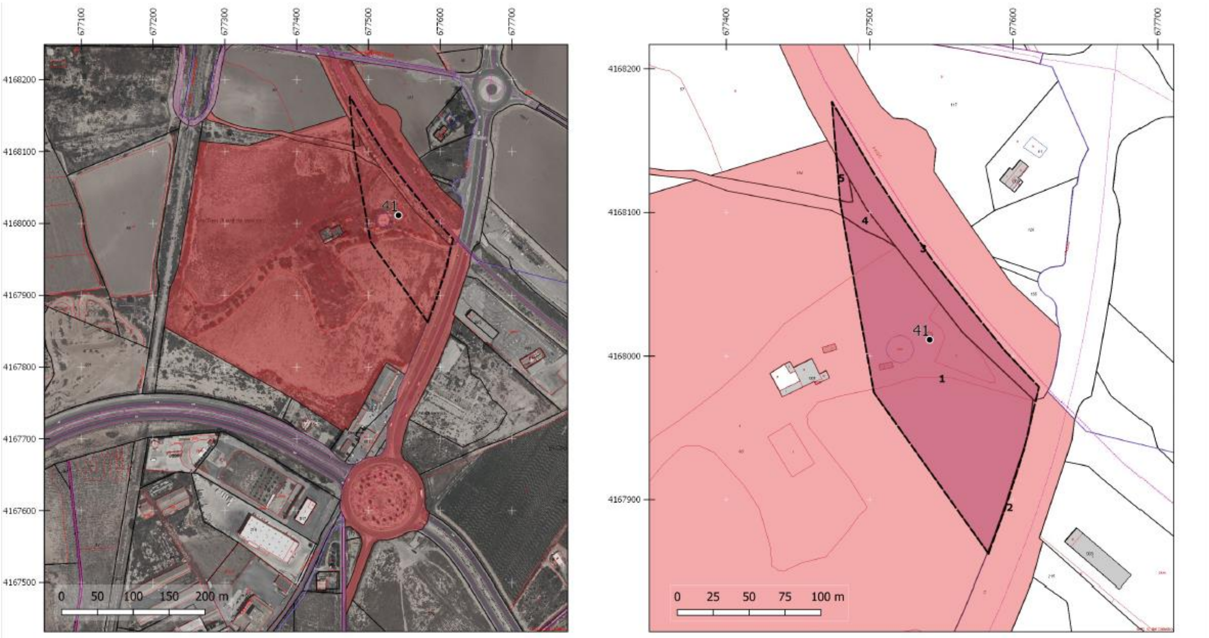
Equally relevant about the location of the windmills is the joint reading of the orography and the layers corresponding to the inventory of watercourses of the Confederación Hidrográfica del Segura and the cattle tracks. Figure 5 shows that the former takes the direction perpendicular to the contour lines while the cattle tracks are mainly oriented parallel to them. In any case, the windmills for raising water are mainly aligned about the watercourses. At the same time, it is possible to identify the proximity of the windmills for grinding cereal to the cattle tracks.

### 3.2 Delimitation of the environment affected by the BIC declaration

The criteria defined by the Dirección General de Bienes Culturales must be taken into account in the delimitation of the protected environment, which include the inclusion of the fundamental elements, establishing, whenever possible, a minimum perimeter of 50 metres around them in the case of rural environments; in urban environments, the boundaries of the plots bordering the public space perimeter of the property will be taken as limits; the minimum possible number of castral plots in the case of private properties will be taken into account, ensuring, whenever possible, that the property is exclusively affected by the plot where the BIC is located. In the same way, orographic limits recognisable in the terrain, roads, tracks, paths, wadis, watercourses, livestock tracks, greenways, etc., will be considered. In addition, whenever possible, the archaeological area will be established within the protected environment of the property, and the urban and territorial regulations will be considered. The associated buildings will be identified in the Vuelo Ruiz de Alda orthophotography.

In this sense, cadastral information from the Dirección General de Catastro (DG CATASTRO, 2019) is added to the project and made available through the vector mapping download section and a WMS service. This information provides the address, cadastral reference, and surface area of the plot, as well as, for authorised users, the identification of the owners.

By superimposing the affected environments, initially delimited, on the cadastral cartography, it is possible to determine and quantify the surface area and level of affectation for each affected plot. The generation of individual maps for each windmill, Figure 6, helps to definitively define the environments above in Phase III, incorporating, in addition, all the requirements indicated and the knowledge once the analyses corresponding to the different thematic layers have been carried out.




Referencia catastral: 51016A015000600000AY Superficie gráfica: 109.396 m2

Localización: FN PEQUEÑO, LO-DS SAN FELIX Polígono 15 Parcela 60 VIA FERREA. 30395 CARTAGENA (CARTAGENA) (MURCIA)
Clase: Rústico
Uso principa: lAgrario
Superficie construida: 370 m2
Año construcción: 1988

| Nº ID | REF. CATATASTRAL | AREA | AREA AFECTADA |
|---|---|---|---|
| 1 | 51016A01500060 | 109396 | 13553 |
| 2 | 51016A01609595 | 22322 | 70 |
| 3 | 51016A01509003 | 14627 | 3394 |
| 4 | 51016A01509016 | 1869 | 464 |
| 5 | 51016A01500154 | 2034 | 189 |

**Figure 6**. Affected environment on cadastral mapping. Source: Author´s elaboration based on Map De Andrés et al. (2020).

### 3.3 Historical study

The analysis of the historical evolution is carried out on the collection of orthophotography available as a WMS service of the Cartographic Service: Ortofotos de la Región de Murcia de SITMURCIA (SITMURCIA, 2019), which provides a catalogue of orthophotographs including the valuable black and white photogrammetric flight of the Cuenca del Segura made by Julio Ruiz de Alda between the end of the 1920s and the beginning of the 1930s, flights *Americano Serie A* from 1945-46 and *Serie B* from 1956-57 and flights *PNOA* from 2004, among others. The WMS incorporation process is shown in Figure 8, which contains the available orthographies catalogue. Figure 7 allows us to appreciate the image quality of the Ruiz de Alda flight compared to the PNOA 2019.

In this meticulous work, each of the windmills is visited in search of variations, appearances or disappearances of associated constructions (historical and industrial elements, machinery, warehouses), paths, ponds, water resources, irrigation networks and historical elements of logistical support about the uses of the windmills, which are plotted and dated to obtain a sequence that narrates the evolution of each one of them.

This study is complemented by analysing texts, images and plans compiled from different archives and catalogues.


**Figure 7.** Windmills 50, 51 and 218 were on the Ruiz de Alda flight and PNOA 2019.
Source: Author´s elaboration based on Map De Andrés et al. (2020).

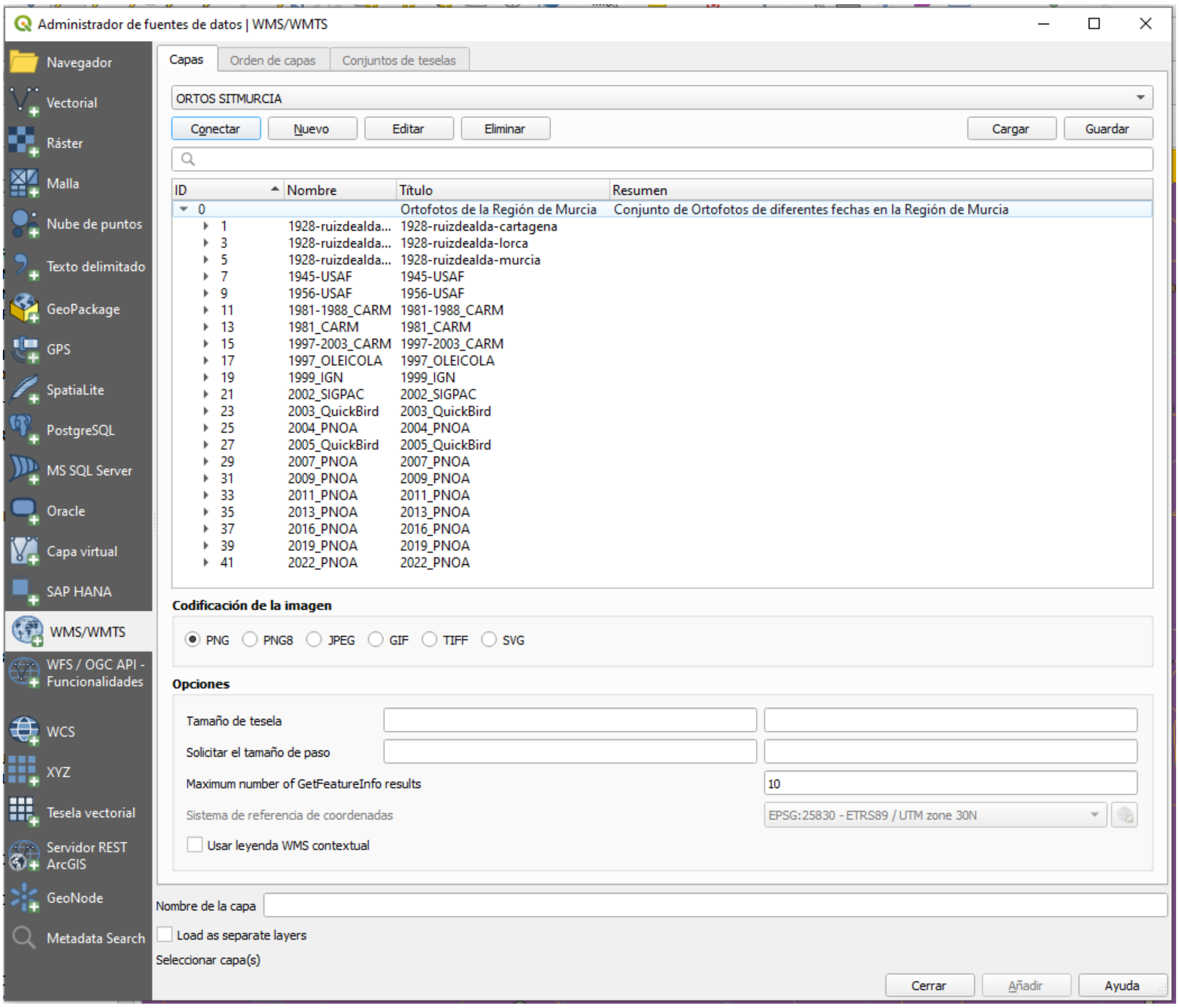



**Figure 8**. Incorporation of the SITMURCIA orthographic collection as a WMS. Source: Author's elaboration.

### 3.4 Urban analysis

The urban planning analysis includes, in addition to identifying the applicable regulations by municipal planning, the consideration of those protections that may affect the BIC from different planning instruments. In this sense, the Project incorporates the layers corresponding to the flood risk of the Confederación Hidrográfica del Segura (CHS): Flood Zones associated with return periods of 5, 10, 25, 50, 100 and 500 years, Figure 9, then available on its website (CHS, 2019) and the protections contained in the Guidelines and Land Management Plan of the Coast (SITMURCIA, 2019) that may limit the level of action or condition it by the conditions of the protection imposed, Figure 10.

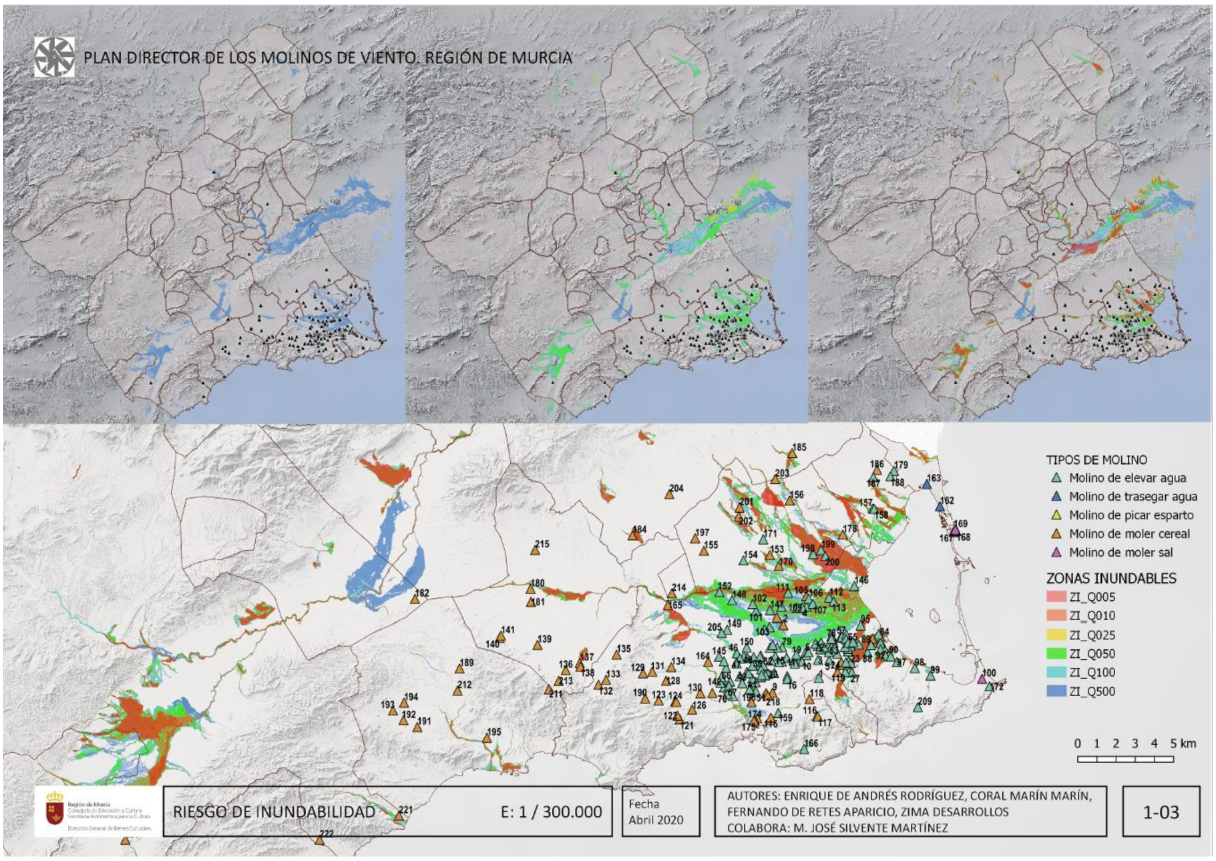



**Figure 9.** Inability risk map. Source: De Andrés et al. (2020).

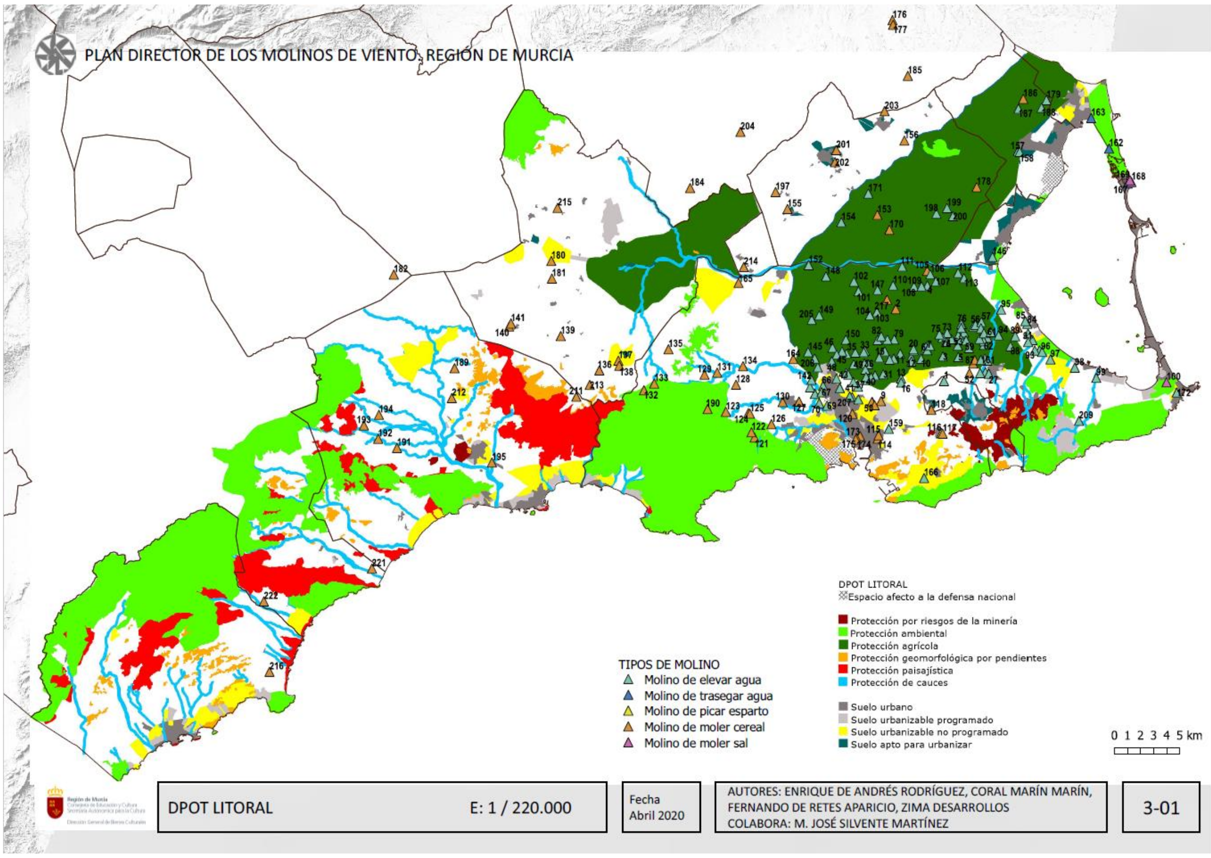



**Figure 10.** Map of protections of the Coastal DPOTs. Source: De Andrés et al. (2020).

## 4. Results

Combining more than 60 vector and raster layers incorporated in local or remote service and using the atlas generation functionality, a battery of 224 maps is obtained with the information available for each location. Using a unique symbology defined for each project layer, the maps obtained have a homogeneous treatment that facilitates their reading and comparison. This tool allows the parameterisation of the content, thus automating the referencing of texts and legends, which greatly speeds up the graphic output of such a large collection of maps.

These maps are the basis for defining the environments affected and defining seven Proposed Areas of Intervention (Áreas Propuestas de Intervención, APIs), as shown in Figure 11, to establish joint protection actions that are more effective than individual protection and which must include not only the windmills but also their surroundings. Figure 12 provides an example of applying the ecosystem environment sets in APIs.

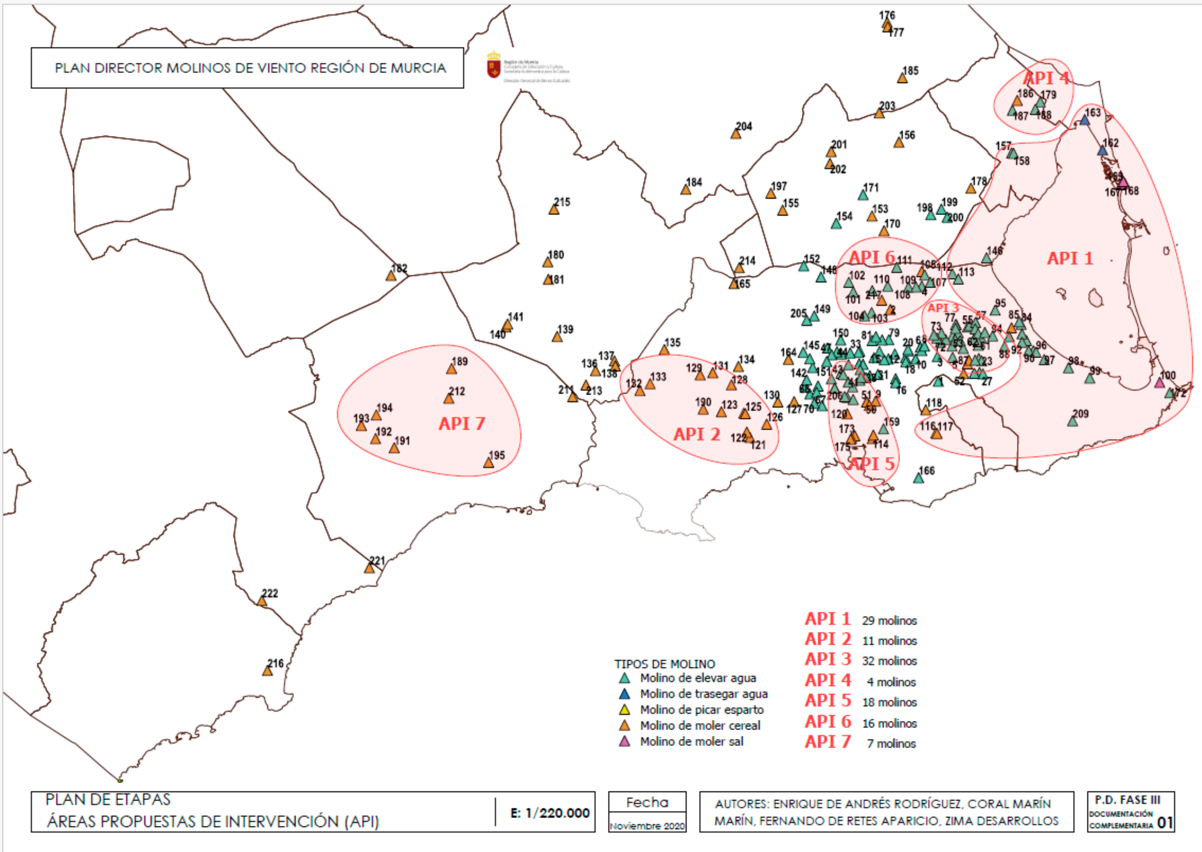



**Figure 11.** Proposed areas of intervention. Source: De Andrés et al. (2020).


**Figure 12.** Examples of applications of ecosystem environments are set in APIs 1 and 3. Source: De Andrés et al. (2020).

## 5. Conclusions

The results show the importance of incorporating GIS tools in the heritage management of elements of territorial and landscape importance, such as windmills in the Region of Murcia. Their functionality has made it possible to generate basic and complex cartographies that define the windmills and their surroundings at different scales by processing very diverse thematic cartographies.

The knowledge provided by the Master Plan for the Windmills of the Region of Murcia (PDMVRM) should serve to reverse the process of deterioration in which a large part of these monuments find themselves and facilitate the management of this heritage through the activation of integrated conservation actions incorporating the environments and territorial connections as a guarantee of maximum protection.

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# Restoration Site sheet GIS: Use of Digital Tools for Collecting Data on Heritage Site intervention

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***Abstract***

*This contribution aims to illustrate the author's research work within the research group HBIMSIG-Turismo at the Universitat Politècnica de València. The research between Rome and Valencia connects two investigative realities in different fields and locations through an exchange and collaboration. The investigation intends to define a digital methodology for recovering the knowledge emerging from restoration site interventions on "widespread" cultural heritage.*

*Conservation interventions represent fundamental moments in the history of buildings as they allow for a direct understanding of the material reality of the asset. Therefore, preserving the memory of these interventions is crucial to ensuring thorough and updated knowledge of the heritage and for the virtuous management of future interventions on the asset.*

*The illustrated case study is situated in the historic centre of the city of Rome, in the ancient Rione Parione. The protection of widespread private heritage is extremely complex in this tourist area. The interventions subject to archiving involve the external surfaces of two buildings that are part of a vast and varied heritage within the multi-layered historic city.*

*The authors have defined an operational tab called the Restoration Site sheet to collect and share information related to these interventions. This digital database guides the user in filling it out. Sharing the research group's experience regarding the tourist management of the public space adjacent to the Cathedral of Valencia has enabled the integration of the digital Restoration Site sheet within a georeferenced GIS model.*

*This work illustrates the methodology used to integrate geometric-spatial data into a semantic model (database) designed to meet a specific need: preserving the memory of conservation site interventions on cultural heritage.*

***Keywords:*** *Cultural heritage, Informative system, GIS, Semantic model, Conservative site, Widespread heritage.*

## 1. Introduction: The Context of the Research

The intervention site in historical architecture is defined as a place of knowledge in two aspects. On the one hand, all direct action on the heritage building allows one to closely understand the object, acquiring new information about its constituent materials, construction technology, and transformations. On the other hand, the site of intervention is a “place of culture”, as it represents human action in history, reflecting the sensitivity of an era in its complex relationship with the ancient. The restoration project is both a new work, with equal dignity to the work being intervened upon, and a critical act of interpretation of the heritage. According to Carbonara (2011), restoration's architectural and linguistic choices must be guided by sensitivity and a critical method, allowing the project to adapt to the needs of the architecture and the site.

This demonstrates that the intervention represents a phase in the life of the building and, as such, must be documented. Indeed, a gap in knowledge concerning the history of the building can easily lead to decision-making errors during the operational phase, potentially negatively impacting the conservation of the asset and its parts. As testified by several authors, the knowledge of previous restorations, especially regarding the interventions on architectural heritage in the last century, is crucial for the project and the correct interpretation of conservation issues (Bartolomucci, 2023). It is often the case that preliminary investigations cannot be carried out during the project definition phase. This makes it very challenging for operators to develop a quality project without scientific data to support the formulated hypotheses. Access to the knowledge gained from past intervention sites would enable the production of a more informed and scientifically grounded project.

### 1.1. Computerised Documentation of Cultural Heritage in GIS: state of the art

Documentation of heritage buildings has a crucial role in safeguarding and preserving the cultural and material value of the building for the next generation. This operation is central to protecting heritage within the current Italian regulations, specifically under the Italian Code of Cultural Heritage (Art. 17 - Legislative Decree 42/2004). Like most areas of human activity, the humanities disciplines related to heritage conservation have also been influenced by the digital revolution that began in the 1980s. The first area to be reformed was the graphic representation of built structures, transitioning from manual drawing to CAD (Computer-Aided Design) software. In 2000, there was a shift from 2D digital representation to 3D modelling with the advent of BIM (Building Information Modelling) methodology (Khalil et al., 2020).

The progress of these tools is continually evolving and now also encompasses the cataloguing of cultural heritage. This has led to the emergence of new research fields investigating the application and use of ICT (Information and Communications Technology) and digital technologies in cultural heritage, and numerous policy documents identify them as a solution or catalyst for making heritage a Common Good (European Heritage Alliance, 2020).

In Italy, several research examples have been aimed at cataloguing heritage through digital tools. An early experience involved the computerised documentation for the architectural conservation of the surface conditions of the Chiostro di St. Chiara in Naples and the Mura Serviane in Rome. These experiments from the late 1980s used a precursor to GIS, associating information on materials and surface degradation with a simplified graphic representation of the elements (Ferragni et al., 1987). The first large-scale GIS experiment materialised in the Information System, known as the Risk Map of Cultural Heritage, developed by the Italian Istituto Centrale del Restauro in 1997 under the guidance of Giovanni Urbani. This was the first attempt to georeference the Italian Cultural Heritage Catalogue archive, simultaneously analysing the potential risks to which individual assets are exposed in their respective territories (Bartolomucci, 2008). During that period, individual experiments were also developed to gather information useful for the conservation of specific assets; notable GIS experiments include the "medical record" of St. Maria di Collemaggio in L’Aquila (Bartolomucci, 2004) and the information system for the documentation of the restoration of the stone surfaces of the Torre of Pisa, named AKIRA GIS Server (Capponi et al., 2001). The GIS experience for the Torre of Pisa later evolved in 2007 into the Information System for the Documentation of Restoration Sites (SICAR).

Concurrently with these GIS experiments, the BIM methodology also emerged as a potential response to historic heritage documentation needs. Building Information Modeling (BIM) offers a collaborative working methodology that, supported by digital technologies, generates more efficient methods for the design, execution, and maintenance of buildings (HM Government, 2015).

### 1.2. The Restoration Site sheet tool

Given the testimonial value of interventions, there arises a need to develop a tool for collecting and preserving information related to the construction site.

This involves primarily three categories of information:

- Indirect knowledge, that is, the preliminary research[1] and the consequent planned intervention;
- The history of the restoration site, which includes all the transformation carried out and the work of each day on the site;
- Direct knowledge gained from the site through close interaction with the object of intervention.

The research develops from these premises within the PhD program in Architectural Restoration at the Sapienza University of Rome[2], and it is enriched through the exchange with the HBIMSIGTUR research group at the Universitat Politècnica de València. This study aims to create and test a methodology for collecting data related to intervention sites on cultural heritage and to enhance their potential through digitalisation and collaborative software.

The *Restoration Site Sheet* database has been developed and divided into sections where information can be collected and catalogued to meet this need. This includes data related to preliminary research and the building's history, integrated with findings that emerged during the intervention. These pieces of information can be extracted from the database and graphically placed in a summary sheet.

The database was developed within a Microsoft Excel spreadsheet. This intuitive and widely used software is open source and compatible with other spreadsheet programs.

The database structure (Figure 1) adheres to the cataloguing standards of the Italian Central Institute for Catalog and Documentation[3]. The fields to be filled are divided into paragraphs and subparagraphs and possess the same properties as the cataloguing sheets for cultural assets developed by the Italian Ministry of Culture.

All information can be entered into the respective fields, most of which have guided completion through defined vocabularies. The definition of closed vocabularies is an important tool to collect homogeneous and high-quality data (Acierno, 2023).

[1] For public interventions on heritage in Italy, it is mandatory to draft a technical report containing information collected by specialized personnel during a preliminary survey (DM 154/2017). For interventions on private heritage, a request for authorization from the protection authorities is required, which includes the preliminary study carried out to develop the project (art. 31 D.lgs 42/2004).

[2] These topics are part of a PhD thesis in the Department of History, Drawing, and Restoration of Architecture at Sapienza University of Rome, XXXVIII cycle, under the supervision of Professor Simona Salvo (PNRRN research grant, ex m.d 351/22 or m.d 352/22). The application to the case study presented in this article was made possible thanks to the collaboration with an Italian restoration company and the Universitat Politècnica de València, in which the implementation and the application to the case study are being developed thanks to the research group HBIMSIG-Turismo (Dra. María José Viñals, Dra. Concepción López González, Dr. Jorge García Valldecabres, Pablo Ariel Escudero, Renan Cornelio Vieira de Souza Rolim and Patricio Rodrigo Orozco Carpio).

[3] The Central Institute for Cataloging and Documentation (ICCD) is affiliated with the Italian Ministry of Culture. It has scientific and administrative autonomy and is now part of the Central Institute for the Digitization of Cultural Heritage - Digital Library.

The cataloguing of data on interventions within a Knowledge Organization System (KOS), such as the *Restoration Site sheet,* can be instrumental in defining a quality project. Sharing all this information, gathering it in a single container, allows the operator to systematise the project hypotheses with the reality of the conservation site, calibrating the intervention. Furthermore, it is a strategic tool for planning future interventions on heritage and managing the asset.

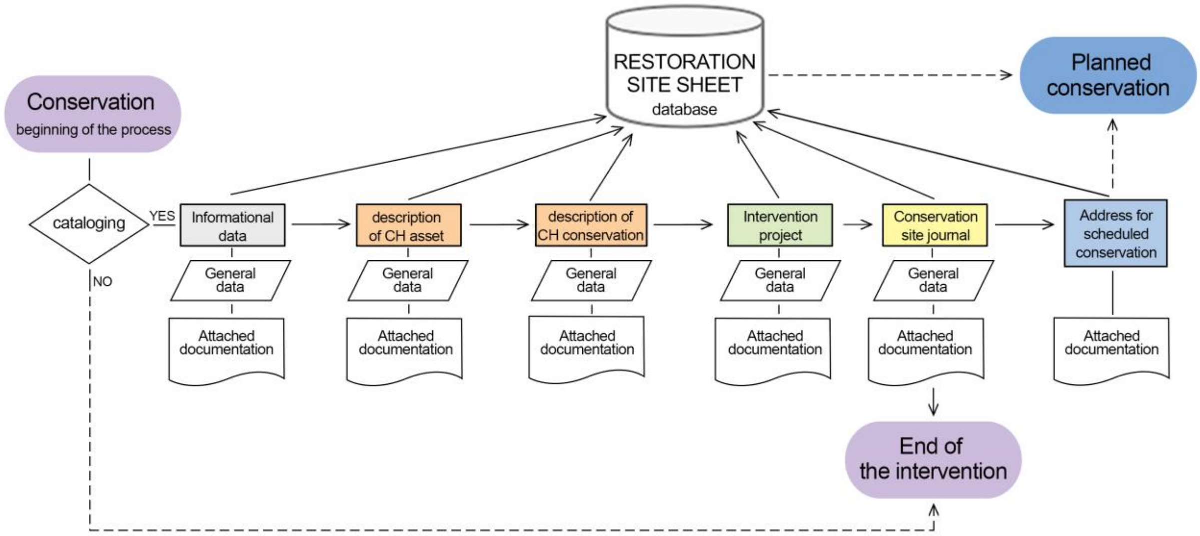


**Figure 1.** The structure of the Restoration Site Sheet database. Source: Author’s elaboration.

### 1.3. The advantages of implementing the Restoration Site Sheet with a collaborative methodology

Historical architecture cannot be considered a single entity but the result of transformations and stratifications over time. These complex buildings require optimal interdisciplinary coordination among all the figures involved in the conservation and heritage management process. This peculiarity of intervention on built heritage increases the complexity of the intervention and suggests the use of a holistic and collaborative methodology.

BIM tools link information coherently and easily to a graphical representation known as a parametric model. Additionally, when adapted to collaborative platforms, BIM tools aid in developing interdisciplinary activities (Building Smart Spain, 2018). It is an architectural project management methodology that allows for the simultaneous and integrated intervention of various professionals in a single space: the digital model of the building. The application of BIM to cultural heritage is referred to as Heritage Building Information Modeling (HBIM). Given the potential of the described tool, an effort was made to integrate the methodology with the sheet's developed instrument.

## 2. Objective of the research

The ongoing research at the Department of Architectural Graphic Expression at the Universitat Politècnica de València aims to develop a collaborative methodology for the expeditious collection of data related to conservation and restoration sites, integrating the *Restoration Site sheet* database into a more complex process.

Furthermore, it was crucial to understand the best way to utilise the data collected during the 3D surveys by the research team or by a company. The objective was to develop a three-dimensional model from the available point clouds of the buildings, using the spreadsheet as an external database.

Generally, we refer to HBIM when we think about collaborative, informative systems for heritage. It is important to emphasise that it is not merely a digital tool or software but a methodology for managing data related to the conservation project. According to the Bew-Richards model (Figure 2) concerning the maturity levels, it is necessary to reach Level 2 to achieve a "collaborative" tool. In this case, work is carried out in a common data environment with two different databases: the BIM model, a database of geometric information and data, and another database with extended data (Excel, Access, etc.) outside the BIM model. In collaborative BIM models, information from both databases is connected by plug-ins (García-Valldecabres et al., 2020). For this initial phase of the research, it has been decided to develop a 3D model at this collaborative level of maturity, starting from the point cloud we have and using the *Restoration Site sheet* as the external database.

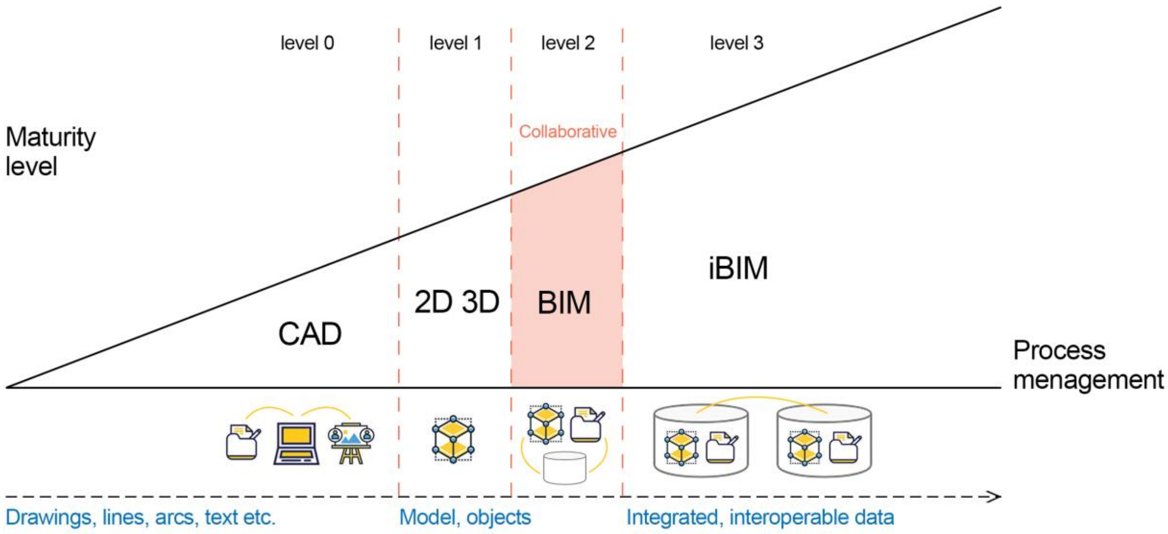


**Figure 2.** Level of maturity according to the Bew-Richards model. Source: Author's elaboration.

## 3. Methodology and Application

In the analysed case, the external database has already been defined by developing the *Restoration Site sheet*. Therefore, it was necessary to create the second database, the digital model[4] of the buildings. This process began with the data provided by the company, which included laser scanner surveys of the buildings to be intervened upon. Among these surveys, a model representing five buildings undergoing conservation of their external facades was chosen for development.

It should be noted that the company's current standard process greatly limits the potential of the captured point clouds. The survey technicians generally use point clouds to obtain orthophotos of the building facades. These images, extrapolated from the point cloud, are then used to create a 2D survey using Autodesk AutoCAD® software. To understand the methodology for developing the 3D model in depth, it is necessary to introduce the analysed case study.

### 3.1. The application: company's Conservation Sites in Rione VI Parione in Rome

The survey of the company's conservation sites in January 2023 highlighted 65 ongoing or scheduled sites involving restoring the external surfaces of private buildings. Among these buildings, 13 were declared by the Italian Ministry of Culture as architectures of National Cultural Interest. More than half of the sites are located in the historic centre of Rome, with seven buildings specifically situated in the ancient Rione Parione (Figure 3). The case study selection focused on 5 of these sites in the district, for which a unified 3D laser scanner survey had been conducted by the company.

[4] The methodology described below was developed by the research group HMIBSIG-Turismo (Universitat Politècnica de València).

### *3.1.1. The Reasons for the Case Study Selection*

The reasons for this choice are also linked to the exceptional richness of the area in terms of historic architectural surfaces. The name Rione Parione is believed to derive from the word "*paries*", meaning large wall or rampart. During the Roman era, it was home to the Stadium and Theater of Domiziano and the Theater and Curia of Pompeo (Pericoli Ridolfini, 1973). It maintained a cultural significance for centuries, characterised by the presence of theatres, bookstores, printing houses, shops, and hotels where wealthy travellers and diplomats stayed. In the 15th and 16th centuries, many of Rome's most notable families resided in their palaces, including the Orsini, Borgia, Sforza, Nardini, and Massimo families. Among these splendid residences, the Massimo family's palace on the current Corso Vittorio, Palazzo Massimo alle Colonne, stands out. It was designed in the early 16th century by the architect Baldassarre Peruzzi (1481-1536).


**Figure 3.** Localisation of the case study sites. On the top left is Rome's city centre, and on the Rione VI Parione. Top right, the Rione VI Parione. Bottom left is the point cloud captured in the 3d survey. Bottom right is the localisation of the buildings on the point cloud. Source: Author's elaboration.

At the same time, in Rome, especially in the Ponte and Parione districts, there was a trend to beautify building facades using graffiti and monochromatic chiaroscuro techniques. Of these interventions, carried out by the greatest artists of the time, only a few traces remain today, on the verge of disappearing. Therefore, the investigation is set in a context of fragile yet highly valuable cultural preservation, aiming to test how a tool like this can contribute to conserving these valuable external surfaces.

Another factor in the selection was the proximity of the sites and the presence of a single-point cloud for the area. This proximity simplifies data collection on site and allows for developing a single model to compile information from multiple sites, creating a georeferenced territorial information system, albeit on a small scale.

 

Compiling this data in a single model also allows these architectures to be seen not as isolated points but within a complex context with strong historical and artistic connections. This context includes the public road represented in the model, serving as a place of daily exchange and visual enjoyment of these architectures.

Finally, the surveyed sites in the point cloud are at different stages of progress; some have been completed, and others are about to begin. This allows testing the flexibility of the *Restoration Site sheet* database to collect data a priori and during the intervention, as initially planned, and *a posteriori* as a final repository for all the company's construction sites.

### 3.2. GIS or HBIM? How to obtain an expeditious and collaborative model

The described case study presents certain specificities, as it involves private interventions for conserving external surfaces in culturally significant buildings within an extremely value-rich and fragile urban context. Therefore, the developed methodology had to meet the needs for cost-effectiveness and speed of interventions. Additionally, it was necessary to use the data collected through the company's surveys to develop digital models of the buildings.

Thus, it was considered appropriate to develop an expedited modelling methodology that utilised the point clouds directly to develop a mesh model where the information from the survey forms could be collected. At the same time, the developed mesh retained the "raw" data from the surveys, which could be analysed in the future for subsequent interventions on the building. The developed workflow aims to be economical and quick to be applicable by companies operating in the field of historic building conservation. Moreover, as previously described, the analysed interventions concerned the external surfaces of the buildings, which is why developing a parametric three-dimensional model by modelling the individual elements could be extremely complex and unsuitable for the extent of the interventions planned on the historic surfaces. For the reasons described, it was decided to abandon the idea of developing an HBIM model and instead use a three-dimensional collaborative model obtained from the point cloud, which will then be linked to a semantic model in GIS.

It is essential to define the characteristics of the informative model to be developed based on the peculiarities of the building and the type of intervention it is subjected to. The choice of methodology should start from these premises, leading to the decision of which software to use based on the expected level of maturity.

### 3.3. Tools and Method

The first step was to verify the accuracy of the surveys conducted to understand the quality of the available data. For the 3D laser scanner survey, the FARO® CAM2 FocusS 70 by CAM2® (the Italian subsidiary of the FARO® group) was used. The manufacturer reported in the technical datasheet that the measurement noise was 0.3 mm at 10 m for 90% (white) and 0.4 mm at 10 m for 10% (dark grey). The same data were 0.3 mm at 25 m for 90% (white) and 0.5 mm at 25 m for 10% (dark grey). It was verified that the average registration error of the nine scanning stations was less than 6 mm for the overlap parameter.

The point cloud of the construction sites located in the Parione area was aligned and registered using FARO® SCENE version 2022.1 software. The registered point cloud was imported in .E57 format into Autodesk® Recap 2023 version 23.0 to begin the point noise clean-up process. Subsequently, it was decided to use the open-source software Cloud Compare version 2.13 alpha to eliminate redundancy defects and irrelevant elements reported in the 3D survey (Figure 4), which were not pertinent to the research.

The same software was used to classify the cloud into facades and pavement and then to segment the facades according to the building's limits. After that, the segmented point clouds were exported to Meshlab 2022.02 to generate the respective textured meshes (Figure 5). The resulting meshes were exported as .obj files to introduce them in a GIS, in this case, ArcGIS pro 3.2.2 (Figure 6).

In ArcGIS, it was possible to link the semantic information to its corresponding element; for this, the sheet was formatted in Excel and then inserted as a data table in the GIS (Figure 7-8). This will allow the information to be visualised through pop-ups.

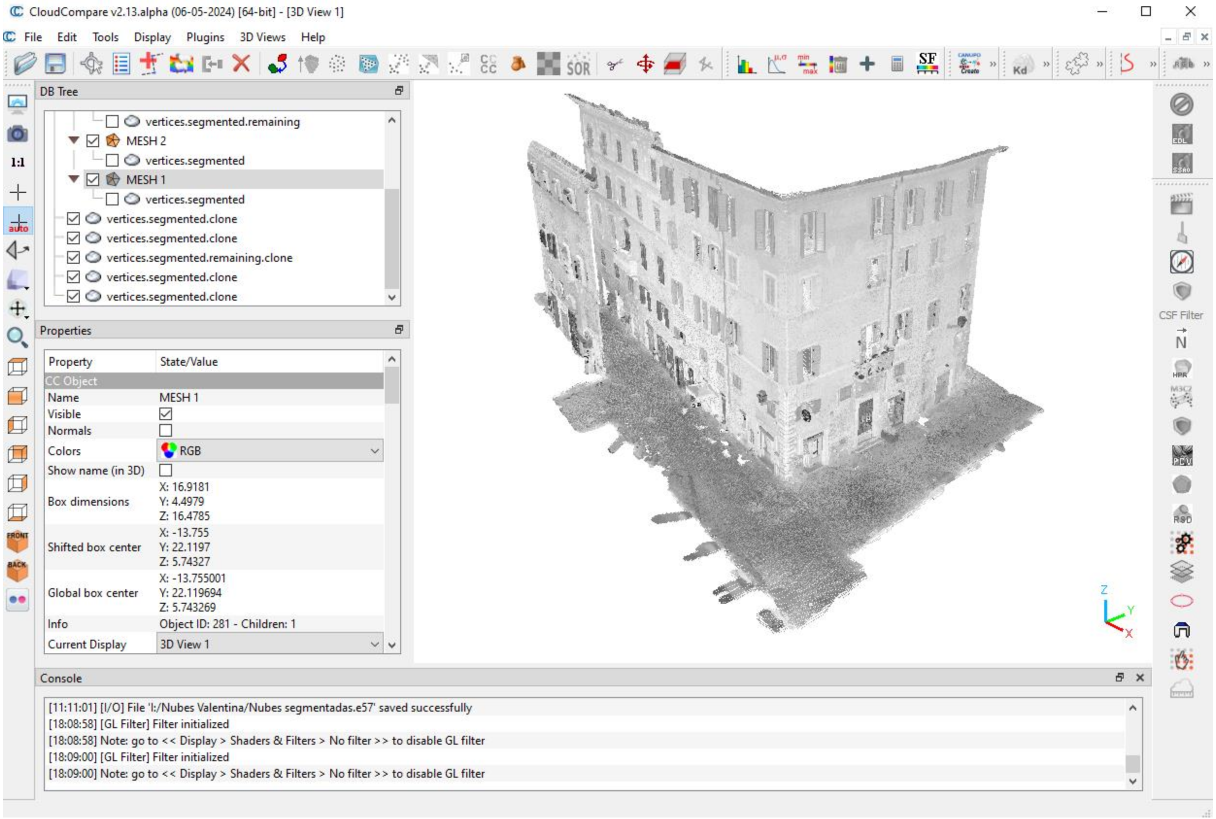


**Figure 4.** Point cloud in Cloud Compare after the noise clean-up process. Source: Author's elaboration.

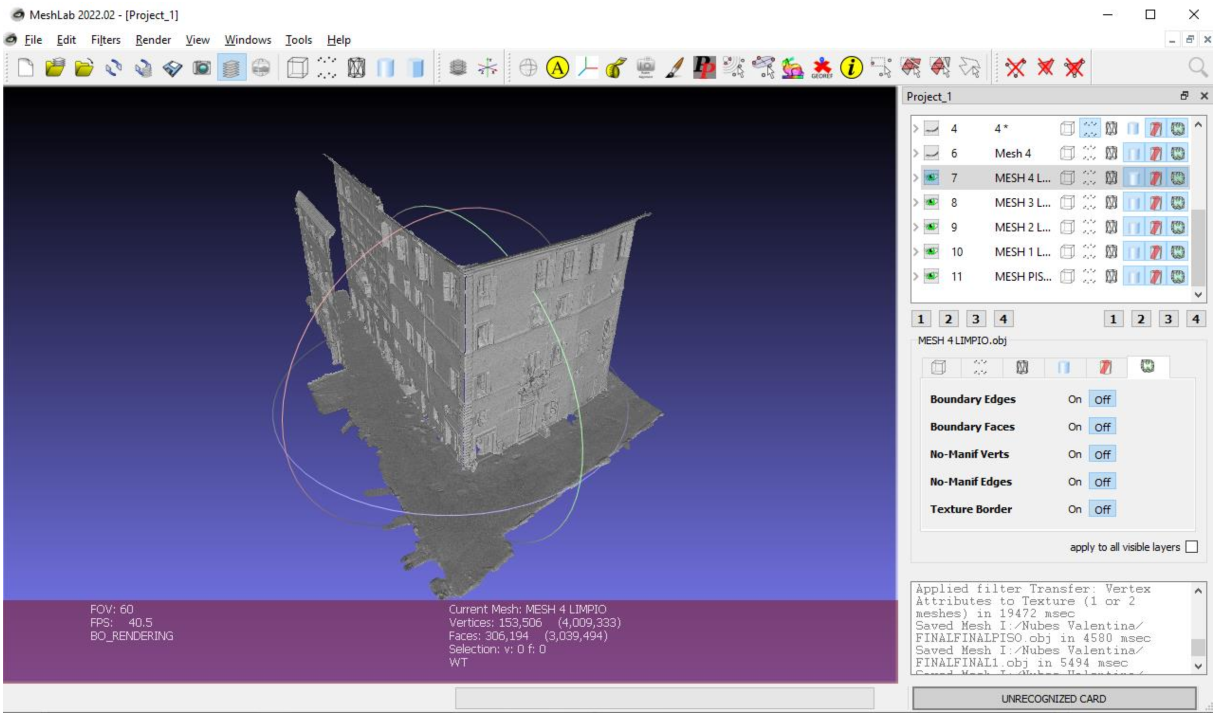


**Figure 5.** Digital model in MeshLab. Source: Author's elaboration.

## 4. Results

A model was obtained in ArcGIS where the facades are visualised as segmented 3D mesh elements containing the information from the sheets. This information can be easily visualised and modified interoperably as required.

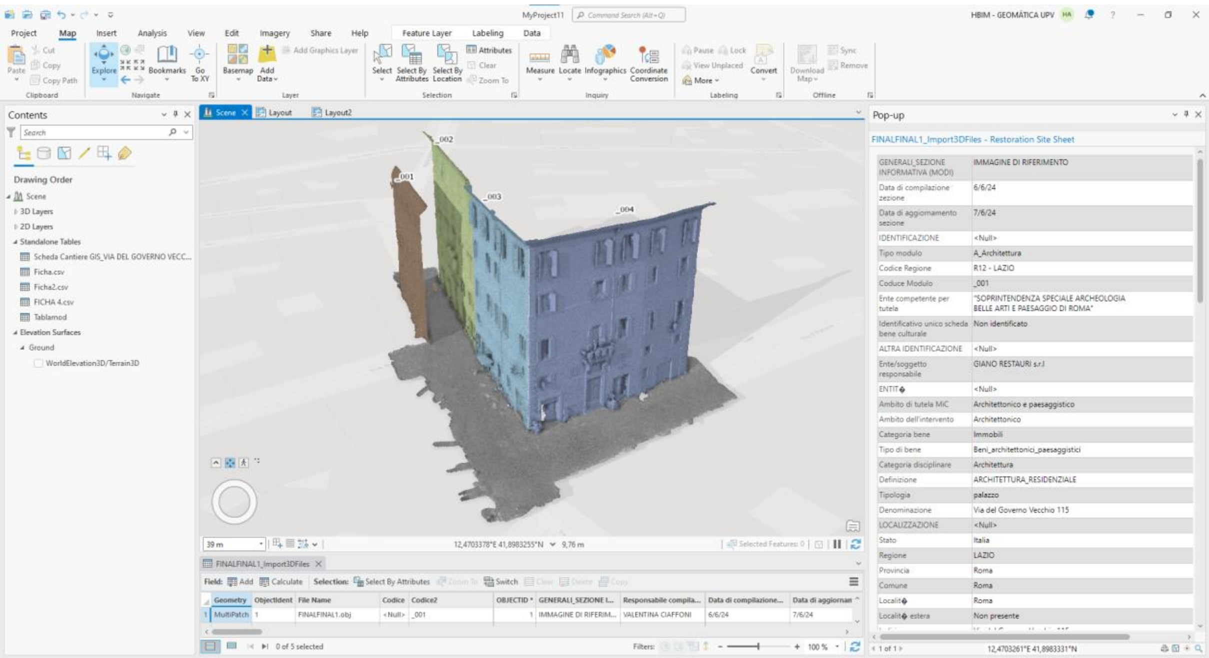

**Figure 6.** Visualisation of the collaborative model in ArcGIS. The Restoration Site Sheet is linked to the collaborative model on the right side. Source: Author's elaboration.


**Figure 7.** The collaborative model in ArcGIS. Source: Author's elaboration.

## 5. Conclusions

The application to the case study has demonstrated the validity of the developed methodology. The model allows for the collection and visualisation of documentation as planned in the preliminary phase. The modelling method has several advantages: it is quick, cost-effective, and easy to visualise. These elements are fundamental to making the workflow applicable to heritage conservation sites. Furthermore, this methodology enables the use of data collected by private companies during surveys, ensuring the cost-effectiveness of the operation.

The research also highlighted that collecting coloured point clouds could be an improvement, as it preserves the chromatic data of the buildings, which is significant for the conservation of historic building surfaces. Additionally, the potential integration of this methodology with photogrammetry is noted, as it allows for preserving the "image" and the state of surface degradation over time. Moreover, a photogrammetric survey enables the comparison of the pre-intervention and post-intervention states to evaluate the conservation, which, being strongly linked to a certain historical period, must be open to discussion. It is essential to geolocate the intervention sites to place the information within the specific context of interest. This way, the developed information model can be associated with other territorial geographic systems to control and manage heritage interventions.

Additionally, it would be beneficial to test the use of the methodology during the ongoing work to verify the actual collaborative nature of the tool; in this initial test, the building model was used only as a repository without real-time data exchange. One of the current limitations of using point clouds is the software constraints, as these files are extremely large and not usable by all users on any device. Using a mesh, as in this case, partially resolves the problem. Still, it is important to continue working in this direction to make these systems suitable for the needs of sector operators. Furthermore, the choice to use ArcGIS software imposes a limitation. The program offers a good level of visualisation and the ability to share it online, which is better than other attempts in this experiment. Nonetheless, it would be preferable to use open-source software. In conclusion, the research has shown that the development of such a digital information model is a project in itself, whose objectives and characteristics must be defined in advance based on the type of intervention to be carried out and, above all, the intrinsic characteristics of the building to be conserved.

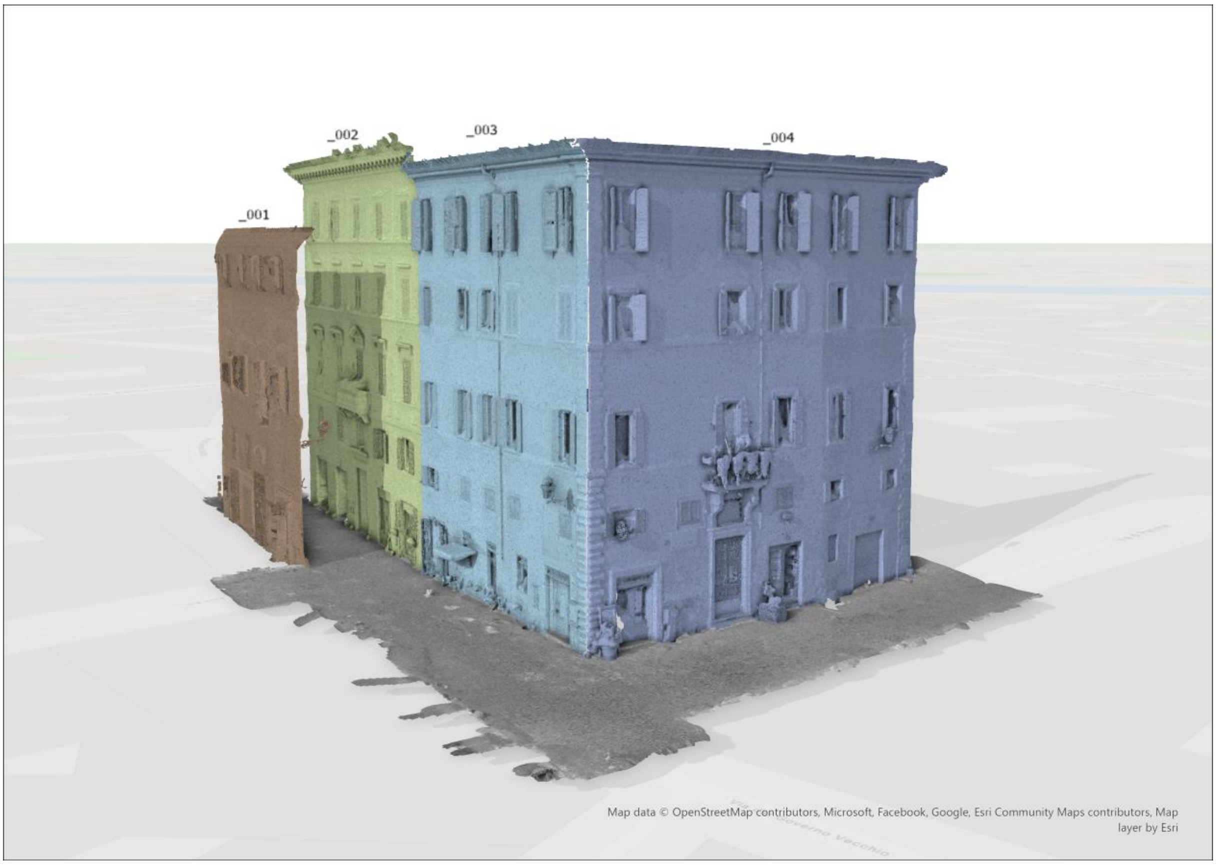


**Figure 8.** The collaborative model in ArcGIS with the segmented facades. Source: Author’s elaboration.

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# Digital technologies to improve public fruition in Heritage sites through cultural significances and perception analysis

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***Abstract***

*In the field of Cultural Heritage, digital documentation is currently a necessity to manage monitoring and maintenance actions, as an essential support for thorough analyses. The use of digital surveying techniques and 3D models has a strategic relevance in the conservation and mitigation process, considering possible risks and natural hazards. In this framework, the paper addresses documentation as a tool of knowledge (digital and not), considering it as essential in the initial phase of construction of urban and landscape models and capable of giving the bases for in-depth analyses and the prefiguration of strategies for regeneration. Starting from historical maps, the aim is to integrate different analysis methods through the use of digital models, which more and more have the capacity to include several data simultaneously (urban, territorial, social, cultural). The research is part of the iNEST project (Interconnected Nord-Est Innovation Ecosystem), an interdisciplinary study which aims at extending the beneficial effects of digitalisation to the areas of "Nord-Est" Italy, also through digital data as a cross-domain analysis tool, founded by PNRR (Piano Nazionale Ripresa Resilienza). Focusing on the case study of the historical city and landscape of Piazzola sul Brenta, the research is aimed at understanding the dynamics between the natural environment, the historical built one and the inhabitants, bringing together psycho-physical factors linked to the physical space and the perception of the place. The main topics of research exploration include new strategies to access, discover, and understand cultural assets leveraging on digital technologies and digital data management, applications for small cultural sites also focusing on social aspects linked to heritage significances, and possible new perspectives in the use of digital documentation for the management of public use of heritage.*

***Keywords:*** *cultural heritage, digital documentation, historic landscapes management, perception analysis, heritage awareness, 3D models.*

## 1. Introduction

In the field of Cultural Heritage, the use of digital documentation has become essential for effectively managing monitoring and maintenance endeavours. It provides a comprehensive and accessible means of capturing complex details and characteristics of cultural artifacts, sites, and monuments. Through digital technologies such as high-resolution imaging, 3D scanning, and Geographic Information Systems (GIS), it is now possible to develop detailed records that not only document the current state of heritage assets but also facilitate ongoing monitoring and preservation efforts. Digital repositories and databases give the possibility to monitor changes over time, assess deterioration, and plan conservation interventions. Overall, in the field of Cultural Heritage, digital documentation serves as an essential tool for managing, monitoring, and maintenance actions, ensuring the preservation and safeguarding of our Cultural Heritage for future generations.

Digital documentation plays a crucial role in disaster preparedness and response for cultural heritage sites. By creating digital backups of cultural assets, institutions can mitigate the risk of permanent loss in the event of natural disasters, conflicts, or other emergencies. Digital documentation also facilitates collaborative conservation efforts by enabling the sharing of data and resources among institutions and stakeholders worldwide (Bonazza et al., 2018). Moreover, Cultural Heritage is a crucial identity element of cities, sites and landscapes, and digital technologies can be an extremely useful tool for supporting Heritage interpretation and analysis of significances, providing new data to strengthen awareness, and accessibility and enhance fruition experiences (Giovannini et al., 2021; Münster et al., 2021).

Using documentation as a tool to acquire knowledge should be the initial stage in constructing models of urban and landscape environments, facilitating detailed analyses and the anticipation of strategies for regeneration. Alongside traditional methods of representing and describing on a territorial scale (such as planimetric representations and cartography), the advancement of 3D surveying technologies and modelling systems opens up new methodologies for understanding and representing the landscape. Accurate documentation as a tool of knowledge, both digital and not, is essential in the initial phase of the construction of urban and landscape models and is able to provide the basis for in-depth analysis and the prefiguration of strategies for regeneration and mitigation. This concept extends beyond the mere collection of information: Documentation, whether "analogue" or digital, plays a crucial role in capturing and preserving the complexity and richness of our urban and landscape settings.

Besides serving as a tool for acquiring knowledge, documentation also acts as a means for the preservation of historical and cultural memory. Through the accurate and detailed recording of structures, monuments, and landscape contexts, we are able to preserve tangible evidence of the past for future generations. This is particularly important in a rapidly changing world, where many urban areas and landscapes are undergoing significant changes due to population growth, urbanisation and climate change. It is important to remember that documentation (and its interpretation) is not limited to the preservation of existing heritage but plays an active role in planning and decision-making for future urban and landscape development. The collected information provides a solid foundation for the design of sustainable and culturally sensitive urban regeneration interventions. This approach allows to develop strategies that respect the historical and cultural identity of a place while ensuring harmonious and environmentally friendly urban growth (Contin et al., 2014).

Since this research examines the correlation between individuals and historical buildings and sites located within the case study chosen, to investigate whether residing in a small city with a rich historical backdrop significantly influences the psychological and physical well-being of inhabitants, the notion of "place attachment" has a central role in the analysis. In this regard, place identity has been considered as the way in which a place contributes to the identity of a person or people (Proshansky, 1983) and the composites of its characteristic features (Relph, 1976). The concept of place identity was explored as the manner in which a place contributes to an individual's or community's sense of self, encompassing its defining characteristics and features. Within an urban setting, the study posited that identity is shaped to varying degrees by the elements, activities, and events occurring within the environment. Digital representations and city models allow to integrate various types of data (urban, territorial, social, cultural) (Campi et al., 2022) and give the possibility to consider spaces in their whole entire complexity.

Additionally, digital documentation enables the dissemination of Cultural Heritage information to a wider audience through online platforms and virtual exhibitions, fostering greater public engagement and appreciation for heritage conservation efforts. Digital documentation in the field of Cultural Heritage allows for the dissemination of valuable information to a broader audience through online platforms and virtual exhibitions. Traditionally, access to cultural heritage artifacts and sites has been limited to physical visits, which may be constrained by factors such as geographical distance, travel costs, or time constraints. However, digital documentation offers possible solutions to these limitations by providing virtual access to heritage resources from anywhere in the world with an internet connection. This increased accessibility fosters greater public engagement with cultural heritage and encourages a broader appreciation for heritage conservation efforts, especially for those "minor" sites that usually struggle to reach a wider audience (Maietti, 2023). The potential of digital technologies also makes it possible to enhance the physical enjoyment of cultural heritage through applications that facilitate or stimulate cultural routes or make people discover previously unknown places. Moreover, people who may not have had the opportunity to visit heritage sites in person can now access them virtually, gaining insights into their historical, artistic, and cultural significance. This virtual access also extends to individuals with disabilities or mobility issues, ensuring that Cultural Heritage remains inclusive and accessible to all.

Furthermore, digital documentation facilitates educational initiatives and research collaborations by providing researchers, students, and educators with online resources and tools for studying and analysing Cultural Heritage materials. Digital archives, databases, and online repositories enable the sharing of data and research findings, fostering collaboration and knowledge exchange within the global cultural heritage community.

Overall, digital documentation plays a vital role in democratising access to cultural heritage and promoting public engagement and appreciation for heritage conservation efforts. By leveraging digital technologies to make cultural heritage resources more accessible and interactive, institutions can inspire curiosity, learning, and preservation of our shared cultural heritage for future generations.

The first article of the document by the European Commission entitled “Commission Recommendation of 10.11.2021 on a common European data space for cultural heritage” states that “Digital technologies have been changing our lives at a fast pace, providing new opportunities for society, including cultural heritage institutions. Digital technologies offer cultural heritage institutions more effective tools with which they can digitise cultural heritage assets and reach broader audiences. This creates more ways for the public to access, discover, explore and enjoy cultural assets and creates more possibilities for reusing cultural assets for innovative and creative services and products in various sectors, such as other cultural and creative sectors, as well as tourism”. And, article 8 states that “The development of advanced digital technologies, such as 3D, artificial intelligence, machine learning, cloud computing, data technologies, virtual reality and augmented reality, has brought unprecedented opportunities for digitisation, online access and digital preservation. Advanced digital technologies lead to more efficient processes (e.g. automated generation of metadata, knowledge extraction, automated translation, text recognition by optical character recognition systems) and higher-quality content. They allow innovative forms of artistic creation while opening up new ways of digitally engaging with and enjoying cultural content through co-curation, co-design and crowdsourcing, empowering public participation […]”. This document is particularly significant in revealing how digitisation is creating unprecedented opportunities for Cultural Heritage while emphasising the urgency of digitally preserve heritage assets, improving accessibility, fostering the reuse of contents, including previously digitised assets, and providing solutions for processing, accessing and managing datasets (Commission proposes a common European data space for cultural heritage, n.d.).

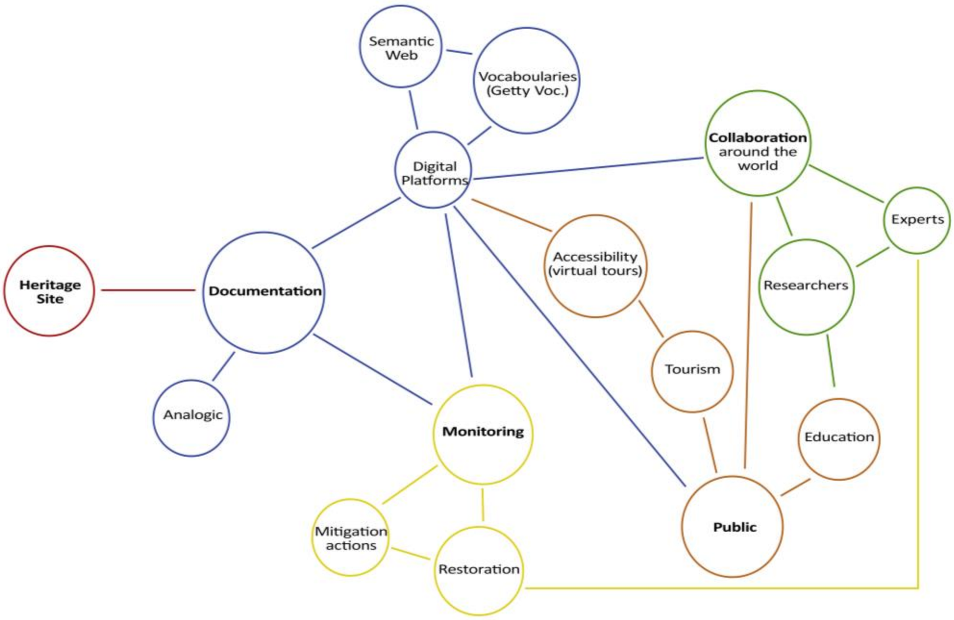


**Figure 1.** The importance of Digital Documentation in the field of Cultural Heritage (image of the authors).

## 2. Aims and objective

This research seeks to comprehend the relationships among the natural surroundings, historical architecture, and inhabitants, considering the psycho-physical elements associated with the physical space and people's perception of it. Key areas of research exploration involve devising fresh approaches to accessing, uncovering, and comprehending cultural resources through digital technologies and data management. It also examines applications tailored for smaller cultural sites, with attention to social aspects related to heritage significance, alongside potential novel perspectives on employing digital documentation to manage public usage of heritage sites. Focusing on the case study of the historical city and landscape of Piazzola sul Brenta, in the province of Padua, in the north-east of Italy, this research integrates different analysis methods in order to have a proper base for digital models, which more and more have the capacity to include several data simultaneously (urban, territorial, social, cultural), and since this research is concerned with investigating such a huge subject which interferes with so many factors, this characteristic is a fundamental element. By integrating different datasets into digital models, it is possible to reach a comprehensive understanding of the complex dynamics within urban environments. For example, it is possible to analyse how social factors intersect with spatial configurations to influence community dynamics or assess how Cultural Heritage assets contribute to the overall identity of a city.

Furthermore, the ability to incorporate multiple types of data into digital models enables more holistic assessments and decision-making processes. In the field of urban planning, these complex models can be used to simulate different scenarios and evaluate the potential impacts of various interventions or policies on urban, social, and cultural dynamics. This facilitates more informed and sustainable urban development strategies that take into account a broader range of factors and stakeholders' perspectives.

## 3. Methods and procedure

Examining the case of Piazzola sul Brenta, a small town in the Veneto region, a territorial examination was developed to explore the interplay between natural and man-made environments.

 

The historical and naturalistic context of Piazzola sul Brenta represents a particularly significant ensemble of cultural and natural heritage gathered in a small historical centre, making it a representative case study of many settings, not only in Italy, where historical evolution, the most iconic monuments - such as the Villa Camerini-Contarini - and territorial ones, such as the river Brenta, provide an ideal research scenario to investigate the role of digital tools for knowledge and enhancement, and to analyse intangible significances and emotional perceptions.

In this context, where space includes both physical dimensions and the perceptions of those inhabiting it, adopting an interdisciplinary approach is crucial. Consequently, the initial phase of spatial analysis focused on juxtaposing current conditions in the studied area with historical maps. This method of landscape analysis not only facilitates understanding the historical relationships between built and natural surroundings but also sheds light on how human actions have influenced the landscape positively and may continue to do so in the future, rectifying past errors or addressing issues stemming from previous experiences.

**Figure 2.** Villa Camerini-Contarini and the portici of the square in front of the Villa (images of the authors, from ProLoco Piazzola sul Brenta, from Gallery of the Municipality of Piazzola sul Brenta).

The initial stage of the research started with a comprehensive review of historical maps to gain understanding into the development of both the natural and built landscapes. During this preliminary investigation, particular attention was focused to studying the historical changes of the Brenta riverbed and Villa Camerini-Contarini. The research started by examining historical maps sourced from the State Archive of Venice, specifically focusing on those illustrating the Villa and the interaction between the Villa and the Brenta River's course. By closely analyzing primarily two maps and overlaying them onto the current landscape, noticeable alterations in the Brenta River's curvature were observed. The analysis revealed a deliberate modification in the river's trajectory, characterized by the creation of a diversion intended to facilitate field irrigation.

Exploring the human-made spaces within Piazzola sul Brenta's territorial boundaries, previous studies uncovered the existence of Roman axes traversing the village, although gradually disappearing over time. Additionally, an evaluation of Piazzola's urban layout was conducted, juxtaposing it with the orientation of the Roman axes. However, no correlation was identified between them. This preliminary examination highlighted the historical significance of Villa Contarini, particularly revealing that the village's urban configuration deviates from the Roman axes and, instead, aligns with the grid influenced by the orientation of Villa Contarini. By examining those historical maps, insights were gained into the alterations of the natural landscape and whether these changes were attributed to human activities. Utilizing historical maps as a layered document, the study delved into the evolution of the Brenta River, a pivotal natural feature in this small urban context, and the architectural structure that significantly defines the area's identity. Specifically, this examination emphasized the significant role of Villa

Contarini in shaping Piazzola, revealing that the entire urban structure revolves around the orientation of the Villa. This departure from the ancient Roman axes highlights the substantial influence of Villa Contarini on molding the spatial arrangement of the town.

During the comparison between historical maps and the contemporary state of the area, a significant inquiry emerged concerning its boundaries. Given that Piazzola sul Brenta is a small urban enclave nestled within the Venetian countryside, the demarcation between the city and the rural landscape is ambiguous. As buildings gradually dissipate, blending with the contours of the terrain and reinforcing its forms, the delineation between urban and rural becomes blurred. This issue holds considerable importance in a study focused on the dynamic interplay among human beings, environment, and nature. Indeed, boundaries can be either natural or man-made, yet they can also be perceived subjectively. In his very well known work "The Image of the City," Kevin Lynch explores how individuals perceive urban environments, investigating the processes by which people develop impressions and recollections of a city's layout, encompassing both its tangible and abstract boundaries. A central aspect of his examination is the notion of "boundary perception" and the significance of boundaries in shaping coherent and comprehensible mental representations of the urban landscape. A central topic in this research, individuals construct their cognitive maps of urban spaces through five key components known as "image elements." These elements, comprising paths, edges, districts, nodes, and landmarks, collectively contribute to the cognitive mapping of the city. Specifically, the concept of 'edges' assumes particular importance in the perception of boundaries within this cognitive mapping framework. Therefore, recognizable and clear boundaries influence the orientation that the individual has of the city, avoiding a sense of loss which would interfere with the perception that inhabitants have of the space. While clarity and legibility are not the sole defining features of a visually appealing city, Lynch observes, they become particularly significant when assessing the urban environment in terms of its size, temporality, and intricacy. To comprehend this, we must view the city not merely as an entity but rather through the lens of how its residents perceive it. The recognition of these boundaries, whether tangible or intangible, contributes to the formation of a unified mental representation of the city, impacting individuals' capacity to navigate and engage with their surroundings. This mental image subsequently informs the behaviors and routines adopted by citizens in their everyday interactions within urban environments (Lynch, 1964).

During the research, physical limits and perceived but also natural limits were identified. Furthermore, the boundaries of the city and the municipal one were compared, noting differences and inconsistencies with what is the surrounding natural landscape. The traces drawn on the landscape and the comparison of them with the historical maps were fundamental elements to carry out an in-depth analysis, necessary to understand a place with such a historical stratification.

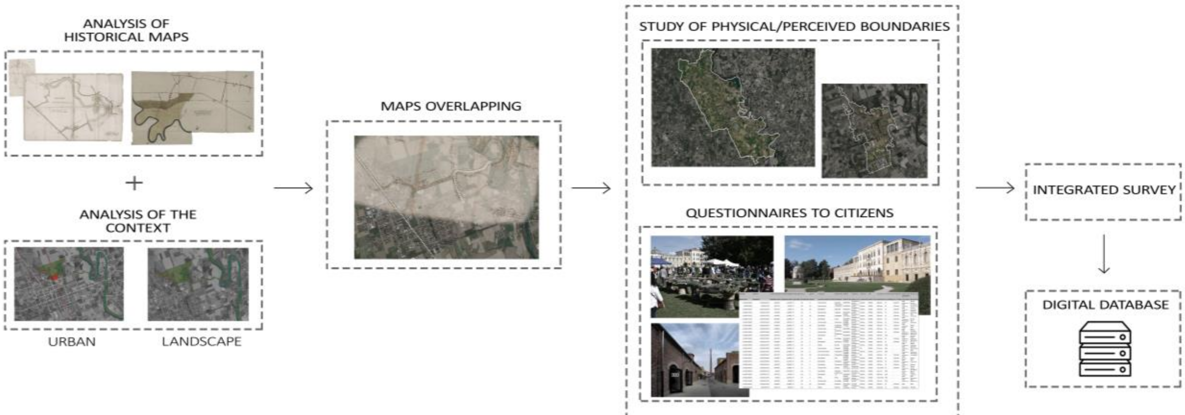


**Figure 3.** Documentation and analysis are the fundamental first step. Methodology scheme of the research.

 

## 4. Results

Preliminary outcomes of the research are a systematisation of direct and indirect sources, the comparison of which aims to search for new perspectives of analysis for knowledge and for the development of new strategies for understanding, awareness and thus conservation of historic centres. The integration of different documentation methodologies highlighs the essential role of merging different "layers" of knowledge, including physical and immaterial elements, using the 2D digitization, and creating the essential basis for the application of 3D surveying tools. Careful survey design and planning, when using "quantitative" surveying technologies such as these tools are, is indeed the core of the critical approach, which must always be applied, particularly when investigating Cultural Heritage. This critical approach opens up new perspectives in the field of digitisation, focusing on which data can be brought into the "system" of knowledge to answer new questions.

In this case, the interdisciplinary iNEST project (iNEST – Interconnected Nord-Est Innovation Ecosystem, s.d.) focuses on the human being and its well-being in experiencing natural and built environments, analysing the relationships between psycho-physical and perceptual elements with places in their current conformation and through the analysis of changes over time. With these intentions, citizens were provided with a questionnaire in which they were asked to identify three places that they thought were significant for the city's identity. Demonstrating the clear legibility of the city, the result of recognizable landmarks and a strong social identity in the place, citizens recognized around ten places (natural and artificial) as identity elements. Among these obviously Villa Contarini-Camerini was listed, as was its Park, the Brenta river, the city's Cathedral, the square in front of Villa Contarini-Camerini (in which various city activities take place) and others.

The next steps of the research involve the digital survey of the most significant contexts of the Piazzola sul Brenta case study in order to develop three-dimensional models that have the ability to collect different data, aggregating intangible perceptual levels to the digital representation of physical places.

## 5. Conclusions

Finally, digital documentation has the potential to democratise access to knowledge and public participation in urban planning and landscape conservation. Through online platforms and interactive tools, the information collected can be shared and accessible to a wide range of stakeholders, enabling a wider and more inclusive involvement in defining the future of our cities and landscapes. In short, documentation is a vital bridge between the past, present and future of our urban communities and natural environments. Through its role in collecting, storing and using information, documentation helps us understand, protect and responsibly shape the world around us. One of the aims of the research is to achieve effective utilisation of the digital data acquired, moving digital documentation and modeling out of a static and exclusive domain - reserved for those who make digital models or for experts in the field - and pursuing openness towards concrete and practical use.

There already are studies testifying how new technologies have the ability to "revolutionize" research and teaching by implementing collaborative theory and practice in the field of Digital Humanities (Giordano et al., 2022), embracing the analysis of urban systems with a new methodology in the interpretation of cultural sites complexities. An additional challenge for the future concerns data integration, finding new ways for merging information and communication technologies and digitization, with people's well-being, assuming the concept of "care" as pivotal (care for people, for the environment, for heritage assets, and care in managing new tools to guide future transformations of the territory), where citizens have a central role. Nevertheless, from a social point of view, the promotion by digital media of heritage sites not well know but evidence of cultural reality worthy of attention, can arise a social awareness and sense of belonging by local communities.

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# 400 Years of Cultural Legacy: Research and dissemination of the heritage of a historic building during a fifteen-year period

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**Abstract**

*This communication aims to showcase the research and dissemination work carried out over fifteen years on a historically significant historic building celebrating its 400th anniversary this year.*

*The methodological approach ranged from extensive data collection to obtain an accurate digital twin of the construction, modelling key architectural elements, to creating models using 3D printing technology, enabling a tangible physical representation.*

*Furthermore, the results have been widely disseminated in various media and formats. These findings have significantly enriched knowledge about this historical monument, providing new perspectives and facilitating its local and global valorisation. Likewise, they have contributed to preserving and promoting their cultural legacy for present and future generations.*

***Keywords:** heritage, dissemination, Cultural Legacy, research.*

## 1. Introduction

Vistabella del Maestrazgo is a small mountain town located 1250 meters above sea level in Castellon, Valencian Community, Spain. The municipality belonged to the "Reino de Valencia" during the Middle and Modern Ages. In this small municipality with medieval roots, there is an important building, its parish church, the church of "Nuestra Señora de la Asunción". The building was built outside the medieval walls in the early seventeenth century (Figure 1). This is one of the finest Renaissance churches in Valencian architecture and was declared a Cultural Heritage with the category of the monument on September 28th 2007.

**Figure 1.** Construction site. Source: Mañez (2014).

Legacy, synonymous with inheritance, encompasses tangible and intangible things passed on to one or more persons. We obtain a more precise definition by adding the term "cultural" to legacy. Cultural inheritance can be considered as inheritance related to art, intellect, and education. This transmission should ideally contribute to the evolution and education of society.

There is no doubt that when we speak of a religious building, we deal with transmitting religious manifestations and the religious legacy. This legacy makes it possible to preserve and maintain spiritual and social values.

Therefore, the cultural legacy related to religious architectural heritage is invaluable. It is a symbol of cultural and spiritual identity. In addition to being extraordinary construction and artistic landmarks, these buildings have hosted traditions and events for years, brought people together, and given them a sense of belonging and rootedness to their community. These structures have witnessed the history, culture, faith, and communities that built them and continue to preserve them (Viñals & López-González, 2022).

In terms of preservation, religious architectural heritage presents unique challenges due to its age and often lacks financial resources for its maintenance. However, its conservation is crucial to ensure that future generations can learn from these architectural, cultural, and spiritual treasures.

The rules and principles for preserving monuments have been numerous and have evolved from the Renaissance to contemporary UNESCO initiatives.

Interest in the preservation and study of classical architectural heritage emerged during the Renaissance. In the 19th century, the figure of Viollet-le-Duc in France emphasised the importance of authenticity in restoration. In the 20th century, the "Carta del Restauro" promoted minimal intervention in heritage conservation. Riegl (Riegl, 1987), also in the 20th century, emphasised the importance of valuing monuments for their historical and cultural significance and preserving these buildings for future generations. The UNESCO World Heritage Lists and recommendations for conserving cultural and natural sites are also fundamental. In 2018, the European Year of Cultural Heritage was declared, highlighting that European cultural heritage is not only a legacy of the past but also an indispensable resource for our future, given its unquestionable educational and social value, its considerable economic potential, as well as its important dimension in international cooperation (Ministerio de Cultura, 2018).

All these norms and principles, influenced by key figures and movements throughout history, have contributed to establishing international standards for preserving architectural and cultural heritage.

Considering all of the above, it can be affirmed that the Vistabella parish church represents a significant cultural legacy not only for the village itself but also for the province level. This church symbolises faith and devotion to the local community and embodies a rich architectural and cultural history spanning centuries. Its importance must transcend local borders and be recognised both regionally and globally.

## 2. Aims and objectives

The communication aims to show the research and dissemination work carried out over fifteen years in a building of great historical importance, celebrating its 400th anniversary this year. In addition, an analysis of the impact of these works, both academically and socially, is carried out.

## 3. Procedure

The various activities carried out during the last fifteen years are listed below. They have followed the three fundamental pillars of this type of study: conducting architectural surveys, preparing documents that objectively and rigorously represent the buildings, and disseminating the results.

### 3.1. Precedents

Initially, the research focused on preparing a doctoral thesis from 2010 to 2014 (Mañez, 2014). The thesis was framed in the conservation and enhancement of architectural heritage. The aim was to study renaissance religious architecture in Castellón, focusing on the parish church of Vistabella del Maestrazgo and to prepare a graphic and written document that would document the building and serve as a reference for future work. At the same time, other buildings with similar characteristics were studied.

The research was justified by the importance of the temple within the Valencian Renaissance architectural context and the lack of previous exhaustive studies. Moreover, despite the oblivion that Renaissance architecture had suffered in the lands of Castellón, recognised authors such as Elías Tormo (Tormo, 1923), Fernando Chueca (Chueca, 1953), José Camón (Camón, 1984), and Joaquín Bérchez (Bérchez,1994) had highlighted the exceptional nature of the Vistabella parish church in their books. However, until then, only superficial descriptions, small articles by local authors, some photographs, and two restoration projects were available.

### 3.2. PhD thesis completion

The thesis focused on the period from the mid-16th century to the beginning of the 17th century, characterised by the transition from Gothic to Baroque. Renaissance ornamental and constructive solutions were combined with Gothic elements, such as ribbed vaults, during this architectural period. In addition, the study delved into Renaissance religious architecture in the province of Castellón, with a specific focus on the Vistabella del Maestrazgo Parish Church (Figure 2), to prepare a document, both graphic and written, that testifies the building and served as a reference for future work. In parallel, other buildings with similar characteristics were analysed.

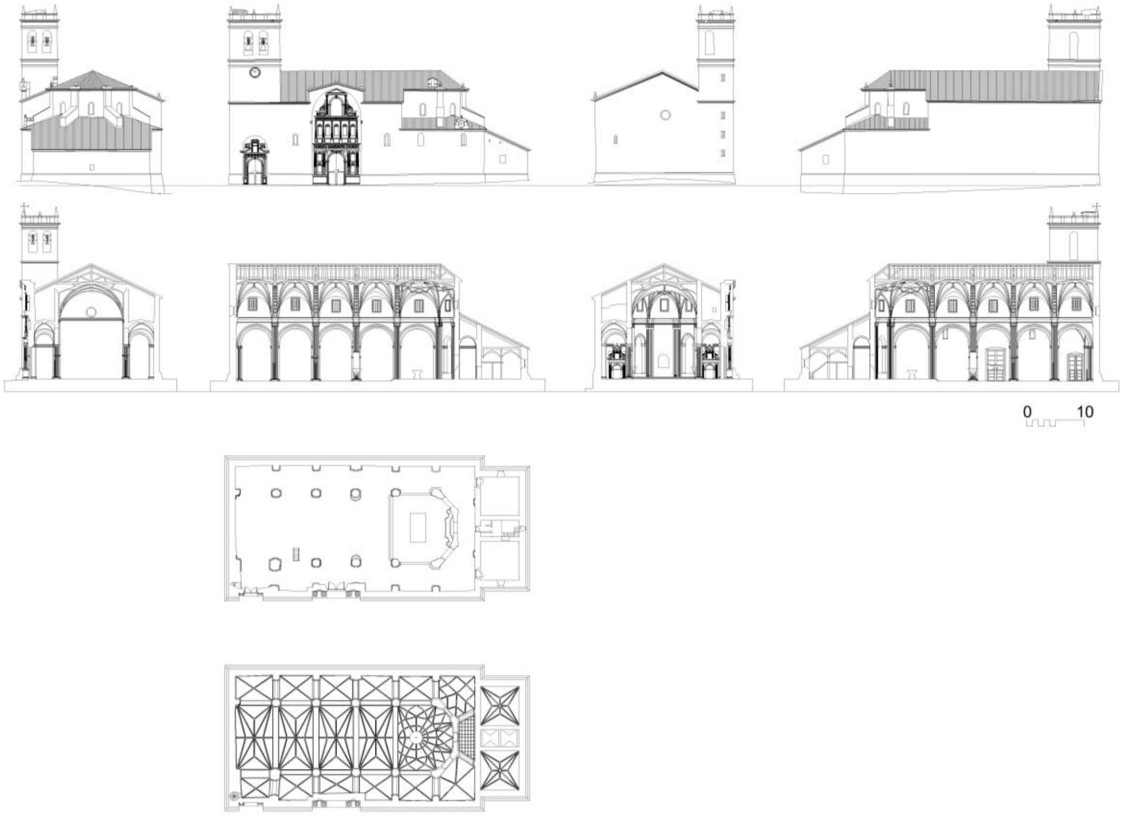


**Figure 2.** The church of "Nuestra Señora de la Asunción" Source: Mañez (2014).

#### *3.2.1. PhD thesis methodology*

For the thesis, a deep architectural survey was carried out. This consisted of a mixed information capture system comprising three activities. In the first, a large number of archives and publications were consulted. In the second, an exhaustive graphic survey was carried out with a 3D scanner, which provided a digital twin of the construction. This allowed for precise building planimetry and the creation of physical and digital models. Finally, in the third activity, a comparison was made with buildings of the same style and period.

It is important to highlight that, of all the activities carried out, the graphic survey was the activity that provided the most data for the development of the work, providing a very precise and previously unpublished clone of the construction.

#### *3.2.2. PhD thesis presentation*

The PhD thesis, supervised by Dr Concepción López and Dr Fernando Fargueta, was defended on March 21, 2014, at the Universitat Politècnica de València (UPV). The PhD thesis received an outstanding grade from the examining committee. This milestone represented years of research, analysis, and intense work, culminating in Ph.D. studies. A thesis review was published in the journal EGA n.24 in 2014. The following year, this institution was awarded the extraordinary Ph.D. prize.

### 3.3. Academic publications

Detailed documentation of the research findings has been conducted through numerous reports, conferences, scientific articles, and book chapters. This has facilitated disseminating research results, knowledge, and experiences to the academic community and the general public. These activities have contributed to the advancement of knowledge.

### 3.4. Research projects

Three research projects were undertaken as part of the research.

The project "El Renacimiento: Impronta arquitectónica en la provincia de Castellón. Huellas, rastros, trazas y vestigios" was conducted from 2016 to 2018 and funded by the Universitat Jaume I. It aimed to investigate Renaissance buildings in rural areas of Castellón, providing previously unpublished documentation and creating accessible Renaissance routes. These routes included tactile and tangible models, allowing people with visual impairments to experience the heritage through tactile exploration. This project was built upon the doctoral thesis on Renaissance religious architecture in Vistabella del Maestrazgo and additional research on integrating three-dimensional symbols in tactile maps by researcher Jaume Gual Ortí.

The project "Estudio de técnicas y materiales de prototipado rápido para la obtención de relieves táctiles permanentes del patrimonio arquitectónico aptos para exteriores y orientados a personas con discapacidad visual", was financed by the Generalitat Valenciana. The objective of the project was to investigate the potential of rapid prototyping systems to produce haptic reliefs of architectural heritage suitable for outdoor use.

### 3.5. Publication on social networks

Dissemination activities have been conducted to share the research findings with a broader audience, utilising social media platforms. An email account was set up, along with creating a website, a Facebook page, and an Instagram account.

Email account: arquitecturarenacentista@uji.es
Website: www.arquitecturarenacentista.uji.es
Facebook page: www.arquitectura renacentista.com/Facebook
Instagram account: www.instagram.com/arquitecturarenacentista/

### 3.6. Making physical and tactile models

Over time, elements ranging from the building's floor plan to vaults or facades have been modelled and printed using 3D printers (Figure 3) and a numerical control milling machine (Figure 4).

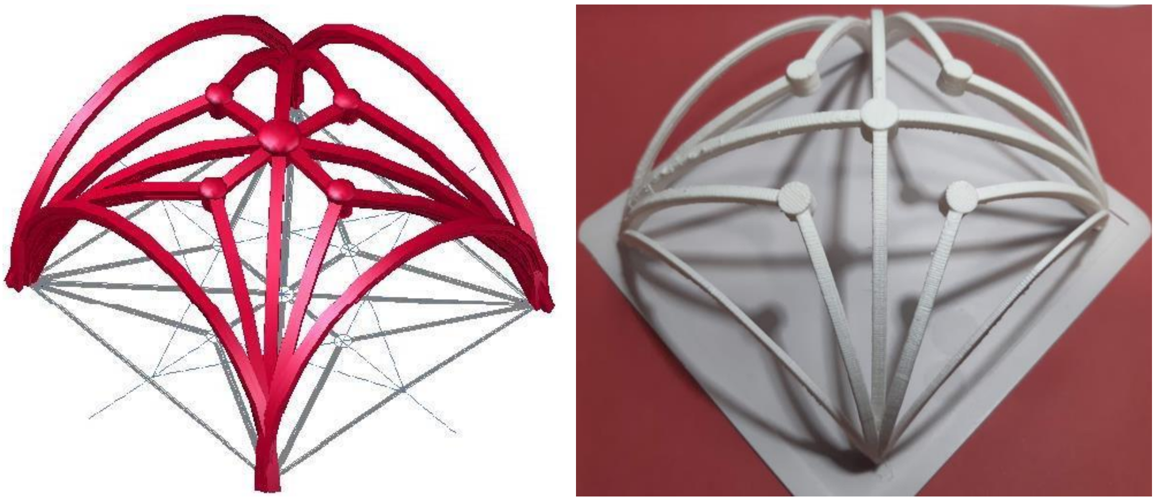

**Figure 3.** Model of a vault and 3D printed model. Source: Mañez, MJ. & Garfella, J. (2024)

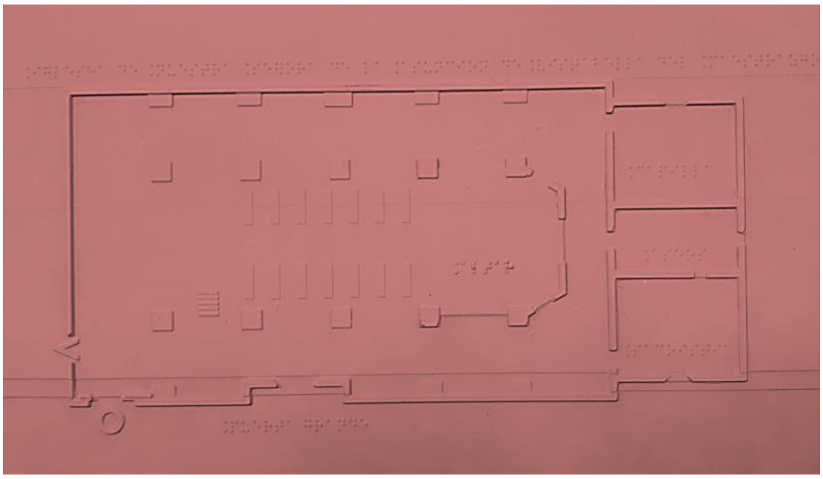

**Figure 4.** Tactile map. Source: Gual, J. (2020)

### 3.7. Teaching activities

Through the teaching aspect, the research findings have been utilised to deliver classes and cultivate students' interest in architectural heritage. Moreover, a significant number of students have received training in these disciplines through scholarships or internships within the ARDIPA research group. This has played a role in fostering the development of skills and competencies necessary for research and work across various disciplines. In addition, several final degree projects have been developed. Notable examples include "Estudio arquitectónico, constructivo y modelado virtual del palacio castillo de Betxi" in 2014 and "Estudio y representación gráfica de la Iglesia Parroquial de la Asunción de Nuestra Señora de Benlloch" in 2022.

### 3.8. 400 years exhibition

This year, the Vistabella monument is celebrated 400 years since its construction. To commemorate this milestone, panels and models are being created for a permanent exhibition. In addition, there are plans to host a conference in August. The objective is to make all inhabitants and visitors aware of the importance of this monument, which has been a witness to numerous social, political, economic, and cultural changes over the past four centuries.

## 4. Results

In this section, a distinction is made between results or impacts that are academically focused, such as research advances, academic publications or educational achievements, and those that relate to social aspects, such as community influence.

### 4.1. Academic results or impacts

#### *4.1.1. PhD thesis results*

After conducting research in over 20 documentary and photographic archives, consulting around 400 publications, and conducting a thorough graphic survey, 28 buildings were identified. These included churches, hermitages, and chapels constructed in the Castellón province during the study period. Additionally, connections were established with Gothic-Renaissance temples in the Teruel and Tarragona provinces.

The research contextualised the building and analysed its formal, morphological, constructive, and artistic aspects. Details were discovered about the French architect Joan Tell, emphasising his French, gothic and Renaissance influence on the temple's design despite using the Valencian span as a unit of measurement. The author's habit of connecting the chapels between buttresses with large semicircular arches was also noted, creating the impression of side naves. This aligned with the Jesuit model initiated in “Il Gesú” in Rome, designed by Vignola and subsequently followed by a large number of Baroque churches.

The church, constructed between 1604 and 1624, exhibits distinct Renaissance characteristics such as symmetry, proportion, modulation, correct distribution, correspondence of parts, and the sizing of elements about the whole and its module. Notable features include separate doorways for men and women, a retablo-façade, and strategically positioned windows designed to admit sunlight during religious festivals. For instance, on the 15th of August, sunlight illuminates the altar in the afternoon. The bell tower, standing at 29.48 meters, also dominates the urban landscape.

The retable façade is divided into three sections following the Doric, ionic, and Corinthian orders, influenced by the main altarpiece of the “El Escorial” basilica, which transmitted the dogmas of the Catholic Church promulgated by the Council of Trent. A potential connection was also identified between this architectural element and the master Joan Rigor and the church of “Natividad” in Andorra (Teruel).

The building occupies a surface area of 1209 m2, similar to other contemporary churches. However, its distinction as a freestanding structure, with a single roof encompassing both the main nave and the side chapels at the same height and the fact that the side facade serves as the main facade enhances its grandeur.

*4.1.2. Academic publications*

The various conferences, scientific articles, book chapters, and national and international significance conferences are listed below, along with a synthesis of the most relevant results. The publications are fully referenced in the biography.

**Table 1.** Academic publications

| Year | Title | Relevant results |
|---|---|---|
| **2010** | The parish church of Nuestra Señora de la Asunción of Vistabella del Maestrazgo in Castellón. APEGA 2010 | The first results of the research are presented |
| **2012** | The parish church of “San Bartolome” of La Jana in Castellón. APEGA 2012 | First studies of another church designed by Joan Tell. |
| **2013** | Study of the concordance between the historical documentation and the graphic documentation applied for the study and analysis of the chapel of San Vicente Ferrer (1610-1618), located in the town of Catí (Castellón-Spain). AID MONUMENTS | It was found that Master Tell used the Valencian span of 23 cm. |
| **2013** | The graphic documentation of architectural heritage through the use of advanced methodologies and their application Tortosa Diocese region. TERRES DE CRUÏLLA | The precision of graphic surveys with 3D scanners is shown. |
| **2014** | The late Gothic religious architecture in the lands of Castellón at the beginning 17th century. SEVILLA 1514. | There is a synthesis of Tell's work and the metrology used. |
| **2014** | Photogrammetry and laser scanning systems, in combination with traditional methods in heritage documentation, for obtaining an inverse architecture and its preservation. REHABEND. | Obtaining 3D models from architectural graphic surveys . |
| **2014** | The modeling based on techniques advanced of takes of data for the study of the church of the Asunción in Vistabella del Maestrazgo 1604-24. LE VIE MERCANTI | Explanation of the accuracy of the graphics surveys in the of Vistabella parish |
| **2014** | The discovery of the proportions established by Vitruvius and Alberti in the "Maestrazgo de Montesa" lands, thanks to architectural graphic surveys. EGE | Study of the proportions used by Joan Tell in the church.. |
| **2015** | The instructions of s. Carlo Borromeo in the Vistabella church. Castellón. España. LE VIE MERCANTI | Application of St. Carlo Borromeo text in the design of the monument.. |
| **2015** | The implementation of the new technologies for advanced graphic expression in studies conducted using structural graphical statics and its comparison with architectural treatises of the time. CMMOST | Static graphic structural studies. |
| **2015** | Comparative Study of Graphic Representation Methods on Architectural Heritage. IGI | Comparative studies using Maestre's land as a test laboratory. |

| | | |
|---|---|---|
| **2016** | Geometric studies in the blossoming of the Renaissance in Castellón lands. Between the Gothic and Baroque tradition. TIRANT LO BLANCH | Study of the utilization of geometry by the architect Joan Tell. |
| **2016** | The retablo-façade of the Church of "Nuestra Señora de la Asunción "in Vistabella del Maestrazgo(Castellón). EGA | Comparison between the retablo-façade of Vistabella and Andorra (Teruel) |
| **2016** | Renaissance-Style Architecture in El Maestrazgo: From Virtual to Tactile Models.IGI | Sample conversion from virtual to tactile models.. |
| **2018** | Process of transformation of architectural graphic documentation into tactile models.EGE | Sample conversion from virtual to tactile models.. |
| **2018** | Study on Different Graphic Representations in Architectural Heritage: Digital and Physical Modelling. IJCMHS | Digital and physical models of the church portal. |
| **2019** | Possibilities of additive manufacturing for creating inclusive tactile models. TIRANT HUMANIDADES. | Inclusive tactile models through additive manufacturing. 3D printing |
| **2019** | The diffusion of architectural Heritage, through social networks, as a digital Heritage. DISEGNARECON | Reflections on the use of social networks in the dissemination of architectural Heritage. |
| **2021** | Promotion and restoration of the architectural heritage of the valencian community through 3D additive manufacturing technologies with ceramic material. TIRANT HUMANIDADES. | Dissemination of Valencian architectural heritage through 3D printable models and the potential restoration of monuments using ceramic materials was explored |
| **2021** | Comparative studies of the churches of “santa María de Morella” and “Nuestra Señora de la Asunción de Vistabella del Maestrazgo”. Province of castellón. TIRANT HUMANIDADES. | Similarities and differences between two significant buildings.- |
| **2023** | Natural lighting in a Renaissance temple. SIN PUBLICAR. | Explanation of the illumination of the temple through the sun's rays and how they can give information about the building. |

*4.1.3 Research projects*

In addition to the dissemination through the aforementioned publications, the results obtained about 3D printing and the development of tactile models allowed for two research contracts and two research actions, facilitating knowledge transfer to society.

The first contract involved the design and installation of an outdoor tactile map in an inclusive park in the city of Valencia.

The second contract was carried out within the "3D RestaurAM" project (Mañez et al., 2021). The objective was to adapt new 3D printing using ceramic materials to restore and promote Valencian Heritage. This included scanning, modelling and prototyping techniques and disseminating these models in a free, accessible format.

The two research actions in the medical field were carried out by researchers from the Universitat Jaume I (UJI) and FISABIO. These works included prototyping the designs with 3D printing. One of them obtained a patent.

### 4.2. Social results or impacts

In the pursuit of disseminating knowledge to society, several actions have taken place over the past 15 years.

In July 2010, a conference and visit to the church in the municipality, led by María Jesús Mañez, took place at the Seu del Penyagolosa of the UJI as part of the summer course "L'arquitectura en pedra. Patrimoni cultural."

In March 2014, a diptych was prepared to summarise the main conclusions of the thesis. This diptych should be disseminated for greater knowledge of this emblematic building so that the research does not remain only in the academic field (Figure 5).

La torre campanario tiene 29,48 metros de altura, la misma altura que un edificio de diez plantas, esto hace que sobresalga imponente sobre el resto de construcciones del municipio.

El edificio fue construido con materiales autóctonos tales como rocas de calizas y areniscas, arenas, cales obtenidas a partir de las calizas, tejas y ladrillos de tradición árabe, madera y hierro. El único material no autóctono es la cerámica decorativa del siglo XVII que procede de los hornos de la ciudad de Valencia.

Las obras fueron financiadas probablemente por los habitantes, vecinos y clero de la localidad, siguiendo la costumbre de esos años, con los ingresos del Consell y con donativos.

El templo de Vistabella junto a los templos de la Asunción de Benlloch y San Bartolomé de La Jana, trazados por el mismo autor Joan Tell, y junto a los de San Bartolomé de Càlig, o la Asunción de Traiguera probablemente diseñados también por este maestro, constituyen perfectos ejemplos de iglesias de transición entre el gótico y el barroco, que si se sigue la tradicional interpretación de la arquitectura a partir de la arquitectura de estilo, son y deben considerarse renacentistas, que son únicos en la zona y que preconizan el modelo jesuítico iniciado en Il Gesù de Roma, diseñado por Vignola y que se seguirá posteriormente por un gran número de iglesias barrocas.

María Jesús Máñez Pitarch

Año 2014

IGLESIA
DE NUESTRA SEÑORA DE LA ASUNCIÓN
Y
SAN MIGUEL

VISTABELLA DEL MAESTRAZGO

**Figure 5.** Diptych. Source: Mañez (2014)

In September of the same year, the blog of the "Arxiu de Vistabella del Maestrat" (Ayuntamiento de Vistabella, 2014) and the newspaper Levante (Levante, 2014) echoed the doctoral thesis (Figure 6).

Arxiu de Vistabella del Maestrat

Tesi doctoral sobre l'església de Vistabella del Maestrat

**Maria Jesús Mañez Pitarch** és professora de l'Escola Superior de Tecnologia i Ciències Experimentals de la Universitat de Castelló, i el gener de 2014 ha publicat la seua tesi doctoral sobre l'església de Vistabella. El treball final consta de 692 pàgines i porta el títol: *La Arquitectura religiosa renacentista en tierras del Maestre: la Iglesia de Nuestra Señora de la Asunción de Vistabella del Maestrazgo.*



En aquesta tesi ha reunit totes les dades bibliogràfiques, gràfiques i arxivístiques existents. També ha fet un exhaustiu aixecament gràfic que ha estat realitzat a partir de complets treballs de camp, durant els quals ha utilitzat no només sistemes tradicionals de mesurament, com ara instruments i aparells topogràfics, sinó també programari d'última generació.

Gràcies a la totalitat de la investigació s'ha localitzat als autors de l'obra: d'una banda l'arquitecte francès **Joan Tell** "*(...) en el año 1987 Ferran Olucha encontrara un documento en el archivo municipal de Castellón donde se desvelaba el verdadero autor de la obra, Joan Tell. En dicho documento el propio Joan Tell se define como arquitecto, también maestro de iglesias, y habitador de la villa de Vistabella*". D'altra banda l'autora manté la tesi que **Joan Rigor** va ser l'autor de les portades: "*(...) el autor de las portadas de Vistabella fue Joan Rigor, el cual fue reconocido en su tiempo como un cantero de mucha habilidad*". Aixina mateix també s'explica perquè Joan Anglès, al qual sempre s'ha atribuït l'obra, no podia ser-ne l'autor.

**Una tesis desvela quién fue el arquitecto de la iglesia de Vistabella**

**J. TENA** VISTABELLA

■ La profesora de la Universitat Jaume I de Castellón, María Jesús Máñez Pitarch, ha publicado una tesis doctoral sobre la iglesia renacentista de Vistabella. 692 páginas donde se reúnen todos los datos bibliográficos, gráficos y archivísticos del templo de la localidad del Maestrat.

En la tesis la investigadora defiende que el arquitecto francés Joan Tell fue el autor de la iglesia. Para ello se fundamenta en un documento, que en 1987, fue hallado por Ferran Olucha en el archivo de Castelló. Hasta la fecha la autoría de la iglesia de Vistabella se atribuía a Joan Anglés. La tesis explica por qué no fue éste el autor del templo. Según se describe en la tesis en el documento hallado por Olucha en 1987 se desvela que «en dicho documento el propio Joan Tell se define como arquitecto, también maestro de iglesias y habitador de la villa de Vistabella».

**Figure 6.** Newspaper Levante and Arxiu Vistabella Publication**.** Source: Levante &Arxiu. (2014)

The social media accounts were established solely for scientific dissemination. The limited number of visits, followers, and likes received has been noted.

- Website: www.arquitecturarenacentista.uji.es. Visits: 200
- Facebook page: www.arquitectura renacentista.com/Facebook. 123 likes • 132 followers
- Instagram account: www.instagram.com/arquitecturarenacentista/ 143 followers

Additionally, ITC established a website to share open-access models via the Sketchfab platform.

- ITC website: www.3drestauram.es .Visits: 35780

The models of Vistabella can also be viewed on the Sketchfab platform: https://sketchfab.com/3d-models, by entering the name "3drestauram".

Experts in the field emphasise the need for staff to maintain accounts (social media marketing) and stress the importance of setting objectives, establishing a target audience, specifying content, and monitoring statistics. Additionally, they highlight that the platforms that work best are Instagram, YouTube, and TikTok due to their significant visual impact through images and videos (Barrio, 2022)

## 5. Conclusions

Despite the importance of Renaissance architecture, studies in the Castellón province had been limited mainly to historical aspects in publications such as the "Boletín de la Sociedad Castellonense de Cultura (BSCC)" and the "Boletín del Centro de Estudios del Maestrazgo (BCEM)". Sometimes, the historical documentation and photographs, was accompanied by an approximate planimetry, but exhaustive surveys were non-existent. Rigorous, precise and technical studies have provided a broad knowledge of this valuable cultural heritage, essential for planning protection, conservation, and dissemination.

The creation of accurate documents representing buildings has evolved. Initially, hand-drawn sketches and floor plans were utilised, which were digitised using CAD software. Later, 3D digital representations were adopted. Today, these models are employed in augmented and virtual reality applications. Additionally, 3D additive manufacturing presents an interesting alternative for reproducing and visualising historic buildings, both existing and defunct, for all kinds of audiences.

The traditional dissemination of results in congresses, books, magazines, and tourist brochures, primarily in printed format, has become insufficient. With the emergence of Information and Communication Technologies (ICTs), new opportunities for disseminating cultural heritage are arising, offering free and open access to digital content. These opportunities have a global reach and can engage audiences of any kind, anywhere in the world. However, substantial resources must be allocated for their maintenance. These mediums facilitate scholarly studies to transcend academic barriers and serve as significant sources of information for education, economic development, and international cooperation.

Undoubtedly, the work presented here has improved the knowledge of cultural heritage and socio-economic development in different contexts. Additionally, it has laid the groundwork for future research and collaboration.

The construction of this building was costly financially and in terms of time. It has been ascertained that it took 20 years to build. Experience from research and dissemination work has shown that research into the building and its past is no less costly. However, only knowledge of the past will lead us successfully into the future.

## 6. Funding

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# Challenges to achieve a digital twin in historical monuments: The case of the church of San Antonio Abad

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***Abstract***

*Given the importance of the conservation of cultural property and the use of the digital twin as a tool for the representation of its life cycle and enhancement, we will carry out a digitisation project approach on the Church of San Antonio Abad and its protective environment, located in the city of Valencia (Spain) and currently considered an Asset of Local Relevance.*

*A theoretical approach is made to how the digital twin could be created, taking into account the various existing techniques, namely 3D scanning, photogrammetry, and BIM methodology, to achieve the complete digitisation of the monument. This first approach allows us to understand the evasion of this property and its challenges so that the digital twin can be realised in the future*.

***Keywords:*** *digital twin, cultural heritage, monument, conservation*.

## 1. Introduction

Digitisation captures reality by converting physical source material into digital source material (Rouse, 2024), which has tags with several levels of information called metadata.

This metadata is structured, and the information is organised and associated with the digital product for multiple purposes. (Montero, Fernandez, & Rodriguez, 2003)

Metadata should be recorded according to standards so that the same principles apply universally, regardless of the object, collection or cultural institution.

The rationality of the efforts to digitally represent that material fraction implies an inherent complexity. This is due to the need to select and manage data sets and consider the levels of information accessible in the final digitised product. The concept of digital twins is the starting point for interacting with the digitised heritage. The digital twin should be understood as the origin and not the end of a digitising project, as this is the starting point for interacting with the heritage asset. (Castillejo, 2022)

## 2. Objective

The objective of the research is to perform a theoretical approach that allows us to address the realisation of a digital twin within the singularities of the heritage building called Church of San Antonio Abad, located on Sagunto Street, numbers 188 and 186 (Figure 1-2) to achieve as a first step of a digitising project; a digital twin that I can serve later for other purposes.

It is wanted to put in value good of local relevance, hidden and not visitable of the city of Valencia, directed to the citizens and the members and owners of this building, as well as to future works of investigation and works of rehabilitation and restoration of the monument.


**Figure 1:** Location of the property and its protected environment. Source: Blanco Estévez (2022).

 

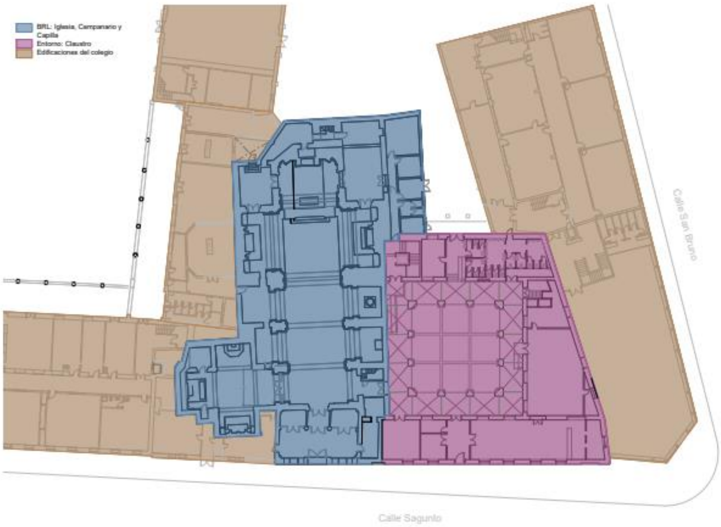


**Figure 2:** Location of the property and its protected environment. Source: Blanco Estévez (2022).

## 3. Methods and procedure

To carry out the objective of the research, it is necessary to know its history from its origins to the present, identifying the gaps in knowledge and establishing a solid base through a documentary, descriptive and explanatory research that allows us to know the monument from a global vision.

The most relevant procedures/techniques are defined for each part of the described property to verify the most effective way to digitise it, given its amplitude and the location of the different relevant elements.

### 3.1. History of the Church of San Antonio Abad

In 1095, the order of the Antonians was born, attributed to Gaston Dauphine, a French nobleman whose son contracted the disease known as St. Anton's fire, which was caused by ergot. In 1228, Pope Honorius III confirmed the Hospitaller Order. The order would adopt the Blue Tau and the brown or black habit as its hallmark. (Burns, 1982; Rubio Vela, 1984) (Figure 3)

**Figure 3:** Picture *Las Tentaciones de San Antonio* from El Bosco. Source: Prado Museum, Spain.

The Antonians arrived in the city through the diocese of Tortosa, Barcelona. The Antonians bought land in the Orriols district, making their "foundation" in 1404 and later building the hospital with diaphragm arches and a Mudejar roof between 1415 and 1440, two of which are still preserved today (Blanco Gómez, 2015). (Figure 4)

**Figure 4:** Detail of the roof at present. Source: Blanco Estévez (2022).

With the construction of the General Hospital of Valencia in 1512, the convent lost its hospital status. It began its transformation into an alms order (obtained by papal bull by John XXII in 1287-1297). The hospital was transformed into a church during the 16th (communion chapel) and 17th centuries (new facade), culminating with the great neoclassical reform carried out by the friar architect Fray Francisco de Santa Barbara, which lasted until 1768, a date engraved on the exterior façade of the convent. During this work, all the Gothic ceilings, arches and other elements of the fifteenth century will be masked, building around them the new building, expanding it to generate a Latin cross church with a dome in the transept and a large adjacent cloister. The bell tower was enlarged to its present size, which can be seen today (Blanco Estévez, 2022) (Figures 5-7).

**Figure 5:** Cloister Aerial view source: Blanco Estévez (2022).


**Figure 6:** Corner of the outer facade of the cloister. Source: Blanco Estévez (2022).

**Figure 7**: Interior of the church at present. Source: Blanco Estévez (2022).

At the end of the 18th century, in 1787, Pope Pius VI suppressed the order, and the Antonians were forced to leave, leaving the church empty until the arrival of the Dominican Order of St. Onofre in 1804. They transformed the communion chapel into a chapel consecrated to the Virgin of the Rosary. They abandoned the convent in 1835 after the disentailment of Mendizabal, the cloister remaining in the State and passing into the hands of individuals and the church was claimed by the Archbishopric and ended up being the parish of Orriols in 1845 (current neighbourhood of the city of Valencia) (Ballester Olmos, 1984; Eslava Castillo, 1976).

In 1872, they bought the conventual part from private individuals to the Order of the Canonesas de San Cristóbal, cloistered nuns who reformed the convent (Ortí, 1899). It would be until 1899 that they sold the convent to the Order of the Salesian Fathers, which is the order that still owns the building today, celebrating 2024, 125 years after its arrival the building. The Salesians will build their school around this property, expanding the adjoining buildings to become the large block that it is today (Díaz Rivas, 1990) (Figure 8).

**Figure 8:** Surrounding area of the current Salesians plot. Source: Google Maps (2022).

### 3.2. Digital Twin: Tools

Having seen the history of the building, we can determine that at the level of digitising, this building has two well-differentiated parts that give value to the monumental set. On the one hand, the Mudejar roof of the XV century, and on the other hand, the neoclassical church completed in 1768, which hides the Gothic remains mentioned.

The rest of the adjacent buildings that exist at present will be observed during the realisation of the twin as they interfere with the building, and it will be perceived if it is necessary or not digitisation. Also, it can be estimated if this is necessary, but it will not be known with certainty until the empirical part is carried out.

With the above seen, the different items to carry out the digital twin project are raised, along with the information we already have about the property.

#### *3.2.1. Photographic survey*

Digital photogrammetry has had a major impact on the digital era by enabling the creation of accurate and detailed three-dimensional models from photographs. Modelling opens new possibilities in architecture, engineering and cultural heritage conservation fields. In addition, photogrammetry is a valuable tool in archaeology and historic building preservation. This technique uses photographs to measure and create accurate three-dimensional (3D) models of objects and structures, allowing researchers and conservation experts to efficiently capture and document cultural heritage in detail. In short, digital photogrammetry is a technological discipline that revolutionises the way we document, study and disseminate cultural heritage by unlocking a range of possibilities for the documentation and conservation of monuments, historic buildings, archaeological pieces and sites (Marqués & Colom Mendoza, 2022; Patrimonio Global, 2023).

In our building, photogrammetry of the Mudejar roof is considered feasible, although it would not be easy to perform.

To begin with, only two bays are preserved, each in a different place, so we would have to make two different surveys. Then, the roof of each bay would have to be divided into several parts to fit in its entirety. That is to say, we would have to treat each roof by the number of sections considered necessary, considering that between the vault and the roof, there is no room for a standing person, and the light is scarce. Therefore, to get a good shot, we would have to create an atmosphere with enough light to create different clouds of dots and then join them together. You can use Agisoft Metashape to do this (Figure 9).

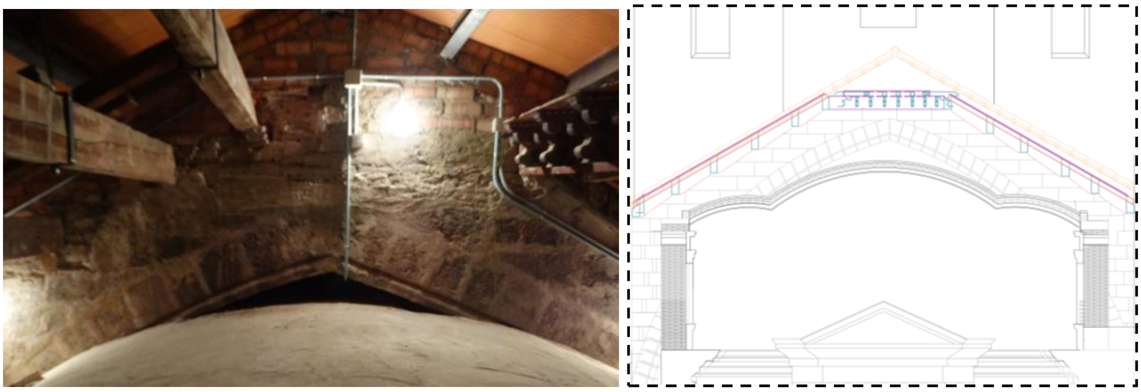

**Figure 9**: Remaining space in the first bay. Source: Blanco Estévez (2022).

### *3.2.2. Scanning technologies*

The 3D scanner provides depth information, the geometry of the scanned object, and, usually, texture or photographic information. It is known that a camera, for example, also captures information about the environment around us based on the surface without providing in-depth information. The 3D scanner digitises objects to have them in virtual form and access more information (Polo et al., 2019).

Scanning an object or scene generates a point cloud, an unorganised set of points in three dimensions. The scan is a massive capture of information, which must be cleaned and processed. This processing includes different operations such as cleaning, merging different scans, filtering, generating a triangle mesh, texturing, etc. It is, therefore, a complex process and depending on the number of scanners, it is expensive.

We currently have a 2D survey carried out using a flexometer, tape, and laser. Therefore, it would be interesting to perform, at least of the church's interior, a scan that improves the accuracy of the data available so far.

It is not considered, in principle, to treat the roof with 3D scanning because of the complexity of the placement of the equipment. Still, it is possible to consider combining both techniques, photogrammetry and 3D scanner.

### *3.2.3. Data management*

The use of the Building Information Modeling methodology in the field of cultural heritage has generated its own disciplinary field under the name Heritage BIM (hereinafter HBIM). The use of BIM methodology is not an abstraction. It is a way of doing things (Rios, 2022).

At this point, the property is at a level of maturity, according to the Bew-Richards Level 0 model, which means that it has been worked on in 2 dimensions with CAD (Computer Aided Design) software. If we go to ISO 196520, we would be at stage 1, where 2D CAD drawings and information models are combined.

Therefore, it makes sense that with the help of the scans to be made and the point clouds obtained by photogrammetry, H-BIM is applied as the main tool for our digital twin to complete the "matryoshka" that is this building and to manage the level of information that a building of these characteristics has (Figure 10).

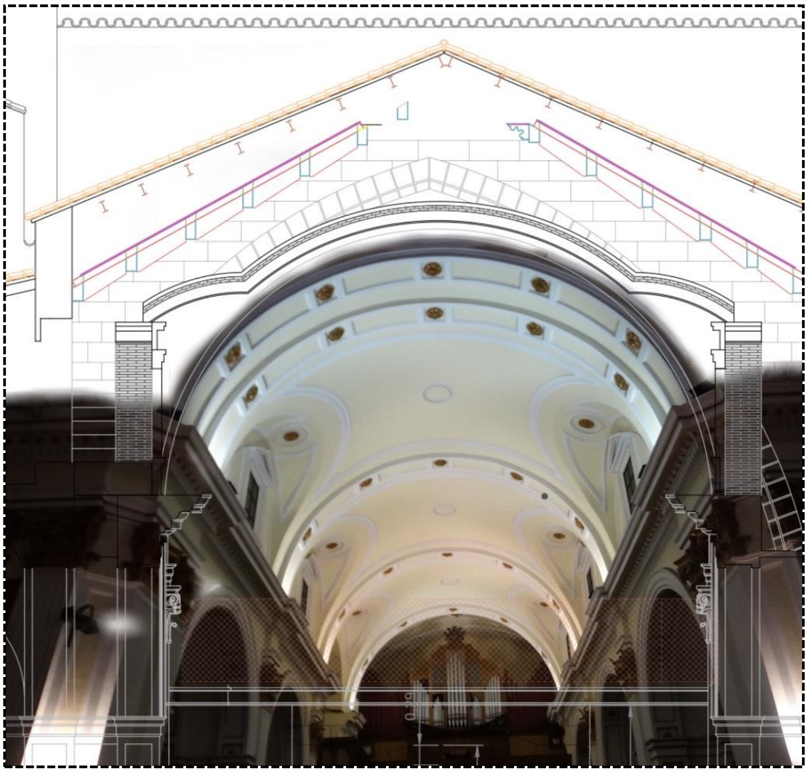

**Figure 10:** Photograph of the interior of the church inserted inside a section by means of Procreate.
Source: Blanco Estévez (2022).

## 4. Results

As observed in the four main works that have been carried out on this building, namely:

- The doctoral thesis "Resultados de la investigación directa en la iglesia de San Antonio Abad". Domingo Alfonso Eslava Castillo in 1976
- The doctoral thesis "Análisis arquitectónico y constructivo de la techumbre en madera policromada de la Iglesia de San Antonio Abad, como pervivencia de la arquitectura tardogótica mediterránea de la Valencia del siglo XV." Pedro Rafael Blanco Gómez in 2015
- The final Master's tesis "Estudio constructivo del convento de los Antonianos en la Valencia extramuros. Desde su fundación hasta las grandes reformas del siglo XVIII y su posterior adaptación a colegio salesiano" Paula Blanco Estévez in 2022.
- The book" La techumbre tardogótica de la madera policromada oculta en la iglesia parroquial de San Antonio Abad (Valencia) from Pedro Rafael Blanco Gómez en 2023.

This heritage asset is important within the city of Valencia and specifically as part of the great forgotten Valencia outside the city walls. This makes it necessary to undertake a digitisation project of this magnitude to enhance its value, disseminate it and be able to intervene and preserve it.

Below are some of the 2D CAD drawings and volumes previously made that are the basis for the digital twin project and have helped us develop the methodology and procedures (Figures 11-13).

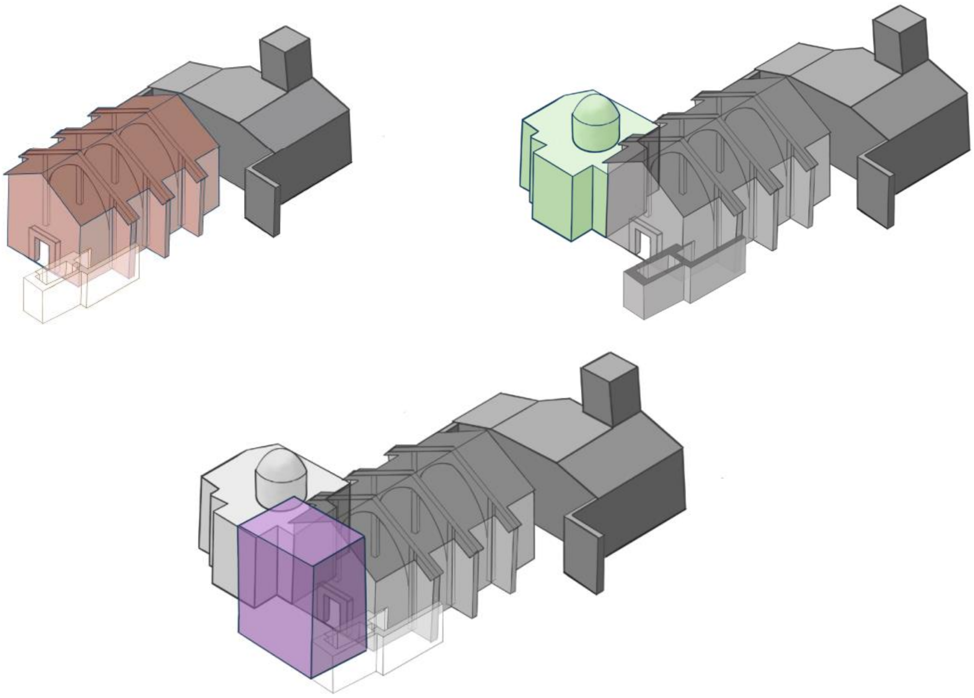

**Figure 11:** Volumes made with Procreate to understand the constructive hypotheses of the building. Source: Blanco Estévez (2022).

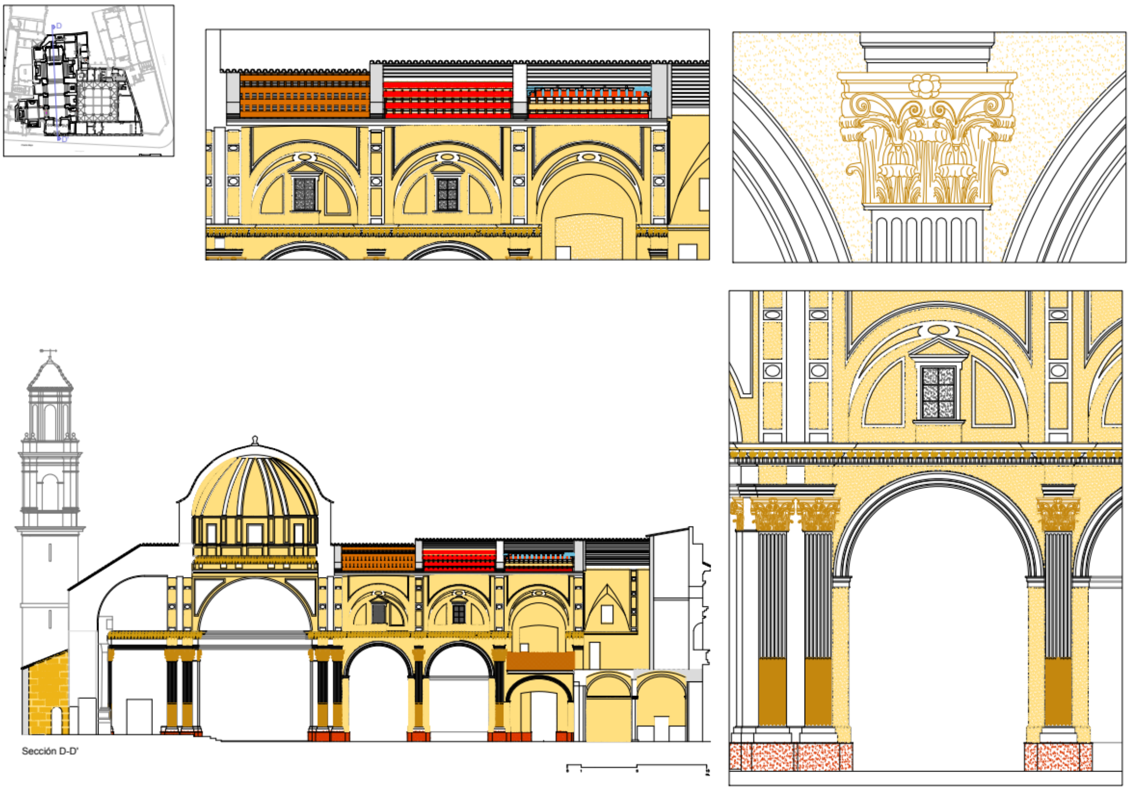


**Figure 12:** Section D-D' Church. Source: Blanco Estévez (2022).

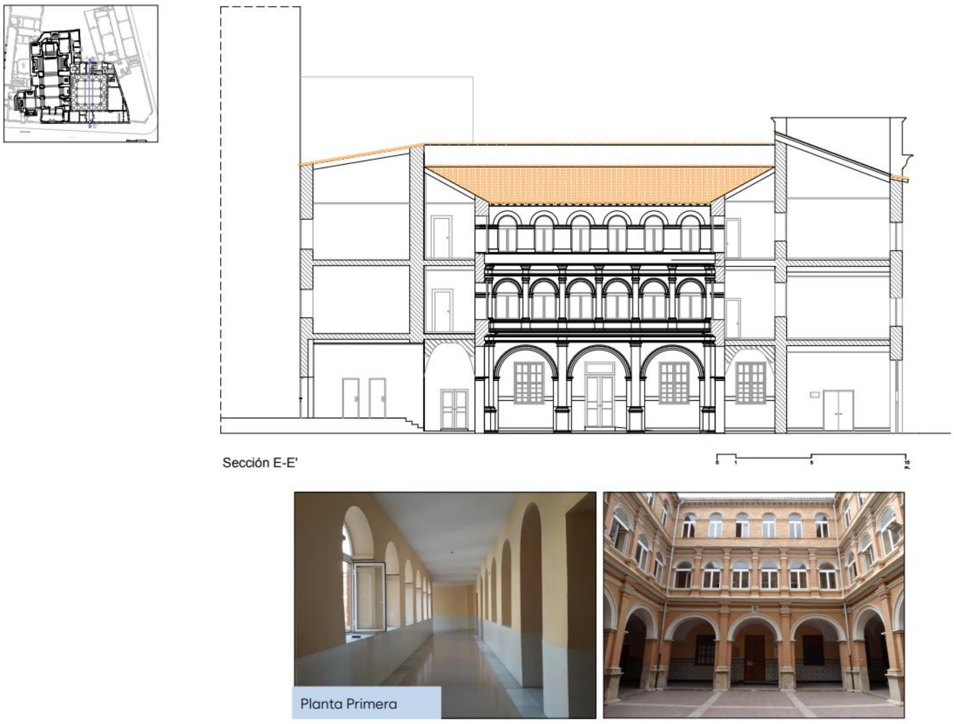


**Figure 13:** Section E-E' Church Source: Blanco Estévez (2022).

## 5. Conclusions

The digital twin is the base digital replica for its subsequent use as a tool for different purposes. It will always consider the type of heritage real estate and its casuistry, as well as its objective and its target audience.

Given the effort that it takes in time and economic cost, we must have a sense and, in turn, know very well what digital tools exist and which ones we can take advantage of. Always bear in mind that this is a field in constant evolution.

I believe that this asset is sufficiently relevant to make it necessary, once and for all, to give it the digital scope it needs, given the interest it arouses, the information available and the current technological possibilities.

## 6. Possible lines of research

### 6.1. Geografic information systems

Create a geographic information system (GIS) to place the monument in context and facilitate spatial data management. To do this, the monument is georeferenced, and geospatial data is obtained from maps, satellite images, topographic data, and document details. Using software such as QGIS, the data is imported to create layers that represent the monument and its context. The location can be compared with other adjacent/geospatial elements to create zones around the monument and evaluate its influence on the environment.

### 6.2. Analysis of the model and possible further uses

As has been said, it is aimed at the citizens, members, and owners of this building, and its potential usefulness is in the dissemination of a little-known asset of the city.

For example, if you have the 3D model, the point cloud of the roof, you could create a visual tour, for example, with Blender (once treated the cloud, obviously), which could be seen on the Internet, and that would allow you to know this Valencian treasure. The same is true for the church and the cloister.

Also, the digital twin could be used to motorise one of the biggest problems this monument has, which is rising dampness, by means of software that would indicate the humidity of the walls and if the current system with electro-osmosis works.

### 6.3. Accessibility

The model could be worked from this perspective:

- Enrich and connect: By indexing the features of the digital product, you give it value. Working to establish connections with other elements that share similarities ensures greater impact. In addition, it is crucial that the digital product can communicate effectively between different systems and formats.
- Open approach: It does not make sense to limit the use of the digital product. It must be designed to be accessible by different profiles within the Knowledge Society. In addition, its capacity to adapt to different social contexts is fundamental.

## 7. Acknowledgements

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# The integration of HBIM into GIS for the development of a tourism planning and preventive conservation protocol for the cultural heritage of a destination (HBIMSIG-TOURISM)

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## Abstract

*Conserving Heritage Assets is a latent fact not only for the field of public administrations and the scientific community, but also for the society in general. The increase in the cultural awareness of the population as well as widespread public access to heritage and the enhancement of numerous monuments and sites have favoured the expansion of so-called cultural tourism. However, poor planning of public use can be a severe risk to the loss or degradation of heritage resources. Currently, there are collaborative methodologies so that all agents involved in the conservation of a Heritage Property can work in a coordinated manner, sharing information about the property with each other with a comprehensive vision of the actions (Heritage Building Information Modelling HBIM).*

*In this framework, the Universitat Politècnica de València is carrying out an R&D&I Project financed by the Ministry of Science and Innovation, aiming at establishing a method or protocol that allows the efficient management of sustainable conservation and planning of cultural tourism of heritage assets located in a specific geographical environment. This method is based on interoperability between HBIM and GIS. To validate the protocol, three emblematic religious buildings in the city of Valencia have been selected. All of them are located in Ciutat Vella* District, *also considered an Asset of Cultural Interest (BIC) in the category of historic centre: The Cathedral, the complex of San Juan del Hospital, and the Real Colegio-Seminario de Corpus Christi.*

*It is a novel technological system that can contribute to the improvement of cultural development and the preservation and conservation of heritage assets through a single integrative tool of HBIM and GIS. The knowledge generated can be framed in the concept of smart cities and applied in the planning of urban tourist environments (Tourist Information Systems -SIT-) that have a significant number of heritage elements and may also have management problems with visitor flows (saturation, congestion, impacts derived from the visit, etc.) and, consequently, the conservation of assets.*

***Keywords:*** *GIS, HBIM, visitor flow, management, survey.*

## 1. Introduction

The optimal results achieved through the application of the BIM methodology in newly constructed buildings are evident, which has been verified by its consolidation in the drafting of projects promoted by the Public Administration across all European countries.

Also, its practice on heritage buildings (HBIM) is being experimented with for the great possibilities it holds as a unifier of dispersed information. HBIM has shown that it can improve the efficiency of heritage information management (Parisi et al., 2019) since it allows the geometric, semantic and documentary information of heritage assets from all the disciplines involved to be centralised in a single common repository, facilitating collaborative work and the exchange of coordinated information between multidisciplinary teams.

In 2009, Murphy et al. already sensed the advantages that the use of the BIM methodology could provide to the study of architectural heritage, carrying out the first approaches in the creation of libraries of objects from existing buildings. The concept of Historic Building Information Modelling (HBIM) was then defined as a new system for modelling and documenting historic buildings and also as a cultural disseminator (Brumana et al., 2013). Murphy et al. (2013) developed a parametric library of classical architectural elements based on classical architectural manuals, from Vitruvius to the architectural pattern books of the 18th century. In this context, the development of a specific plug-in for Revit, called GreenSpider, carried out by Garagnani (2013), was of great value, which allowed the processing of point clouds into parametric objects, which greatly facilitated the creation of libraries.

Since then, scientific literature has highlighted the potential of HBIM to document the existing building (Salvador-García et al., 2020), although the majority are studies referring to a specific heritage building, and few manage to establish working methodologies or prototypes. In Spain, Francisco Pinto Puerto was a pioneer in the research of the BIM methodology applied to architectural heritage developed within the framework of the project "A Digital Information Model for the Knowledge and Management of Real Estate of Cultural Heritage" (HAR2012-34571). Along these lines, studies have been carried out to incorporate information related to the different disciplinary areas that come together in the study and management of a heritage asset. Castellano-Roman (2015) has investigated the ability of HBIM to offer comprehensive heritage asset management around the legal protection of heritage. The great potential of HBIM to manage building maintenance tasks throughout their life cycle has also been confirmed (Fassi et al., 2016). Nik Umar Solihin (2019) insists on the novelty and great potential of incorporating BIM with historic built environments leading to the improvement of building performance through facility management in Malaysia's cultural heritage. Its ability to show the results obtained from sensors intended for the maintenance and conservation of buildings makes it the appropriate tool for carrying out preventive and proactive maintenance of heritage buildings (Bruno et al., 2018). Advances in the documentation and management of HBIM heritage have not only been limited to existing buildings, but historical consideration and the creation of models in the field of archaeology are also being tested (Martín Talaverano and Murillo Fragero, 2020).

Likewise, it contains great potential for the management of public use and heritage tourism (Salvador-García, 2020). Inadequate visitor management may increase the risks of loss or degradation of heritage resources and may not ensure the satisfaction of visitors' tourism experience.

However, HBIM exclusively documents and manages a single asset without considering the cultural, semantic and technical links and connections it may have with other monuments or heritage sites that could be integrated into the same geographical area (municipal, regional, provincial, regional or national). In this sense, the GIS (Geographic Information System) tool allows the management and analysis of information from different sources, linking it to its real location, thereby obtaining results related to statistical data, thematic maps, etc. (Seguí et al., 2012). Therefore, this tool, which has been developed and used for several decades with greater impact on the management of public land assets due to its versatility and effectiveness (Nogués Linares et al., 2008), turns out to be the perfect complement, interoperating with BIM, carry out efficient planning of heritage tourism.

As was the case in the implementation of BIM in historic buildings, research into the integration of HBIM into GIS is usually linked to the study of specific cases (Rolim et al., 2024). In Italy, due to the large amount of heritage assets it has and its tradition in safeguarding its monuments, various studies have been developed around HBIM and its implementation in a GIS. At the Politecnico di Milano (POLIMI), the research group led by Raffaella Brumana has long experience in the use of HBIM and its integration into GIS for the conservation of parks and gardens. At the Università di Pisa, the research group led by Marco Bevilacqua (2019) studies the integration of 3D models in geomatic systems intended for the conservation of cultural heritage. At the Università degli Studi Firenze (UNIFI), geomatics professor Grazia Tucci has investigated, in case studies, the integration of point clouds in geographic networks; and at the Politecnico di Torino, Colugi et al. (2020) study the integration of HBIM in GIS using the church of San Lorenzo Norcia (Italy) as a case study, in order to obtain a unique model and also a vocabulary for the 3D GIS project aimed at the conservation of the monument. At the Univertà di Cagliari, Vacca et al. (2018) use HBIM and GIS for the study and conservation of the *Gran Torre di Oristano*. Matrone et al. (2019) perform a reconstruction and visualisation of complex architectures as a result of the integration of an HBIM model in a structured spatial database (DB) and its 3D visualisation in a GIS environment. This study is related to the European project ResCult (Increasing Resilience of Cultural Heritage), in which the church of *Santa Maria dei Miracoli* in Venice was chosen as a case study. It should also be noted that HBIM integration in GIS is not only being used for the study of specific heritage buildings but, increasingly, there are works that frame the study in an urban geographical area. Thus, Martín et al. (2020) evaluate the potential risks to which the heritage assets of a given locality may be subject. Mascort-Albea et al. (2016) investigate the generation of interactive maps of heritage sites for public consultation through Spatial Data Infrastructures. For their part, Bruno et al. (2018) study the development of a web information system capable of integrating BIM and GIS data, focusing on the analysis of the historic city and its main buildings over time, taking into consideration three aspects: the conceptual organisation of data to integrate GIS and BIM in a single environment; the integration of data belonging to different historical periods for analysis over time (4D); and the integration into the system of pre-existing data sets. In the same line of integration of historic buildings in the urban environment, Chenaux et al. (2019) address the integration of BIM with GIS as part of the workflow in the creation of Virtual Historic Dublin. Thus, they designed an interactive 3D model based on a web of the buildings and the historic centre of the city of Dublin.

In Spain, Francisco Pinto of the University of Seville is making important advances in research into the application of digital models based on BIM and GIS to the comprehensive and sustainable management of heritage guardianship: from an element or set to territorial scale figures (Project: HAR2016 Project 78113-R "Sustainable protection of cultural heritage through BIM and GIS digital models. Contribution to knowledge and social innovation" TUTSOSMOD).

On the other hand, it must be remembered that the increase in the educational level of society, the widespread public access to heritage, and the enhancement of numerous monuments and sites have favoured the expansion of tourism (García-Hernández, 2003). Many cities have their heritage as their main economic driver, and, therefore, moving forward in improving their planning and management is an obligation to guarantee sustainability, especially within the framework of their tourism development (Viñals, 2021). The planning of cultural tourism through GIS would facilitate, for its part, the consideration of the recreational carrying capacity of the territory where the heritage assets are located beyond that of a single heritage building so that it would guide how strategies to use to manage visitor flows (disperse visitor flows in various spaces of a territory or city, etc.) and occasionally relieve pressure (saturation and congestion) in spaces or buildings, equipment and facilities, or in public spaces.

However, the great management capacity that can be achieved with interoperability between BIM and GIS is not being exploited to its full extent. An example of this is that it has not yet been tested for the management of public use and cultural and heritage tourism. No studies have been found on the capabilities of HBIM-SIG for tourism planning, visitor management, or heritage interpretation. It should be noted that some applications have been found in the field of dissemination thanks to the availability of 3D models of buildings and other virtual products. At a time when public administrations demonstrate a desire to enhance knowledge and dissemination of their heritage assets, research into new non-invasive technologies that involve efficient work methods related to the planning of cultural tourism and preventive maintenance of heritage buildings. Given the impacts caused by the public visit, it is very timely.

For all these reasons, the research project titled "Analysis and development of HBIM integration in GIS for the creation of a tourism planning protocol for the cultural heritage of a destination (HBIMSIG-TOURISM)" proposes the creation of a working prototype HBIM-Online GIS where all interdisciplinary actors related to the planning and management of public visits as well as preventive conservation of heritage can participate synchronously.

Therefore, the general objective of this project is: Explore and determine the underlying possibilities of interoperability between HBIM and GIS for the creation of a Protocol aimed at synchronising and managing information on heritage architecture, sustainable conservation of assets, planning territorial and cultural tourism.

## 2. Methods and materials

To carry out the research, the scope of implementation of the documentary results in HBIM has been restricted to three monumental buildings integrated into the same geographical area of an urban environment. This testing laboratory is large enough so that the research results are reliable and can be sufficiently tested. Work has been done on three monuments in the *Ciutat Vella* district of the city of Valencia, designated BIC in the "historic centre" category, for which its Special Protection Plan (2020) has recently been approved. The selected case studies are three religious buildings: the *Cathedral of Valencia*, the church of *San Juan del Hospital* and the Real Colegio-Seminario de Corpus Christi (*El Patriarca*), which are part of the tourist offer of Valencia (Figure 1).


**Figure 1.** Location of the case studies in the historic centre of Valencia.
1, *Cathedral*; 2, *San Juan del Hospital*; 3, *El Patriarca.*

To achieve the proposed objective, the three selected monuments and their urban environment were scanned, implementing the point clouds in HBIM. The digital models of the three buildings as point clouds of the urban environment were implemented in GIS. For this, ArcGIS Pro 3.2.2 software has been used. Their choice was determined by the advantages it provided. Thus, we have that this online platform facilitates the combination of 2D and 3D digitisation prepared using different software, enabling their visualisation, as well as the analysis and processing of images. In addition, it allows data management, integrating all the information generated, both that included in HBIM of the three buildings, and that incorporated in the GIS related to the urban environment, including people counting. The work carried out can be channelled in three directions:

- The study of the volumes of visitor influx, their spatial and temporal distribution, and the density levels of visitor flow and derived from all of this, frequentation trends can be established.
- Digital modelling of buildings and their surroundings
- Detection of the impact generated by public use on the heritage asset in the short, medium and long term and its implications for preventive conservation.

 

### 2.1. Visitor flow study

Visitor flow study is a vital element to optimise the management carried out by the organisations responsible for cultural visits (Baggio and Scaglione, 2017). To study the flow of visitors, both inside the three selected buildings and in the urban area that integrates them, various methods and tools were used. In this way, several direct and participant observation campaigns were carried out, as well as in-depth interviews with cultural managers of heritage buildings and with tourism service providers to obtain qualitative information. Likewise, automated data collection was carried out on visitor volumes and their distribution in space and time based on manual counts and counts by 2D video cameras. Various linked studies and tools have been developed for the *Cathedral* and its surroundings to facilitate the flow of visitors and its relationship with the management of public use.

- Analysis of the attributes of the interior visiting spaces and also the urban public space (streetscape) to know the characteristics that favoured pedestrian traffic and other activities for public use (visual appearance, aesthetic values, integrity, uniqueness, sensory attributes, imaginability, legibility, intangible elements, socioeconomic vitality, sociocultural dynamism, etc.).
- Determination of the visitor carrying capacity. This tool addresses the study of the number of people that a space can accommodate, allowing a visit in conditions of physical-psychological comfort and without negatively affecting the heritage space (Broquetas, 2024; Orozco et al., 2023; 2024). The design of the visit pattern aims to create the optimal itinerary for carrying out the tour in the most comfortable and intuitive manner, avoiding encounters with other groups.
- Interpretive route that is developed both for the interior and for the external route of the *Cathedral* around a theme or interpretive message that structures the visit, allowing intellectual and emotional access to the heritage element in an enjoyable way based on the identification of the values heritage of the *Cathedral* (Viñals and López-González, 2022).

To count people, direct methods have been used, as proposed by authors such as Le Corre et al. (2012) and, more recently, Spenceley et al. (2021), especially for the interior spaces of these religious buildings. In this way, the volume of people was estimated from the ticket sales made. These data were double-verified by a team of 10 people located at strategic points, on specific days of high influx (days of disembarkation of cruise passengers, local festivities, etc.), to confirm the veracity of the data and the congestion points of the visit itinerary.

Likewise, automated methods have also been using image sensors (2D video cameras) for counts in the urban environment of the *Cathedral* and San Juan del Hospital. Thus, on Trinquete de Caballeros Street, where the access to San Juan del Hospital is located, the first specific experimental trial was launched to obtain images from simple mobile devices (Galaxy A20e) with internal storage of 32 GB and a 5,000 mAh battery with fast charging (Collado et al., 2022). Subsequently, 2D video cameras (CPF-SENSOR, model WTK10070) with person recognition software were installed in the streets adjacent to the *Cathedral* (Miguelete and Barchilla) that provide precise data and can perform detailed monitoring of the movement of people, offering information continuously and remotely and, at the same time, respecting people's privacy since the images can be analysed with the software in real-time but the data stored and sent to the servers is purely numerical (Figure 2).


**Figure 2.** Left. Camara 2D (CPF-SENSOR , model WTK10070).
Right. An image is taken from the camera for people counting in the Miguelete Street.

### 2.2. Digital modelling of buildings and their surroundings

The acquisition of massive data for the digital modelling of the three selected buildings and the urban environment that integrates them for subsequent integration into the GIS was carried out using 3D laser scanning. This system was chosen for its ability to capture the geometry of the scanned element with excellent dimensional accuracy (Molina et al., 2021). Likewise, its integration into HBIM is not difficult.

A Leica RTC360 laser scanner was used to collect data from the urban environment. For the registration and subsequent processing of the point clouds, the Cyclone Register 360 software associated with Leica was used. For the necessary georeferencing, the project used 8 predefined ground control points, and the clouds were subsequently aligned.

To scan the three buildings, different types of scanners were used depending on the spatial and environmental characteristics of each spatial unit.

In San Juan del Hospital, a Faro brand scanner, Focus-130 3D model, was used because it is a church composed of large spaces of little complexity. However, in both the *Cathedral* and *El Patriarca*, the Faro Focus Premium model scanner was used, given its great efficiency in data capture, which represents a great saving of time in architectural spaces as complex as those of these two buildings. For those spaces that were difficult to transport the scanner due to its geometry and small dimensions, such as spiral staircases, the Faro portable scanner model FARO Freestyle 2 was used. Finally, the Focus 360 model was used to create virtual itineraries (Figure 3).


**Figure 3.** Left. Faro portable scanner model FARO Freestyle 2. Right. Faro Focus Premium model scanner.

The point clouds, obtained from laser scanners, were implemented in Revit for digital modelling. For this, the Scan to BIM plug-in was used because it allows automatic modelling from the point cloud, although it simplifies parametric elements that have complex geometry (Dore and Murphy, 2017). These simplifications are compatible with the objectives of the research since the detailed modelling of the buildings is not intended, but rather the final obtaining of digital twins that provide real-time data related to the number of visitors and environmental conditions.

### 2.3. Detection of the impact generated by public use on the conservation of the heritage asset

To detect the impact that the public visit can have on the conservation of the buildings, sensors have been used to provide data related to the environmental characteristics that can damage the building's construction materials as well as paints or other valuable material elements, such as the case of the collection of Notarial Protocols collected since the 16th century that is preserved in *El Patriarca*'s Archive.

For this reason, sensors have been used to measure Temperature, $CO_2$ and Humidity. These three parameters indicate the quality of indoor air as well as the appearance of condensation that affects paints or other materials and stones. An excessive concentration of $CO_2$ and Humidity can affect artistic elements such as fresco paintings, canvases or paper (García-Valldecabres et al., 2022).

The sensors used to measure ambient $CO_2$ are based on a non-dispersive infrared (NDIR) principle. The infrared (IR) detector is the one that takes the light sample and determines the proportion of $CO_2$ in the air inside the cavity. This sensor communicates with a microcontroller central unit through the I2C communications protocol through

 

16-bit commands. The default measurement interval is measured and displayed on a display every 2 seconds, but this value is adjustable between 2 seconds and 30 minutes. The measurements, in turn, are uploaded to a server database via a WIFI data connection with a proposed cadence of every 5 minutes. The information can also be accessed via Bluetooth connection with a mobile device and after synchronising it. The characteristics of the sensor are reflected in Table 1.

**Table 1.** Characteristics of $CO_2$ sensors

| | | |
|---|---|---|
| **Measurement range** | 400 – 10.000 | ppm |
| **Precision** | ± (30 ppm + 3%) | 400 – 10.000 ppm |
| **Repeatability** | ± 10 ppm | 400 – 10.000 ppm |
| **Thermal stability** | 0ºC … 50ºC U | ± 2.5 ppm / ºC |
| **Response time** | τ63% | 20 s |
| **Derived accuracy over sensor life** | ± 50 ppm | 400 – 10.000 ppm |
| **Operating temperature** | 0 – 50 | ºC |
| **Operating humidity** | 0 - 95 | %HR |
| **Sensor lifetime** | 15 | years |

The temperature sensor measures with a linearity of ±0.5ºC in all measurement ranges. The measurement of relative humidity is measured with a precision of ±5% for humidity between 0% and 59%, and ±8% for ranges between 60% and 100%.

These sensors were placed in the most conflictive points of the three buildings:

- *Cathedral*: In the chapel of the Holy Chalice, because it is a semi-confined place with a large influx of visitors and whose stone, of great porosity, can be affected by the high condensations produced by an excess of people. Sensors were also placed on the altarpiece of the main altar to check the impact that condensation may have on the valuable Renaissance paintings in the apse vault. At this time, efflorescence and stains are appearing, so it is very important to determine their origin.
- *San Juan del Hospital*: Sensors have been placed in the chapel of San Miguel Arcángel due to the danger that excess humidity would represent in the magnificent Romanesque paintings that cover the vault.
- *El Patriarca*: Sensors have been placed in the temple and in the Notarial Protocols archive due to the danger that may exist in the conservation of stored paper.

To facilitate the obtaining, consultation and analysis of data, the information emanating from the sensors is sent in real-time through a Wi-Fi connection to a platform that can be viewed through an APP. The data is sent to a MySQL database hosted on a secure server, where it is processed and saved for presentation on the web or APP. This system has been connected by viewing the data through the web platform. The sensors are configured in such a way that they are connected to a data network identifying the Wi-Fi SSID, requiring a password to view it.

## 3. Results and discussion

### 3.1. Results relating to visitor flow

A considerable difference in the volume of visitors has been detected in each of the selected buildings. The monument with the highest number of visits among the three is the *Cathedral***;** in 2022, it was 310,827, and 430,238 in 2023[1], detecting a constant growth in attendance. That is because the *Cathedral* is the most universally recognised building among the three, making it a popular attraction for most tourists visiting the city of Valencia. The largest number of visits corresponds to autonomous visits. This religious complex has audio guides in nine

[1] Oral communication by Carlos Gener.

languages so that the visitor can take a guided tour independently (Viñals et al., 2024), which is why many tourists choose this option. However, numerous group visits only tour the exterior of the *Cathedral*, without actually accessing the interior.

In *San Juan del Hospital*, individual visits to the Church are free, and groups, both with external guides and their own guides, must reserve a visiting time in advance. This space makes public-use activities compatible with liturgical activities and also with administrative tasks of the Foundation that manages this space.

*El Patriarca* makes religious activities compatible with public visits and accommodation for the institution's seminarians. There is a low flow of tourists due to reduced visiting hours and little information on the web about this topic. There is a regular flow of self-guided visitors, while guided and group tours must be pre-arranged and are carried out by a specialised service company. On the other hand, it is worth highlighting its important historical archive that attracts visits from researchers.

The count of visitors in the vicinity of the *Cathedral* carried out since September 2023 has provided very interesting specific data that highlights the importance of local and religious festivities in the quantitative and qualitative configuration of the flows. Thus, it can be said that the days with the greatest flow of visitors are linked to local and religious festivities, the members of these flows being basically the local population. These events cause saturation situations in the streets and squares around the *Cathedral*. As an example of this volume, the figure of 215,289 people registered on Miguelete Street on Tuesday, March 19, 2024, Saint Joseph's Day, the main festival of the city of Valencia, is presented.

### 3.2. Results related to digital modelling

The two buildings with the greatest architectural complexity are the *Cathedral* and the Real Colegio-Seminario de Corpus Christi. The scanning of both and the subsequent cloud registration and data processing with the SCENE software associated with FARO was very laborious, obtaining results of great precision and reliability.

The scanning of the *Cathedral* was carried out over 22 days. 573 scans were carried out and grouped into 130 clusters. The average error of all the scans was 4.1 mm, a perfectly acceptable value when considering the size and complexity of the building and the research objectives (Figures 4, 5).

Professors from Auburn University (Alabama) and Georgia Institute of Technology - Atlanta (Georgia) participated in the scanning of the Real Colegio-Seminario de Corpus Christi. 42 hours of work were used with a total of 341 scanning stations whose clouds were gathered into 11 groupings with an average error of 2.7 mm (Liu et al., 2023) (Figures 6, 7).

**Figure 4**. Left. Point Cloud image of the *Cathedral* of Valencia
Right. Scan positions inside the *Cathedral* and its surroundings. Source: Escudero, P.A.

**Figure 5**. Orthophoto of the *Cathedral*'s baroque facade extracted from the point cloud. Source: Escudero, P.A.

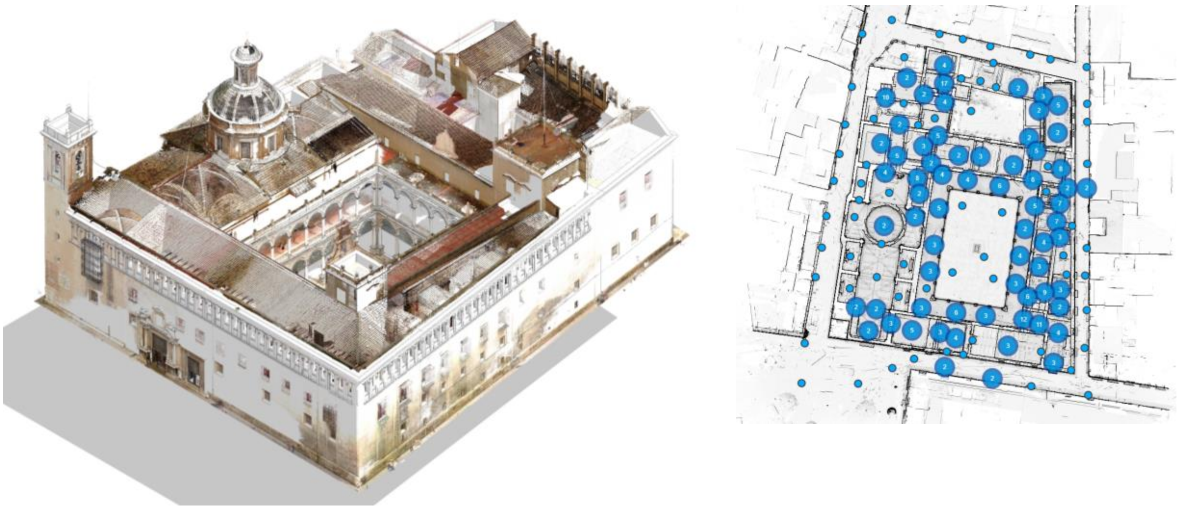

**Figure 6**. Left. Perspective of *El Patriarca* extracted from the point cloud. Right. Scan positions of *El Patriarca*. Source: Rolim, R.

**Figure 7**. Orthophoto of *El Patriarca*'s longitudinal section through the cloister extracted from the point cloud. Source: Rolim, R.

The *San Juan del Hospital* scan lasted 16 hours. 152 scans were performed with an average error of 3.1 mm. (López-González & García-Valldecabres, 2023). To scan the route, careful prior programming was carried out to avoid peak traffic hours. It lasted 2 days, performing a total of 94 scans with an average error of 4.7 mm. (García-Valldecabres et al., 2023).

### 3.3. Results related to environmental quality monitoring

The advice, selection and placement of the different sensors in the selected buildings has been carried out by the SMART monitoring research group of the Universitat Politècnica de València made up of professors Juan Soto, Manuel Valcuende and José Manuel Gandía and Professor Antonio Galiano of the University of Alicante.

The following have been used as risk indicators:

- In the case of $CO_2$ measurement, 900 ppm has been taken as the acceptable limit value. Higher values imply an excess of visitors
- Humidity: Those situations in which the dew humidity coincides with the relative humidity have been taken as a risk value because it implies the formation of condensations. Temperatures above 35º imply a lack of comfort for the visitor and can damage certain materials.
- When the sensors exceed any of these indicators, they launch an alert through HBIM, producing a heat map that is easily visible due to the colour acquired by the digital twin, and easily visible by the tour managers.
- Large increases in $CO_2$, temperature and humidity have been detected coinciding with a large influx of people in the chapel of the Holy Chalice of the *Cathedral*, as well as in the church of *San Juan del Hospital*. However, no considerable increases are seen in the apse of the *Cathedral* or in the church and archive of *El Patriarca*. This implies the necessary incorporation of forced ventilation in the two most conflictive spaces.

This is due to the small space of the Holy Chalice Chapel and the large influx of people it has with long-term visits. This is not the case in the apse of the *Cathedral*, where the large space of the temple, its great height and the ventilation that occurs through the dome weaken the problem (Figure 8).

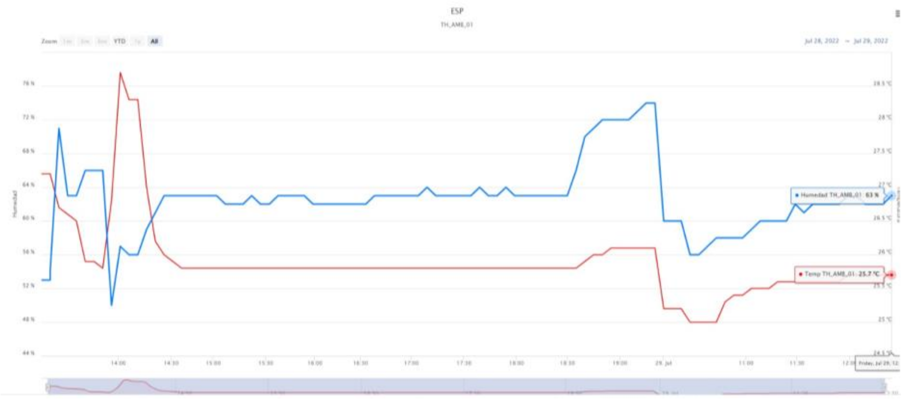


**Figure 8**. Graphs of humidity and temperature in the month of July in the Holy Chalice Chapel (*Cathedral* of Valencia)

### 3.4. Results related to the integration of HBIM in GIS

The ArcGIS Pro software being used allows direct implementation of HBIM in the GIS (Figure 9). In addition, digital twins of the three buildings have been created to store the real-time information that has been generated with each type of sensor. They have been developed through a 3D-GIS model prototype in which the LoD-200 HBIM digital twins of the three selected buildings are incorporated. The LoD-200 does not reach a great level of detail regarding the morphology of the elements; however, it is more than enough to incorporate the databases that are associated with the HBIM models of the selected buildings coming from the results of the sensors.

**Figure 9**. Visualisation of the integration of digital models in the GIS in the historic centre of Valencia.
Source: Orozco Carpio, P.R.

## 4. Conclusions

The research carried out has shown the effectiveness of integrating the data included in the HBIM into a GIS. This allows us to verify the interconnection between the data related to the number of visitors with the data provided by the sensors in each space or room of each building.

The effortless visualisation of this data through digital twins integrated into a GIS will allow the manager of the cultural visit to program routes that avoid exceeding the carrying capacity of visitors, and the levels of $CO_2$, temperature and humidity that could compromise comfort and safety of visitors. At the same time, it should be noted that it represents a very powerful tool for the preventive maintenance of heritage assets, thus making the management of public use and cultural heritage more sustainable.

In conclusion, this research project highlights the use of the HBIM-GIS integration tool for the evaluation and management of tourist visits. Its use is compatible, both in buildings and in urban environments, contributing to more efficient and more sustainable heritage management.

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# The blue domes of Valencia: the challenge of their digitisation

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***Abstract***

*The blue domes are perhaps the architectural element that best defines Valencian architecture. These structures, present in numerous historic and religious buildings, beautify the urban landscape and represent the region's rich cultural and artistic heritage. However, despite their importance, no clear strategic plan exists for their enhancement and conservation.*

*Creating a specialised digital repository for the blue domes of Valencia is an urgent necessity. This repository should include a comprehensive typological classification, documenting each dome's architectural and stylistic characteristics. Advanced technologies such as 3D scanning and photogrammetry can capture and store precise details of these structures. The HBIM methodology can be beneficial, allowing for the integration of detailed data on each dome's construction, materials, and conservation status.*

*A well-organised repository would not only facilitate better heritage management but could also be linked to cultural tourism. Valencia has great potential to attract tourists interested in architecture and history. Promoting tourist routes centred on the blue domes can increase the visibility and cultural value of these elements. Furthermore, the repository could be vital for academic and professional research. Researchers, art historians, and architects would have access to a complete and detailed database, facilitating studies and conservation projects.*

***Keywords:*** *HBIM, dome, repository, evaluation, digitisation.*

## 1. Introduction

As a result of various heritage restoration interventions on domes carried out in recent years, a lack of documentation and technical information has been identified as a prior need for their study or intervention, such as architectural surveys, construction dates, typology, materials and techniques used, etc. This situation has become particularly evident in emergency and/or urgent interventions, where action has had to be immediate.

Although we could determine that domes originate from Eastern construction (Patetta, 1984), blue domes are the DNA of Valencian architecture, especially from the Renaissance and for more than four centuries up to the 20th century, when the Industrial Revolution introduced other materials, such as concrete and steel. The domes are not only a visual aspect—many remain landmarks of the urban landscape and the skyline of many Valencian towns—but also form a constructive artefact demonstrating the mastery of a centuries-old construction tradition. Specialists in structures, architecture, and construction have admired these domes. It is difficult to establish an ordered category regarding their typologies, as each restoration uncovers surprising data, such as brickwork, construction arrangement, brick sizes, etc.

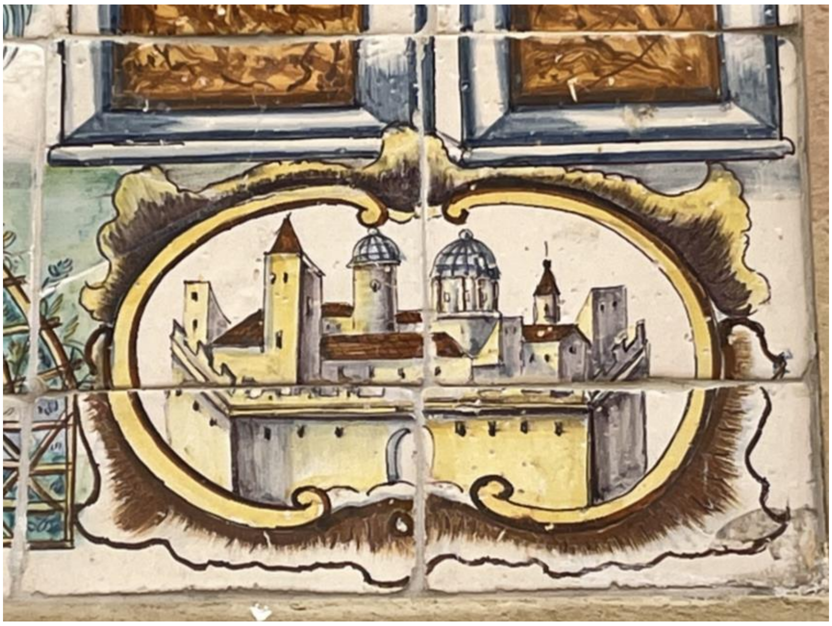

**Figure 1.** A partial image of the 1786 ceramic panel of Our Lady of Consolation on the façade of the Church of Saint Thomas and Saint Philip Neri in Valencia depicts two domes in the skyline of a walled town. Source: Cortés, L. (2016).

In this sense, innovative studies emerge on significant domes such as Santa Maria del Fiore (Fanelli, 2022) and the Pantheon (Masi, 2018). Although heritage preservation means conservation and restoration, the Valencian heritage law provides the legal framework for conserving, disseminating, promoting, and enhancing cultural heritage within the territorial scope. There is no doubt that the blue domes of Valencia are a hallmark of the Valencian people and a testament to their contribution to culture; not only the Valencian domes but domes, in general, are a universal heritage. Remember that in the logo of the prestigious entity Europa Nostra, we can see the silhouette of a dome in the centre.

This is why a scientific initiative is being launched to highlight the value of the Valencian domes, characterised by the blue of their tiles, with the main focus being their digitisation to establish a comprehensive catalogue.

## 2. Objectives

The main objective of this communication is to highlight the value of Valencian domes through an initial protocol for their digitisation and integration into cultural use, such as tourism. This initiative aims to generate positive impacts for the monuments and/or communities hosting domes. Promoting cultural tourism can stimulate job creation and wealth, especially in smaller communities facing depopulation due to low birth rates and youth emigration seeking opportunities.

As the digitisation of the domes progresses, information can be collected in an accessible repository for tourist use, either through websites or by installing informative signs in the monuments, accompanied by QR codes to provide additional information to interested visitors. In this sense, it is understood that digitisation and sustainability are closely linked in the pursuit of more efficient and responsible development. However, further research is needed to adequately address this aspect, representing a proposed research direction.

Additionally, issues related to training specialised personnel and preserving these construction techniques and architectural typologies are raised. This could include organising specialised seminars or workshops and integrating these topics into vocational training programs or university degrees in Architecture and Technical Architecture.

## 3. Object of study

Domes in Valencia began to be constructed during the Renaissance, following the Council of Trent (1545-1563), with the first being the dome of the Church of Corpus Christi (1595). However, the heyday of domes in Valencian architecture occurred in the 17th and 18th centuries, adorning numerous churches and civic buildings. These domes were primarily built in new chapels dedicated to the adoration of the Sacrament, with a centralised plan located on one side of the existing Gothic churches, which were being renovated with a new coating to suit the period's aesthetics.

With its oval dome, the Basilica of Our Lady of the Forsaken symbolises Valencian Baroque. The dome reached its largest possible dimension in 1770 with the construction of the Church of the Pious Schools, 24.5 metres, within the prestigious group of great European domes. The Royal Academy of Fine Arts of San Carlos holds many designs from the last third of the 18th century (Soler, 2017). The dome of the Central Market, built in the early 20th century, reflects Valencian Modernism and its ability to fuse tradition and innovation, with Rafael Guastavino being the foremost exporter of this tradition to North America in the 20th century. Although hundreds of domes that could be cited as Valencian still stand, there was a period of fear of building them due to many documented collapses during the 18th century (Gil, 2015).

Domes in Valencia represent several significant aspects of the culture and history of the entire Valencian territory:

a) Wealth and power: Domes, especially in religious and civic buildings, symbolise the wealth and power of the institutions that built them. Their majesty and ornamentation reflect the prosperity of Valencia in different eras.
b) Architectural development: The presence of domes in many historical buildings shows the architectural evolution of Valencia from the Renaissance to Modernism. Each dome reflects the trends and construction techniques of its time.
c) Cultural heritage: Domes are integral to Valencian cultural heritage. Buildings such as the Basilica of Our Lady of the Forsaken and the Church of the Pious Schools stand out for their domes and are essential landmarks for locals and tourists.
d) Spirituality and religion: In churches, domes symbolise the connection between heaven and earth, representing a sacred space and elevating the spirituality of the faithful.

**Figure 2.** The dome of the Church of the Pious Schools of Valencia during its restoration in 2024. Source: Cortés, L. (2024)

## 4. Methodology and Procedure

When discussing cataloguing, we find ourselves in a situation comparable to standing at the edge of a well. Initially, the full extent of the issue is unknown. The task of cataloguing involves facing uncertainty regarding the quantity, diversity, and complexity of the elements to be classified. It is a process that can reveal unknown depth and breadth in its early stages, requiring patience, organisation, and a methodical approach to adequately explore and document all available content.

In this case, cataloguing inherently includes digitisation; digitising to preserve originality is essential. Originality is maintained because, in a restoration or repair project, the original appearance can be restored by having control over its shape and typology. This is especially important in disasters where collapse or significant damage may require reconstruction. Digitisation provides a detailed and precise record of the original state of objects, allowing any future restoration or reconstruction to be carried out with an exact reference, thus ensuring the integrity and authenticity of cultural heritage. An example is the dome of the Church of Sales in Sueca, which has already had six different domes in just 250 years since its founding (Cortés, 2024).

Carrying out cataloguing with its corresponding digitisation depends on several factors, primarily economic factors. This process can be developed through a research project, doctoral thesis, or professional cataloguing work, requiring institutional (political) support in the latter case. Similarly, as in the 1980s when the Conselleria de Cultura of the Generalitat Valenciana commissioned a comprehensive study of monuments to create the Catalogue of Monuments (Bérchez, 1983) after the competencies were transferred to the autonomous communities, a catalogue of domes can be proposed. Another idea, following the collapses of the domes of Crist de Benigànim, Sumacarcer, Sueca, and Massamagrell, or the vault of the Church of Sollana, is for the Administration to formalise a Dome Evaluation Report, similar to the existing one for houses over 50 years old.

Although we are currently at the beginning of a long process and there is no ongoing research apart from articles in research journals, a working methodology is proposed that addresses the scientific documentation of the domes and cultural awareness.

On 13th March 2023, the proposal to introduce the Valencian blue domes as UNESCO World Heritage was initially presented to the national deputy for Valencia, the Most Excellent Mrs Alma Alfonso, in the Congress of Deputies (Madrid). Valuing these highly significant structures, vestiges of the knowledge and construction tradition of Valencian masters will serve as the foundation for the entire process.

**Figure 3.** Submission of the proposal for including the Valencian domes as UNESCO World Heritage by Luis Cortés to the Most Excellent Mrs Alma Alfonso at the Congress of Deputies, Madrid (Spain). Source: Cortés, L. (2024)

The study methodology is initially defined based on the intervention in the largest Valencian dome, which, if we're talking about ceramic tile roofing systems, would be the largest in Spain, funded by the Spanish government through a direct grant.

Regardless of the historical study, the first task would be graphic surveying, which must be approached with precision and state-of-the-art technology such as 3D laser scanning (TLS). The main advantage of this method is that it allows us to obtain a point cloud to represent the virtual dome in three dimensions, with a registration accuracy ranging from 1 to 2 mm. This system facilitates data collection on thickness, shape, curvatures, collapses or other defects, the number of tiles, and even an initial assessment of pathologies in its coating (García, 2024).

Taking photographs with cameras and aerial images with drones is complementary and necessary for optimal graphic representation. Ground-level photographs capture details and textures, while aerial images provide an overall view and a unique perspective of the domes. This combination of techniques ensures complete and accurate documentation, facilitating cataloguing, research, and restoration work. Drone technology, in particular, allows access to angles and heights that are difficult to reach, significantly improving the quality and comprehensiveness of the visual record of architectural heritage.

An intermediate phase would be creating the HBIM (Heritage Building Information Modelling) model, where 3D modelling is generated, and data from laser scanning and photogrammetry are incorporated into the model.

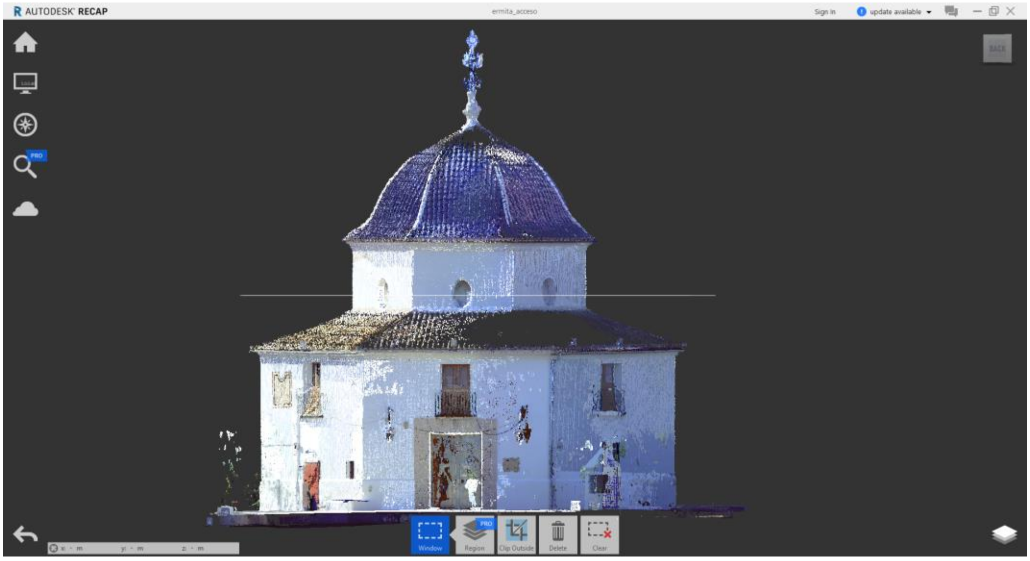


**Figure 4.** Point cloud modelling of the Sant Bernat de Carlet dome in the Autodesk® ReCap® Pro program.

From the pathological study, based on the graphic survey, the following aspects can be determined:

1. Conservation Status: Identify deteriorated areas, cracks, detachments, and other structural damages.
2. Materials and Construction Techniques: Analyse the original materials and construction techniques employed.
3. Causes of Deterioration: Determine the underlying causes of the damages, such as moisture, pollution, or structural movements.
4. Previous Interventions: Detect and evaluate previous restorations, their quality, and their impact on the structure.
5. Restoration Plan: Develop an appropriate and specific intervention plan for the structure's needs, ensuring its stability and future preservation.

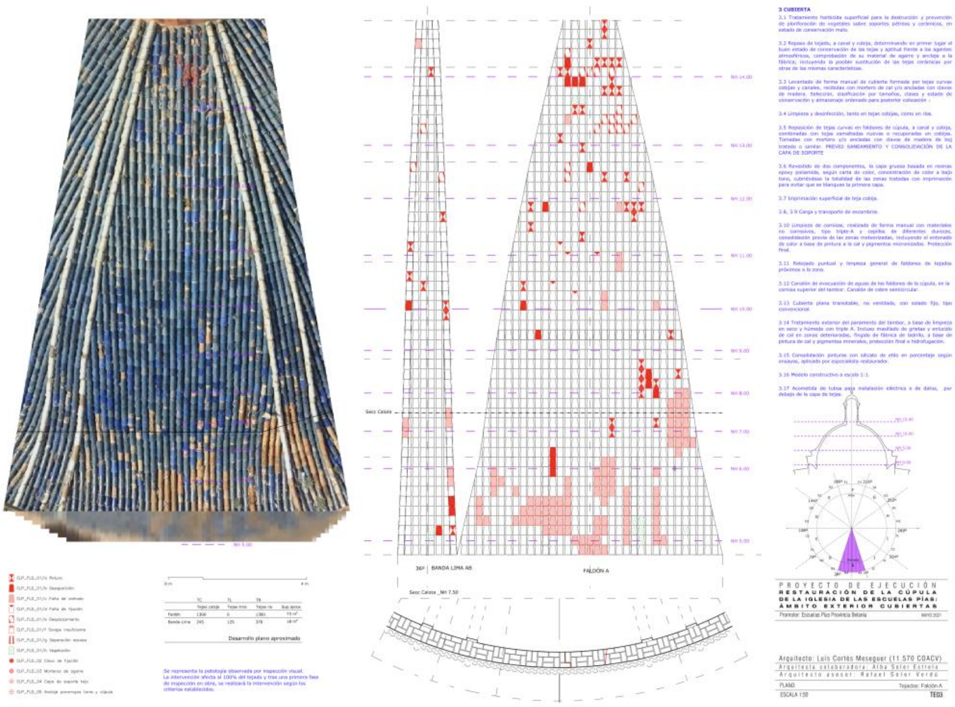

**Figure 5.** Pathological study of the execution project in the Church of the Escuelas Pías in Valencia. Source: Cortés, L. (2022)

This comprehensive approach allows for informed and precise decision-making regarding the conservation and restoration of architectural heritage and the management of budget and project execution, thereby avoiding unfortunate interventions with improper materials or techniques. Additionally, it provides an initial assessment of the dome's originality and identifies any significant repairs at first glance. It's worth noting that determining its construction material can be complex without the necessary core samples.

Following the initial steps of digitisation and pathological study, including structural and built artefact analysis, the classification of domes can be determined based on various parameters:

- *Number of layers*: It can be single or double, with the latter having an air chamber.
- Construction technique: tabicada (tiled) or aparejada (brickwork), with tabicada being thinner than aparejada.
- *Type of tile*: curved ceramic, fish scale, or Roman tile.
- Construction date: crucial for understanding the technology used.
- *Authorship*: requires collaboration with specialists to attempt identification.
- Shape of the drum's floor plan: can be circular, octagonal, or even heptagonal in cases like the hermitages of Nules and Carlet.
- *Number of dome sides*.
- *Shape of the dome:* hemispherical, parabolic, etc.
- *Architectural style:* likely Baroque or Neoclassical, possibly with Renaissance influences.
- *Presence of lantern:* If absent, there's usually a stone top with a metal cross and/or weather vane.
- *Tile colour: natural brown and green, though blue-glazed* tile is characteristic.

This classification can be further subdivided according to Soler's tabicada construction type (Soler, 2015), which includes categories such as "trasdosadas" (backed) or "sin trasdosar" (without backing), with various subtypes for single and double-layer constructions.

Consideration should be given to creating a repository connected with local administrations and the General Directorate of Heritage of the Valencian Government, documenting all restoration interventions on the domes. This would gradually increase the number of cases studied and their classification.

Furthermore, this study facilitates the planning of future interventions for building conservation and restoration and the generation of detailed documentation and management of information related to future projects through Building Information Modeling (BIM). The application of BIM in the conservation of architectural heritage improves the accuracy and efficiency of restoration projects and ensures more sustainable and effective long-term management.

## 5. Results

The main results have arisen from recent architectural interventions in domes, revealing a significant lack of maintenance in buildings and, therefore, in their heritage assessment. On the other hand, publications and press articles highlight the importance of preserving architectural heritage. These communications raise awareness and educate the public about the historical and cultural value of buildings and restoration efforts. Media coverage helps generate social, economic, and political support, which is essential for conservation projects. Additionally, it promotes civic participation and recognition of heritage as an integral part of a community's identity and collective memory.

**Figure 6.** The Dome of the Church of Massamagrell was built in 1953 and restored in 2022. Source: Cortés L. (2024)

After presenting the intervention project with the proposed study methodology to the Ministry of Development in 2020, the Spanish Government, included in the General State Budget for 2022, is funding the restoration of the largest Valencian dome with an amount of one million four hundred thousand euros.

The national deputy, Mr Borja Sémper, is responsible for managing the proposal to include the blue domes on the UNESCO World Heritage List, which will require reports from various prestigious institutions such as Docomomo to support its presentation.

Another result of this knowledge process is precisely the opposite of the approach to the preservation study of Valencian domes; the construction material has been reversed because the finishing material was not suitable for its structure. An example is the Sales church, whose dome was built in 1898 with a metal structure and a zinc sheet covering. In 1919, it was rebuilt using the same metal structure, but an outer layer of brickwork and blue fish scale tiles was added. However, a defective construction joint was found at the eaves, allowing water to enter the interior. The resulting condensation favoured the oxidation and corrosion of the reinforcement, generating solid tensions in the structure and breaking the blue tiles, which were in a completely vertical position. Other design errors also influenced the decision to replace the masonry arrangement with ceramic tiles with a lighter one made of Tecu (oxidised copper), reducing the weight from 60 to 6 tons (Cortés, 2024).

**Figure 7.** Based on the study methodology, the dome of the Sales church in Sueca was reconstructed.
Source: Cortés, L. (2022)

## 6. Conclusions

The domes are the DNA of the masonry construction tradition deeply rooted in Valencia after the Gothic era, and they should be valued, not only through dissemination in books.

Recent interventions following partial collapses highlight the need to undertake conservation studies to prevent future collapses that could result in tragedies. These studies should adopt a standardised methodology to unify criteria as part of a protocol.

Having a documentary and graphic repository of the domes enables the responsible technician to know what they are dealing with in emergencies, avoiding delays in the preliminary study process for project drafting. Additionally, in cases of existing pathological injuries that could cause partial collapse or deterioration, it can serve as a demonstration to society for their conservation. It could be used for crowdfunding or financial support.

The conclusion would be to propose future lines of research to undertake more exhaustive studies and compare them with other domes worldwide.

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# Digital Documentation as a tool for enhancing the value of dispersed defensive architecture in the Valencian geography

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***Abstract***

*The small towns in the inland regions of Castellón boast a rich architectural heritage and remarkable natural surroundings. Much of this heritage is scattered throughout the Castellón mountains as a tangible witness to the Spanish Civil War. These are kilometres of trenches, and countless defensive elements traverse this landscape, seamlessly integrated into its history. This architecture has been gradually rescued from oblivion since it was included as part of the historical and cultural heritage in Valencian legislation in 2017. Its constructions hold significant value as part of our historical memory and from the perspective of military architecture. Therefore, their formal and constructive analysis provides indispensable information for their comprehensive understanding, conservation, and transformation into a tourist resource. This paper presents the results of studies conducted in the inland municipalities of Castellón through which the XYZ defensive line runs, traversing the province from east to west. In addition to compiling the necessary documentation of this heritage, the aim is to provide the small towns where it is located with tools to leverage this heritage to boost cultural tourism.*

***Keywords:*** *XYZ Line, trenches, civil war, Castellón, rural tourism, architectural heritage.*

## 1. Introduction

In recent years, there has been a growing emphasis on a 'new' form of tourism linked to recent historical memory, particularly spaces directly associated with armed conflicts. This is evident in the case of the Spanish Civil War, which led to the creation of numerous defensive infrastructures. After over eighty years, remnants of these structures can still be found throughout the country, seamlessly integrated into the landscape.

Architectural heritage is a symbol of history and a potential tourism resource. One of the driving forces behind tourism has always been the knowledge of different cultures, with a particular interest in landscapes and architecture, leading to what is known as cultural tourism. Properly managed, it is an opportunity to enhance the culture and heritage of a community, as well as contribute to local development, and should be considered among the strategies that enable the progress of a territory.

The new interests of visitors allow for the expansion of the tourism offer. One of the emerging trends is the development of tourist routes, which are created by visiting different places connected by a common theme. The heritage of the Civil War, properly located and signposted, can be part of this cultural itinerary. (González et al., 2022)


**Figure 1.** Cultural Tourism, Viver. Source: own work (2019).

In the Valencian Community, these constructions were officially recognised starting from the year 2017, with the approval of the modification of the Valencian Cultural Heritage Law (Law 9/2017, of April 7, of the Generalitat, modifying Law 4/1998 of the Valencian Cultural Heritage), according to which all military constructions built during the conflict became part of the local heritage of Valencian municipalities.

In fact, the approval of Law 16/1985 of June 25 on Spanish Historical Heritage marked the first official protection for historical sites in Spain, defining them as areas with historical, cultural, or natural significance. This law delegated protection responsibilities to municipalities, requiring them to draft special protection plans or other planning instruments.

Thirteen years later, the Valencian Government adopted Law 4/1998, of June 11, on Valencian Cultural Heritage, mirroring the state law emphasising the protection of historical sites and introducing the 'Local Relevance Real Estate' concept. This concept was further expanded by Law 5/2007, of February 9, of the Valencian Government, categorising these assets into monuments, historic gardens, and archaeological protection areas.

To streamline municipal actions, DECREE 62/2011, of May 20, of the Consell, was approved, regulating the declaration and protection of local relevant assets. It defined Historical Sites of local interest as places with significant value for popular memory.

Lastly, Law 9/2017, of April 7, of the Generalitat explicitly recognised civil and military constructions from the Civil War, amending and expanding the categories of architectural elements considered local relevance assets. This law also initiated a specific inventory of these heritage assets, including detailed records of the constructions related to the XYZ Line.

Since then, various municipal initiatives have emerged to recover and enhance this type of heritage. On the one hand, it aids in understanding a unique historical moment. On the other hand, it increases cultural offerings and the possibility of visits and activities in lesser-known and often sparsely populated areas. In the context of the province of Castellón, 89 out of its 135 municipalities have fewer than 1,000 inhabitants, 115 have fewer than 5,000, and in 43 municipalities, the population density is below ten inhabitants/km2 (INE, 2019), with many facing significant depopulation challenges.

**Figure 2.** Bunker, Viver. Source: own work (2019).

## 2. Aims and objectives

The objective falls within the realm of architectural heritage studies. In this case, it aims to enhance the value of poorly studied military construction remnants scattered in a mountainous environment. Starting from historical studies, documentation is generated, primarily of a graphic and constructive nature, as a contribution to their understanding.

## 3. Methodology

The methodology follows a sequence of steps, beginning with the search for existing information, locating existing military remnants, and determining those to be studied in depth. Conversely, data collection 'in situ' is carried out for subsequent graphic representation and constructive study.

### 3.1. The historical context. The XYZ or Matallana defensive line

The Battle of Levante was crucial in developing the Spanish Civil War. Unlike other fronts, the Republican faction conceived the Levante front as a defensive strategy to halt the advance of the rebel troops towards Valencia, the then-capital of the Republic and the main supply port for Madrid.

This was achieved by constructing a defensive network of three lines deployed along the Castellón mountain range. Among them, the XYZ Line, also known as the Matallana Line in honour of the Republican Colonel Manuel Matallana Gómez, stands out for its extent and strategic value during the war.

After the Aragon offensive in March 1938, with which the rebel army managed to reach the Mediterranean and to prevent the rebel troops from breaking through this defensive line, as had happened on other fronts, 14 Resistance Centers were established as key points, distributed throughout the province of Castellón, from the mountains north of Almenara to Santa Cruz de Moya in the province of Cuenca. (Military General Archive of Ávila)

In addition to these main centres, secondary support points were constructed to ensure defensive continuity, supporting the main centres and allowing the withdrawal of troops in case of enemy penetration. The new defensive structure had a depth design, with resistance points at the forefront and rear of the main line, separated by 2 to 6 km. (Galdón, 2011)

As the conflict continued, the defensive system was expanded with new resistance centres built by the rebel faction. In total, these fortifications occupied a swath of land 10 to 15 km wide in the areas of greatest combat, extending along 150 km with trenches, bunkers, and various structures, constituting the largest fortified line in the history of Spain. In total, the XYZ Line passes through 46 municipalities, of which 40 are located in three regions of the province of Castellón: 3 in Alto Mijares, 14 in Plana Baixa, and 23 in Alto Palancia. (De Manuel & Gil, 2018).

### 3.2. List and location of elements

After the Spanish Civil War ended, many of the defensive infrastructures were forgotten and, over time, disappeared. However, the resilient materials used in their construction have allowed numerous remnants to be preserved more than 80 years after their creation, becoming part of the landscape and blending with it.

The valuable information collected in the regional inventories, organised by municipalities and regions, is complemented and updated with data provided by the localities themselves in their dissemination efforts and by numerous associations dedicated to preserving this historical heritage. Many of these associations have been active since before the approval of Law 9/2017 and have played a crucial role in locating and preserving this historical legacy.

The result is a list of the 40 municipalities in Castellón through which the XYZ Line runs. This list includes the elements inventoried by the Valencian Government, those catalogued by local municipalities, and additional information provided by nonprofit associations, thus enriching the overall understanding of the ensemble.

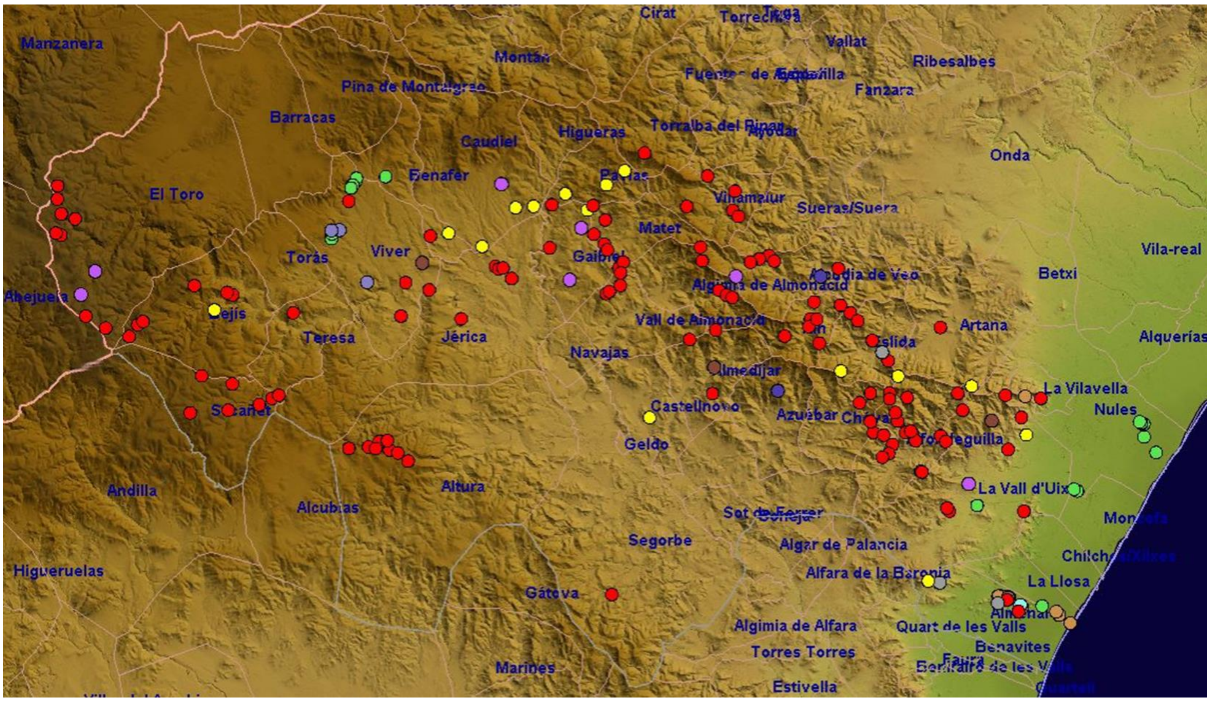


**Figure 3.** Location of local interest assets along the XYZ Line inventoried by the Valencian Government
Source: Based on the Cartographic Viewer of the Valencian Government (2020).

The research has allowed the identification of a variety of elements, such as trenches, parapets, shelters (both anti-aircraft and natural), fortified positions, machine gun nests, observation posts, bunkers, forts, sniper posts, fortified warehouses, command posts, airfields, funerary monuments, and national camps, among other military constructions. These elements are distributed across 33 municipalities in the province, primarily concentrated in the regions of Plana Baixa and Alto Palancia, although they are also found in Alto Mijares. (Cabeza et al., 2020).

### 3.3. Data collection and preparation of graphic documentation

To accurately document the state of these constructions, it is essential to perform on-site data collection. In planning the work, it was necessary to consider the difficulty of accessing many elements to be studied.

With the previously gathered information, we could expedite the location of various remnants, prepare the necessary equipment, and establish routes to optimise fieldwork. We used traditional direct measurement systems supplemented by photogrammetry techniques for on-site data collection.

In cases where the simplicity of the forms and the accessibility of the element allowed it, measurements and data collection were conducted directly on-site, supplementing the information with detailed photographs. In situations where the irregular shape of the element hindered precise data collection, photogrammetry allowed for accurate dimensions and shapes of the most complex surfaces to be obtained, such as in the case of elements excavated in the terrain and, in addition, to enable the creation of a high-resolution virtual model which provide not only geometric data but also surface details. This data enhances the elevations with orthographic images and facilitates the creation of virtual reconstructions and interactive tours of the shelter interiors.

This data collection has enabled the preparation of graphic documentation through its plans and sections, which provide insight into its configuration and dimensions. Furthermore, georeferencing has been carried out, and in the case of urban shelters, this data can be exported for integration into broader Geographic Information Systems, such as the one provided at the regional level by the Institut Cartogràfic Valencià of the Generalitat Valenciana (Cabeza et al., 2023).

## 4. Results

From the procedure described above, we have gained insight into a significant sample of these defensive architectures, whose execution was determined by their location, sometimes to take advantage of the terrain and other times to obtain the material to build these structures.

To illustrate the work, below is a series of military constructions corresponding to Resistance Center Number 1 of the XYZ defensive line, Almenara-La Llosa (Cabeza et al., 2021). Through the preparation of scale drawings, the architecture has been defined.

The graphic representation of the studied elements was carried out by directly transferring the obtained information and elaborating on the corresponding orthographic views. Due to the poor condition of most of the remains, the focus has been on developing plans, and in the case of better-preserved elements, sections are provided. Given the irregularity of the study models, shading has been used as a graphic resource to intuitively express the depth of the different planes on which the element surfaces are located. The result can be appreciated in the four models presented below, selected as a representative sample of the different typologies studied.

An example is these two pillboxes located on a marsh near the coast, built on an approximately circular concrete platform of about 300 m². Both pillboxes have similar characteristics and are in the same state of preservation, with only the lower part of the concrete walls that originally supported the roof. The plan has a keyhole shape, with the casemate located at the circular end featuring three embrasures, accessed indirectly from the other end through an L-shaped passage. Between the two ends, near the entrance, there is a hole in one of the walls used as a storage area. With a total length of just over 6.5 meters and a maximum width of 3.7 meters, the thickness of the walls varies from 60 cm at the entrance to over 100 cm at the embrasures.

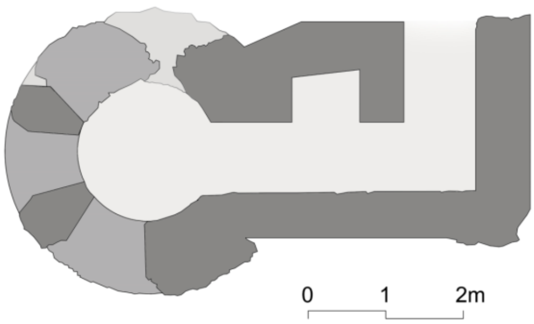


**Figure 4 - 5.** Located on a marsh near the coast. Source: own work (2020).

An opposite case is this other pillbox, called a mine type. Partially excavated in the terrain itself, externally, it appears as just another rocky mound in the mountain, barely recognisable by the openings that form its four embrasures, one of them sealed. The irregularity of the large interior space follows a curved guideline along which the embrasures are serially arranged, distinguishing two areas, one on each side of the entrance, with the one oriented to the east being larger. Its access is through the top, vertically through a rectangular hole measuring 60 x 80 cm. At its bottom, this prior space communicates laterally with the eastern end of the main cavity. The rest of the sides are formed by the terrain itself and a concrete wall supporting the roof. The free height inside the main cavity reaches 180 cm in certain areas, although, in most areas, it does not exceed 160 cm.

 

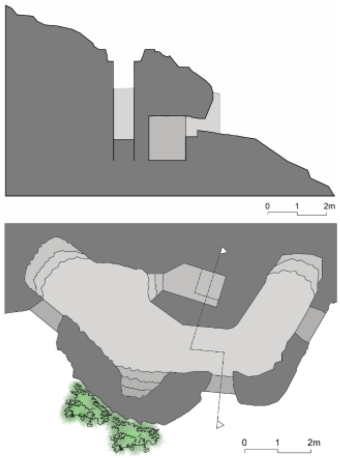


**Figure 6 - 7.** Pillbox mine-type. Source: own work (2020).

Halfway between the previous ones, the next bunker has characteristics similar to the first but in mountainous terrain. It is better preserved and shows part of the roof, corresponding to the access corridor to the casemate with a free height of less than 180 centimeters. It is a vaulted roof finished on the outside with local stones dropped, aiming to camouflage the presence of the bunker from the sky. In this case, the casemate is semicircular with a radius of 2 meters inside and has four embrasures. The access to it also occurs through an L-shaped corridor, which in this case is slightly sloped towards the casemate and is approximately half the length of the previous bunker. The thickness of the walls also varies from one end to the other, showing the same dimensions as the previous example, 60 cm at the entrance and over 100 cm in the curved wall enclosing the casemate.

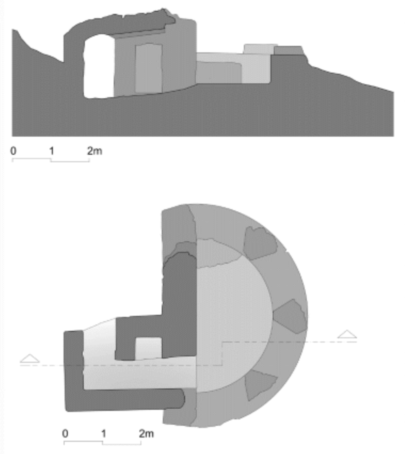


**Figure 8 - 9.** Bunker in mountainous terrain. Source: own work (2020).

The last drawing corresponds to an observatory at the top of a hill. It is built with stone walls reinforced with cement mortar, using remnants of the fortification that runs along this hill's southern slope and is embedded in the old wall. It is a buried rectangular enclosure without any covering, approximately 2 meters long, 1 meter wide, and 1.2 meters high. The access is through the usual L-shaped passage. Its north front is topped with a large embrasure, while the side wall to the east has a storage area embedded within the wall itself.

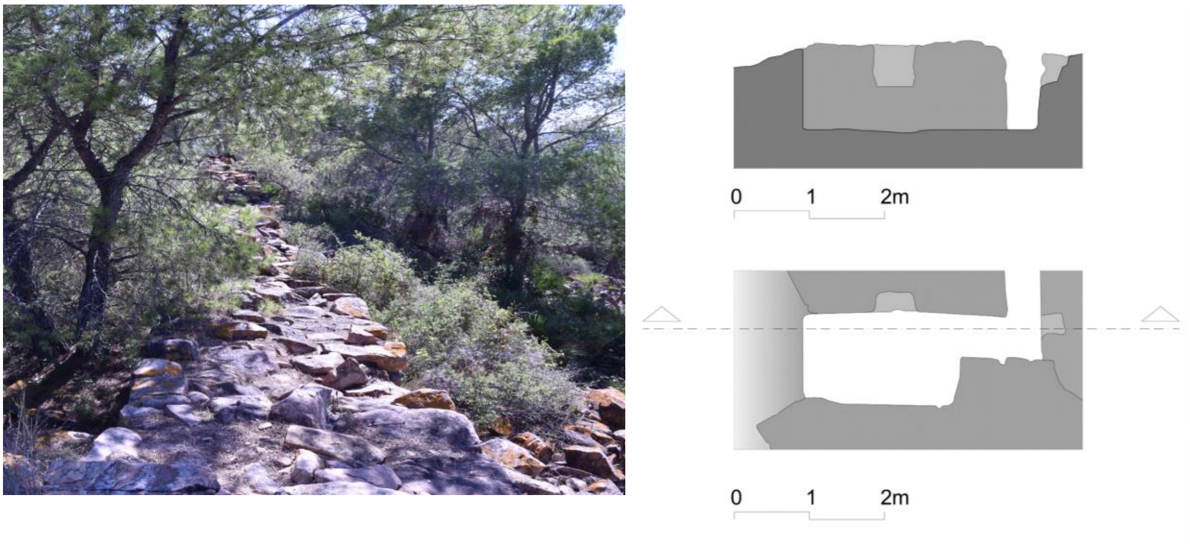


**Figure 10 - 11.** Observatory. Source: own work (2020).

## 5. Conclusions

The cases studied correspond to remains of military constructions that emerged during the Spanish Civil War, which are testimonies of great historical interest. Their dissemination contributes to increasing the knowledge of our past and enhancing the cultural tourism offerings. In this sense, their location, cataloguing, and study of their architecture and construction are shown as indispensable tools for this purpose. For example, a methodology of graphic study has been illustrated, allowing architectural descriptions to be made through scaled plans and enabling detailed understanding. It is a contribution, through graphic surveys, to the knowledge of a little-studied heritage, with the possibility of being incorporated into cultural tourism routes in municipalities in territorial contexts of abandonment and depopulation, which can promote revitalisation and local development.

## 6. Funding

This work has been carried out thanks to Jaume I University through the UJI-A2017-I3 Project "Formal and Constructive Analysis of Civil War Defensive Architectures in the Regions of Castellón" Scientific Research and Technological Development Projects.

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# Visitor Centre for the revaluation of Industrial Heritage: The Averly Foundry

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## *Abstract*

*The old Averly Foundry is in Zaragoza, specifically at number 59 of the current Paseo María Agustín. Its activity began in the eighteenth century, creating strong economic ties around the Ebro Valley. The availability of water and the strategic location were strengthened in the mid-nineteenth century by railway communication. These factors particularly facilitated the development of the flour industry, which was concentrated in the river artery and Zaragoza.*

*To ensure the survival of the preserved buildings, a rehabilitation is proposed by a multidisciplinary team sensitive to heritage, which will seek a reconstruction faithful to the origins of the property, maintaining the authenticity of the architectural language and the clarity of the additions, respecting the buildings.*

*From this new centre, various guided tours will depart, focused on the appropriate sensitivity according to the theme. In this way, the urban growth of Zaragoza from its origin to the present day will be explained. For the industrial stage, the visits will be carried out on the grounds of the Foundry, using elements preserved in situ, such as moulds, architectural typologies, garden, machinery and the musicalisation of the family home.*

***Keywords****: Averly-Foundry, centre, architectural typologies.*

## 1. Introduction and background

The old Averly Foundry is located in Zaragoza, specifically at number 59 of the current Paseo María Agustín, one of the streets of articulation of the city near the centre. It is a space well connected to various public areas.

A few meters from its location, there are some historical landmarks, such as the city's medieval wall and the Aljafería Palace, and two other more contemporary buildings such as the CaixaForum and the Pablo Serrano Museum, located on the same street.

The activity of the Foundry began in the eighteenth century, creating strong economic ties around the Ebro Valley. Water accessibility and strategic location were strengthened in the mid-nineteenth century with railway communication. These factors particularly facilitated the development of the flour industry, which was concentrated along the waterway and especially in Zaragoza[1].

As mentioned, in 1863, the factory was founded by Antonio Averly, an engineer from Lyon who decided to establish his company in Zaragoza, thanks to financial opportunities. The workshops changed locations until they settled beside the Campo Sepulcro railway station. The economic situation was favourable, and the city had already begun to see the emergence of the first public works constructed in metal[2] (Figure 1).

The engineer Luis de la Martiniere was the author of this bridge, and it is believed that perhaps the arrival of engineers such as Antonio Averly, among others, is linked to him. Thus, the entry of French engineering into Aragón is related in this context[3].

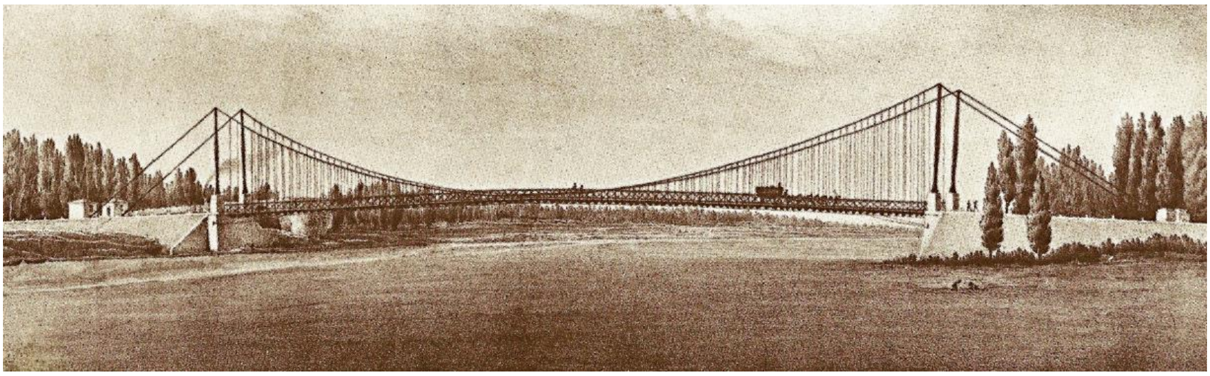

**Figure 1.** Iron bridge over the río Gállego. Source: https://www.memoriadesantaisabel.com/historia-del-puente/ Accessed: 06/05/2024.

In 1853, Averly and his partners founded his first company in Aragon, dedicated to the foundry and construction of machinery. In 1863, the engineer Antonio Averly opened his workshops on San Miguel Street. He established several partnerships over the next two years to expand his market.

1885 was the year of the emergence of the great Basque steel mills, and Antonio founded "Averly y Cia. Fundiciones y Construcción Mecánica de Nervión" in Bilbao. A few years later, between 1894 and 1910, the period of maximum national expansion came with participation and recognition. At this time, they were already

[1] Sora, A.S. (2000). Especialización flexible y empresa familiar: la fundición Averly de Zaragoza (1863-1930). *Revista de Historia Industrial*, 61-95.

[2] The iron bridge over the Gállego river, located in the Santa Isabel neighbourhood. Built between 1839 and 1844. It was in service until 1930, when the new bridge was built. Blázquez Herrero, C. Sancho Marco, T. (1999). Obras hidráulicas en Aragón. *Zaragoza: Caja de Ahorros de la Inmaculada de Aragón*.

[3] Martínez, J.C. (2015). Jules Seguin en España: prefabricación e innovación en los puentes colgantes de Fuentidueña, Arganda, Carandia y Zaragoza construidos por el empresario francés. *In Actas del Noveno Congreso Nacional y Primer Congreso Internacional Hispanoamericano de Historia de la Construcción.* Segovia, 13 a 17 de octubre de 2015 (pp. 347-356). Instituto Juan de Herrera.

 

developing complete projects: machinery construction for industries such as flour mills, paper and brick factories, power plants, tram rails, hydraulic turbines, urban furniture, etc. Thus, it became the first company in Aragón and one of the most prominent in certain specialities[4].

The importance of the foundry's participation in universal industrial exhibitions should also be noted, which expanded its scope of action. Records have been found of numerous orders distributed throughout Spain between 1864 and 1911, as well as two orders in Morocco and Mexico.

Between 1903 and 1970, ownership passed from Antonio Averly to his descendants. Production had evolved to include hydraulic presses, forging, prestressed concrete equipment, and a return to turbine manufacturing by then[5]. The factory reached 131 workers at its peak[6] (Figure 2).


**Figure 2.** Photo montage of current photography with a photograph from the early twentieth century. Source: Gran Archivo Zaragoza Antigua. https://adioszaragoza.blogspot.com/. Accessed: 08/05/2024.

The 20th century did not bring good news. In 2006, the factory complex was impounded due to the construction of the A-68 tunnel through the city, and by 2011, the number of workers had been reduced to ten. The situation forced the closure of the facilities.

Things did not improve between 2013 and 2023 when the construction company Brial-Neurbe bought the facilities and demolished 70% of the complex to build new housing (still in progress today).

[4] Jiménez Zorzo, F.J. (1987). La Industrialización en Aragón: la Fundición Averly de Zaragoza. Zaragoza, Diputación General de Aragón.
[5] Jiménez Zorzo, F.J. (1987). La Industrialización en Aragón: la Fundición Averly de Zaragoza. Zaragoza, Diputación General de Aragón.
[6] Sora, A.S. (2000). Especialización flexible y empresa familiar: la fundición Averly de Zaragoza (1863-1930). *Revista de Historia Industrial*, 61-95.

## 2. Description of the complex

Averly is a historic industrial complex located in the heart of Zaragoza that, over time, became one of the main companies in the metallurgical sector in the Ebro Valley. The complex, as it has come down to the present day, is the result of the association of material and immaterial elements that make up this set of architecture in which business and housing coexist, one of the few cases that endure today.

Analysing the space as a whole, we can see a fusion between the industrial architecture of previous decades and the development of some ideas of the modern movement, which have brick as their main material with variations in their polychromy that dynamise the façades, especially in the access to the enclosure and in the openings of the warehouses. Its homogeneous architectural language highlights eclecticism in appearance and elegant functionality in its spatial distribution and construction, resulting in simplicity not exempt from technical sophistication.

The plan organisation achieves a succession of buildings and open spaces endowed with functionality composed of a monumental access door and two blocks (the owners' home and what were once the adjustment workshop and offices). Both spaces have a rectangular floor plan, and the house stands out for its plastic treatment.

Standing at the entrances to the factory, we find the house on the left, surrounded by a fence that closes the perimeter of the current site. The family residence seems reminiscent of a Renaissance palace inscribed in this new industrial setting (Figure 3). It consists of a basement and three floors; eaves top the last one. The façades of the house alternate between plastered brick as a closing element and exposed brick. For the plinth, a striking chromatic play is proposed. As for the closing wall of the house, a series of arches are prepared that modulate the façade in a uniform composition whose regularity is broken by a balcony.

**Figure 3.** Current photo of the Averly Foundry family home. Author: Antonio Duaso Clusa.

As for the existing nave next to the house, its decoration focuses on using stained glass windows and alternating red and white brick in the openings.

Both buildings are surrounded by the garden (an organic axis that articulates volumes), which gives it a country air that, at the end of the nineteenth century, was integrated into the housing trends of the local high bourgeoisie.

 

## 3. Legal status of the degree of protection and conservation status

As far as the protection of the building is concerned, multiple controversies have addressed this issue from different points of view. On the one hand, the more conservationist public has sought to preserve the entire complex, and on the other, those who support converting part of the complex into new residential buildings.

Finally, the same year in which the purchase and sale contract between the historic property and the construction company-promoter was made, the Provincial Council catalogued it as "Heritage of Architectural Interest" according to the General Urban Development Plan of Zaragoza, being declared "Catalogued Asset of the Aragonese Cultural Heritage"[7].

Considering this level of protection, and due to the lack of political agreement in 2016, the land was not classified as a social and cultural use. Only 30% of the complex remains within the heritage framework, but some movable assets, such as machinery, casting moulds, etc., have been preserved (Figure 4).

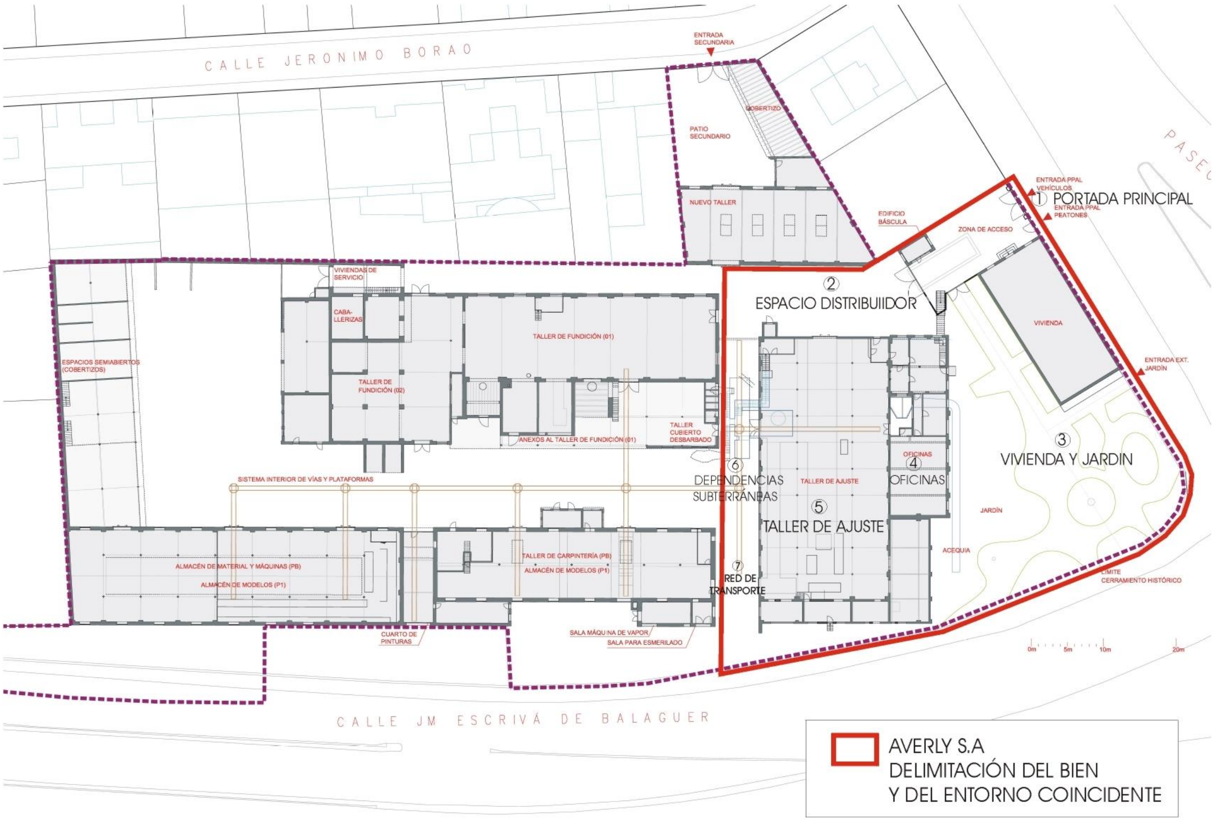


**Figure 4.** View of the delimitation of the heritage property. Source: BOA. Accessed 10/05/2024.

In 2008, Zaragoza was first in the Top 20 provinces with the most assets at risk of disappearing. Even today, it has a very long list of monuments on the red list by Hispania Nostra. In addition, has been declared endangered by the World Monuments Fund[8].

As additional information to the one already mentioned, it is necessary to analyse the main problems of the property to establish a series of objectives.

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[7] Departamento de Educación, Universidad, Cultura y Deporte. *Orden de 28 de noviembre de 2013, por la que se declara la Factoría Averly, sita en el paseo María Agustín, 59, de Zaragoza (Zaragoza), como Bien Catalogado del Patrimonio Cultural Aragonés*. <<BOA>> núm. 247, de 18/12/2013.

[8] Redacción, A. (24 junio, 2016). *World Monuments Fund solicita la conservación integral de Averly*. https://arainfo.org/104547-2. Accessed 10/05/2024.

The main problem of the building stems from the progressive and prolonged abandonment over time, both of the building and the surroundings. This has favoured the creation of an isolated space very close to the city centre. In addition, the abandonment by the owner and the lack of heritage protection has meant ignorance on the part of the citizens, and therefore, the loss of a large part of the industrial complex and the possibility of demolishing the space without consequences.

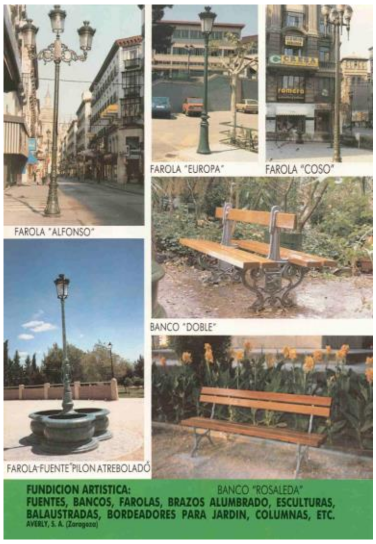
The Averly foundry is part of a long list of forgotten and eventually disappeared properties. For this reason, some associations, such as APUDEPA, and Aragonese heritage professionals in the institutional and educational fields, have mobilised to achieve their goal of resurrecting the architectural complex. Therefore, this project's objective is to recover and enhance the buildings that are still preserved in situ, guaranteeing their use and avoiding their disappearance due to abandonment, purchase, sale or real estate speculation.

## 4. Enhancement

The Averly complex has special relevance due to its importance at a key moment in the industrial development of Zaragoza, transcending the regional framework with its productions and distributing its products throughout a large part of the national geographical area.

The labour policy developed by this family business was based on the production of elaborations adapted to orders and adjusted to customers' needs, creating industrial machinery, urban furniture or iron and bronze cast sculptures, becoming the largest workshop in the artistic and industrial foundry (Figures 5-6-7).






**Figures 5 - 6 - 7.** Urban furniture and sculptures. Source: Averly, S.A. https://averly.es. Accessed: 16/05/2024

That said, and knowing that a large part of the urban furniture of the Aragonese capital is made up of this foundry, it is necessary to strengthen the link between the factory and the population. This industry is now inserted into the urban framework between blocks of flats, overshadowing the small buildings that are beginning to be forgotten.

Currently, the name "Averly" is still active. The company changed and updated the course of the business; however, the original facilities of the factory complex are unused, and their state of conservation is in the progress of degradation.

The lack of heritage cataloguing has led to the owner abandoning its maintenance. Today, the building is propped up and surrounded by construction sites. On one side, the construction of the block of flats by the construction company that bought the land, and on the other side, the sanitation of Paseo María Agustín, which has involved lifting the pavement. The heritage building is surrounded by rubble that piles up, and the works make it physically and visually inaccessible (Figures 8-9).


**Figure 8.** Current view of the Averly foundry among the rubble and the new block of flats under construction. Author: Antonio Duaso Clusa.


**Figure 9.** Current view of the Averly foundry among the rubble and the new block of flats under construction. Author: Antonio Duaso Clusa.

The proposal to enhance the value of this building is based on the idea of forming a visitor centre focused on residents, visitors, and tourists. The objective is to manage the cultural attraction resources available in the city and the building through the hiring of qualified personnel and taking advantage of the furniture and buildings available on the premises of our object of study. To this end, a prior rehabilitation plan for the building is urgently required. In addition, a connection will be established with hotels in the area to guarantee the full experience for those not residing in the city.

## 5. Proposal for a Visitor Centre

The centre will be a space that reveals the meaning and relationship of the visitor with heritage through direct experiences and applying strategies that allow a clear interpretation for its enhancement and dissemination.

That said, the objectives are to welcome the visitor, learn about their concerns and, from there, make them aware of the values of the place where they are and offer them a map with access to the routes of the guided routes that can be accessed through the centre.

Thus, the preserved space of the Averly foundry is proposed as a place capable of bringing together the latest innovations in cultural services practically and functionally, becoming a pioneering centre of these characteristics in Zaragoza. At the same time, the outdoor areas will provide visitors with benches and seats to rest and enjoy the garden of the original family residence while preparing to get to know the city.

## 6. Proposal of contents and results

It is proposed that the visitor centre be multifunctional at different levels, such as the promotion of the space and the building, the improvement of the tourist and cultural attractions of the city, the control of visitor flows and the structuring and organisation of the information to be disseminated about the area.

For all these reasons, a series of guided routes are proposed on the different historical stages of Zaragoza, which start from the building and bring the visitor closer to the city centre progressively and enjoyably.

Next, the different possible routes will be summarised, starting with the Iberian, Roman and Visigothic routes, which will begin with a brief introduction about the foundation of the city in the Iberian period, on which the Roman culture sinks its roots, giving way to the foundation of Caesaraugusta around the 14-13 centuries B.C., the only city to which Caesar Augustus bestowed his name. During the visit, the urban planning of the city will be explained, as well as its main buildings, mentioning specific cases such as the Cathedral of El Salvador, which stands on the site of the first Roman temple, which, according to several hypotheses, was modified by the Visigoths to reuse the space as a Christian temple.

Another option will be the Islamic route, which highlights one of the city's best-known eras. The introduction will be made in the gardens of the Averly complex, focusing on the historical context to obtain a greater perspective of the explanations. The visitor will then go to the Aljafería to understand the complexity of Islamic art and its subsequent influence on architecture as we know it today.

The Romanesque and Gothic Route would focus on these two styles, which have been grouped to provide an overview to the visitor, who will have access to the Basilica of Nuestra Señora del Pilar to see the only remains of the Romanesque church (the Chrismon of the temple still preserved in situ today). Afterwards, the visit will be directed to the head of the Seo del Salvador (both outside and inside, where you will see the hidden capitals behind the cathedral's main altar, accessible on rare occasions).

The Renaissance and Baroque Route will be a route through which you can understand the city as the cradle of cultures, witnessing countless historical events. In this period, the city is known as "La harta". It was the golden age that marked his legacy and encapsulated a period of economic, cultural and artistic splendour. It was in this context that countless Renaissance palaces emerged. Some examples, such as the Real Maestranza de Caballería and the Palacio de Los Luna, will be visited. The route will end in Plaza del Pilar to analyse the Baroque basilica project.

The Route of the 19th and 20th centuries would have the foundry as its headquarters and main place. However, the introduction will take place on the other side of the Paseo María Agustín, who was one of the protagonists of the upcoming speech.

The nineteenth century was a period of technological advances at all levels, which is why the War of Independence was so abrasive as it passed through Zaragoza. At this time, the city still had the medieval wall, which, unlike the Roman (stone) wall, was made of brick and less resistant. This wall was razed during the war and is currently abandoned and on the verge of being part of a new housing project in which it will be inserted into one of the portals (proving to be a controversial topic) (Figure 10).


**Figure 10.** Appearance of a medieval wall fragment from Paseo María Agustín. Author: Irene Duaso Pinilla.

As we mentioned, at the end of the war, some of the names of the heroes and heroines of this battle were collected, and today, they are part of the context of the city's historical memory. One of them, María Agustín, to whom the Paseo on which the foundry is located gives its name.

The route continues its discourse by mentioning the Industrial Revolution by returning to the visitor centre, where there will be a review of trade and industry from the foundation of Caesaraugusta to the 19th century and the strong weight of the Industrial Revolution and the factories established in Zaragoza between the 19th and 20th centuries. The aim is to explain the casting process (supporting the discourse on the preserved movable objects: machinery and moulds), from the previous design to the materialisation of the final object.

In addition, an attempt will be made to transmit the way of life of the bourgeois families of the time, making the home of the Avery family a museum.

Finally, the 21st Century Route. The last one proposed in this new visitor centre corresponds to the last decades of this century. Taking as a reference the site of the 2008 Water Expo and having modern architectural typologies such as the Bridge Pavilion by Zaha Hadid, an exceptional work in the city that today houses the Museum of the City's Mobility, which offers us a journey through the history of the automobile that can also be visited.

## 7. Discussion and conclusions

For the project to be economically profitable, it will be necessary to have a thorough knowledge of the market. When developing this plan, it's important to be realistic and base the project on solid data and analysis. To do this, the idea of the business and the products or services offered will be described. Next, it will be necessary to carry out a study that includes the characteristics of the public that will participate in this type of activity to establish a plan for the prices or rates that we will make available to the client.

The dissemination on social networks and through hotels and tourist offices with which we will collaborate in this project will be influenced during this process.

Do not forget to study the possible risks faced by the business. In this case, it would be wise to carry out a SWOT analysis before implementing the project.

As for the staff who will attend the activity, guides, historians, and archaeologists will be hired to provide the visitor with as close an idea as possible of the concepts to be discussed.

On the other hand, about the restoration, rehabilitation and musealisation of the space, architects, technical architects and videographers will be hired to approach the space with the appropriate sensitivity.

Finally, a plan of key performance indicators is established to measure success or failure and, consequently, the progress and viability of the activity.

An industrial heritage management plan is crucial to preserve and sustainably manage the historical resources of this period, which are still underexploited today compared to other eras. For this type of action, citizen participation is essential, which is why this project aims to raise awareness among visitors by disseminating data within everyone's reach.

However, administrative and legislative protection is crucial to preserve heritage. It is important to ensure that legal frameworks and regulations are in place to protect and manage industrial heritage more effectively.

In short, an industrial heritage management plan must be comprehensive, participatory and sustainable, aiming to save and protect our heritage for present and future generations.

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# Documentation and conservation of contemporary heritage. Daniel Buren's installation at Centre Pompidou Málaga (Spain)

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***Abstract***

*In this communication, we present the work done where the use of photogrammetry has been the protagonist to virtualise the heritage in a 3D model of the installation work Incubé (2015), an installation of the artist Daniel Buren at the Centre Pompidou Malaga. On this occasion, by means of various glass panels in primary colours projected on the architecture, the work generated a play of interspersed stripes of light. Photogrammetry gives us the opportunity to produce accurate models of two-dimensional images, which allows the documentation and conservation of heritage elements, especially those that are endowed with a certain materiality that does not rely on the projection of light or sound reproduction, thus allowing the documentation and conservation of the work.*

***Keywords:*** *photogrammetry, heritage, installation work, preventive conservation, 3D model.*

## 1. Introduction

Talking about the work of contemporary art forces us to dwell on the multiple options and variables offered by its means of creation, to describe the diversity of materials that can be susceptible to be part of it and even beyond its materiality, the volume of the space they inhabit. Sometimes, the architecture of the museum itself becomes part of that work of art; this happens when we find an artistic intervention of an installation nature. Here, we find that the format of the work can be very variable. Its ephemeral nature and the use of sometimes also sensitive materials make it necessary to document the work in the process of creation and installation.

Referring to the work of Llamas Pacheco (Llamas Pacheco, 2012) and the different articles related to this work on three-dimensional contemporary work written by the author, we can define, following her own words, the fundamental role of the conservator restorer of contemporary art is fundamentally preventive. Thus, the criteria that guide the interventions are directed towards preventive conservation. This is a constant attention that we cannot lose when we face the intervention of contemporary work in all the steps we take from the moment the work arrives. Thus, we will consider the first phase of contact and preliminary diagnosis to know how to intervene, and we must think about what we introduce in the work and decide what type of materials we will use depending on the work, the nature of the materials and its history. In this sense, it is important for the contemporary art conservator not to lose sight of the need to have very good previous documentation, if possible, with the artist's intention and the intervention processes, where everything that has been done is specified. This documentation work is usually done using two-dimensional images. Still, photogrammetry offers the possibility of virtualising the work in 3 dimensions, with greater capacity for geometric resolution and higher quality textures, information that can be very useful to check the passage of time in the work's materiality.

## 2. The use of new technologies applied to heritage: documenting, preserving and disseminating

The use of digital heritage, intended not only for the processes of digitisation, collection or dissemination of data but also as a tool to involve different actors in the processes of protection and re-signification, ultimately leads to a democratisation of heritage itself. Currently, the presentation spaces of cultural heritage should focus on interactivity and user experience as the main axis on which the storyline revolves to provide value above aspects such as aesthetics or beauty.

It is here where the use of Information and Communication Technologies (ICT) plays a leading role, tools with which to work on the heritage project (Figure 1) and in the construction of measures with which to design and the conditions of accessibility and dissemination for the sake of sustainable tourism. A process of no return for which different administrations are betting with greater or lesser success in an effort to increase the benefits by reducing the depletion of the resources of the Cultural Heritage immersed in the tourist circuits of the XXI century.

In recent years, the impact of ICTs on the cultural sector has grown exponentially. New technologies offer innovative alternatives to create new experiences for a constantly evolving public. Virtual Reality (VR) and Augmented Reality (AR) are positioned as two of the main ingredients in this recipe we call 'culture + technology'. The potential of ICT, social networks and digital tools related to heritage has been at the centre of the studies of many researchers since their origin, mainly related to their possibility of creating a virtual "showcase" or "showcase" for the public. In these cases, the effects of ICTs are considered highly positive in strengthening cultural identity.

Augmented reality (AR) technology is an interactive virtual environment that enriches the user experience. It consists of inserting virtual graphics into our physical space so that the real and the virtual blend, offering an enriched or augmented image of reality. Since the term Augmented Reality was coined in 1992 (Cárdenas Ruiz, Yesid Mesa, Suarez Barón, 2018), there have been numerous works on the subject (Bimber, 2005; Haller, 2007; Hainich, 2010; Torres, 2011).

 

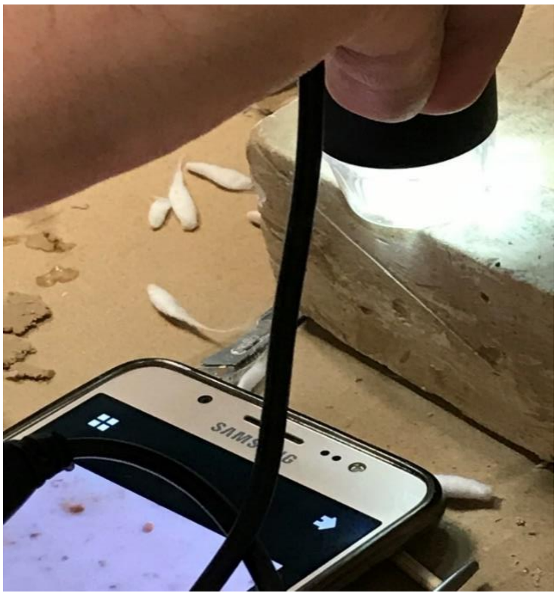

**Figure 1.** Digitisation process before intervention in movable assets. Degree in Conservation and Restoration of Cultural Heritage. University of Seville. The author of the image is Lourdes Royo (2018).

About intervention work, the incorporation of new technologies plays an increasingly relevant role, being an essential reference in all methodological processes of knowledge, treatment and enhancement of cultural property, given the high degree of technology acquired by conservation and restoration in recent years, both at the level of scientific instrumentation and the increasingly accurate and sophisticated analysis (Bellido Gant, 2008). Using new technologies as a complementary working tool in disseminating and interpreting heritage facilitates access to knowledge to society in general and, therefore, protects and conserves our heritage.

This aspect of guardianship is not only related to the consultation of databases or digital documentation but also to access to all types of information, which in turn allows us not only the visit or direct consultation thanks to the digitisation of documents or databases. In addition to this, the utility as support for heritage research and the dissemination and reconstructions and 3D virtual recreations of the goods has become one of the most important tools for research, conservation and dissemination of cultural heritage, allowing us to understand graphically part of our history in the different spaces enabled for their work: museums, documentaries or information sheets.

## 3. Daniel Buren´s work

Daniel Buren (Boulogne-Billancourt, France, 1938) is one of the most internationally recognised French artists. His conceptual work perfectly reflects his ability to fuse art, architecture, and space through the abstraction of form through line and colour. Creator of the concepts he called "degré zéro" and "outil visual", Daniel Buren radicalised at the end of the 60's the exercise of painting through a series of "Manifestations" that he developed together with other members of the group: B.M.P.T. Group (Oliver Mosset, Michel Parmentier and Niele Toroni) from the deconstruction of the traditional forms of pictorial exhibition to question the institutional devices that give meaning and symbolic value.

From this idea of "degree zero of painting", Buren started in his later works to play with the materials and their relationship with the medium and the structure that give shape to the work of art. At the same time, he would use the line as a "visual tool", which, in its repetitive and regular action, turns the work into a neutral and anti-narrative image. If there is something that defines Buren's work, it is its close relationship with the space that will host it. For the artist, it is vital to know both the place and the context. In this creative exercise, he combines the intention of choosing exhibition contexts in the public space that are marginalised from the official centres, which allows him to develop marginal forms of perception. As a result, pieces seek to be a tool to question how we look and perceive, as well as the way in which space is used and appropriated.

This critical view of the institutionalism of art and the need to move his work from the official exhibition spaces to the social and political terrain of public space is what he has sustained for more than 50 years. His intervention projects are fully conceived and created in the site where they are established, taking into account the context that houses them and a colour palette that allows the establishment of sensations and dynamism between the work and the space.

Buren's work has been presented in museums, public spaces and art institutions in Germany, Belgium, the United States, Spain, France, Italy and Mexico. Many of his works have become references for the cities that host them. An obvious example is the work he presented in 2009 in Nuremberg (Figure 2).

**Figure 2.** Facade of Neues Museum in Nuremberg coloured by Daniel Buren. Wikimedia Commons (2009).

An urban scale project designed under environmental and social concepts that seek to expand public spaces and promote social interaction. His design was conceived and produced for the central fountain of the ARTZ Pedregal complex, in which the artist created a dialogue with the space and the environment through the combination of simple materials, geometric figures and solid colours that coexist with water and natural light.

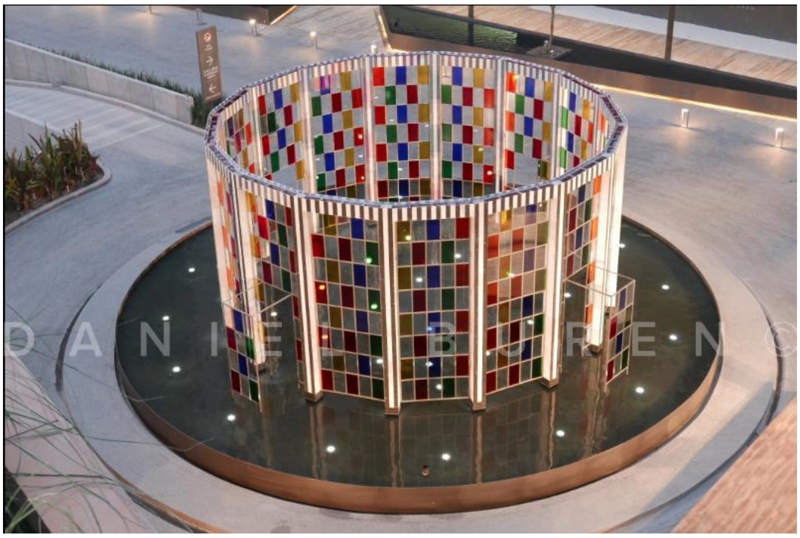

**Figure 3.** From the Rotonda to the fountain. 5 coors for Mexico. Homage to architect Manuel Tolsá, travail in situ permanent, mars 2018, in "[Inauguration d'Artz Pedregal]", Plaza Comercial Artz Pedregal, Mexico, Mexique, à partir du 9 mars 2018. © Daniel Buren/ADAGP, Paris. Détail.

 

## 4. Daniel Burén's installation at Centre Pompidou Málaga

The Centre Pompidou in Malaga is an adapted building designed in 2013 by Javier Pérez de la Fuente and Juan Antonio Marín Malavé, architects of the city's Urban Planning Department, organised on two levels, outside, with 12 meters. High, the image that takes plastic force is a cube built of glass and steel, a transparent element that allows skylight access to natural light but also constitutes a full urban design and a void inside the museum. It is precisely this structure with which it is identified today.

In 2015, the Frenchman Daniel Buren was commissioned to carry out an intervention in the building, choosing this minimalist piece he titled Incubé, i.e. incubated inside the cube. Here again, Daniel Buren created a work conceived specifically for the context in which he was working.

The coloured cube of the Pompidou in Malaga is developed inside the "Cube" on the promenade along the harbour basin. With a rhythmic sense (36 on each side), the cube's glass plates are covered with sheets of self-adhesive vinyl in plain colours, triggering chromatic and luminous pulsations that affect not only the exterior but also the interior of this skylight. With this "cladding", the Cube is the only visible part of the Centre Pompidou Malaga. It imposes itself as the symbol of the institution's presence in the urban landscape of the city, becoming one of the most photographed places, a meeting point for its inhabitants and the most representative image of the museum.

**Figure 4.** Incubé, Centre Pompidou Málaga. The author of the image is Royo-Naranjo (2015).

## 5. Objectives

The main goal of this digitisation was to see and test how translucent and transparent surfaces are recognised by the software Agisoft Metashape Pro. We knew that this kind of surface could inherit some difficulties, and we wanted to check how the object is recognised and how material and textures are translated into the 3D model.

For this purpose, we ran two different digitisations with two sets (chunks) of images, the first one without markers and the second one with designated markers; by the end of the processing, we couldn't tell any differences between the two groups, if so the second one was translated into the 3D model much worse than the first one. As shown in Figure 6, the software wasn´t able to establish a concrete area where you can reminisce about the object of our study.

Since it´s a metal structure with squared crystals attached to it, in the model, you could see the metal part since they´re solid, but transparencies were a complete challenge since it doesn´t recognise the surface as such after running the two rounds we assumed that Agisoft Metashape is not capable at the moment of reading a transparent or translucent object/surface and recognising that it could have a solidity to it. Instead, after running all the improvements at hand, we could still see that the structure is recognised only partially, as you can see in Figure 9.

## 6. Case Study: Results

To carry out the photogrammetric digitisation of Buren's work at the Pompidou Centre Málaga, several factors specific to the work and the space it occupies had to be considered.

Firstly, the work is located in Plaza Muelle 1, on two levels, with the promenade leading to the museum entrance on one side and the cube on the other. The space of preferential perception of the work is either from the street level, being at the foot of It and rising before us, or It can also be partially enjoyed from the inside of the museum itself.

It should be noted that the space that the cube generates inside the museum is a quadrangular courtyard that rises in height from floor 0, the museum's space where frequent on-site installation development occurs; this space is inaccessible to visitors who can enjoy it from the outside. Likewise, one of the characteristics of the cube is both transparency and its ability to reflect light, therefore becoming difficult in terms of digitisation, as it is of the surfaces that so far seems to be the most difficult to digitise using photogrammetry (Marqués, 2023). For this reason, data was taken in two different environments, on the one hand with more uniform and filtered light during a cloudy day and on the other during the early morning hours of a sunny day, to assess which colour results are more in fine with reality.

It has been considered that the installation of the architecture and the glass pieces are developed from the outside of the cube. Therefore, the digitalisation of the work is directed from this same space, taking the two-dimensional data from outside the museum and placing us on the outer circumference of the cube.

The equipment used to take images of Buren's work was a Canon EOS 600 D digital camera and EF - S18 - 55mm f/3.5 - 5.6 IS II zoom lens; after marking the terrain using targets, we could scale the model later during processing. The software chosen to carry out the processing and photogrammetric survey has been Agisoft Metashape Pro, based on previous experience with this software and because data is also usable in all types of GIS and CAD software.

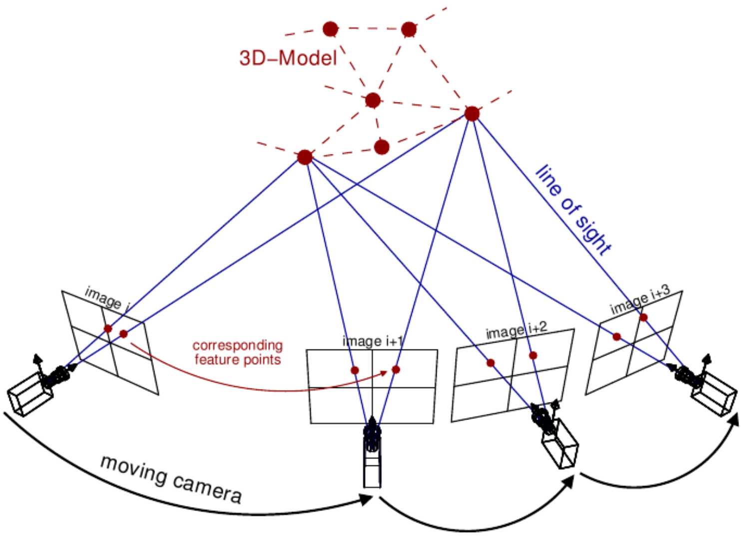


**Figure 5.** Structure from Motion (SfM) photogrammetric principle. Source: Theia-sfm.org (2016)[1].

[1] Exploring the use of 3D GIS as an analytical tool in archaeological excavation practice - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Structure-from-Motion-SfM-photogrammetric-principle-Source-Theia-sfmorg-2016_fig3_303824023 [accessed 7 May, 2024].

We align the photos, a simple but essential step in getting a good result, through a sequential reference pre-selection. Points are used in Agisoft Metashape to calculate the relative location of the cameras. First, a sparse "low density" point cloud from the key point is created, the maximum number of points the program will draw from a photo. The key point limit is set to 40000, and the tie point limit is set to 10000, creating a balance between having a great camera alignment performance without increasing too much processing time and having an overall 25 hours of processing data for this sole step.

The cloud point has been processed in an extra-high setting and a mild depth filtering map to achieve an accurate depiction since it processes images at its original resolution, creating a cloud point with a total of 29275 tie points. We took all the data from the dense cloud point and started the triangulation, which will then build a mesh to enable the making of the 3D model. It should be noted that since we set the programme to draw colour from the vertex, all the colour information extracted from the dense cloud point has been added to the mesh.

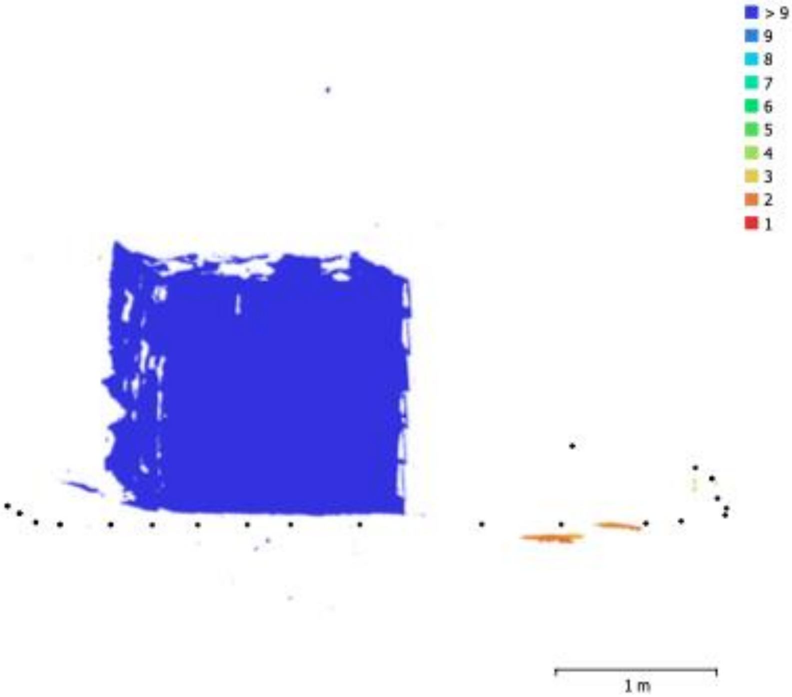


**Figure 7.** Camera location and overlap, Agisoft Report on Daniel Buren´s cube.
Author of the image: Deborah Fernández León, 2024.

**Figure 8.**. 3D model generated from dense point cloud. Author of the image: Deborah Fernandez León, 2024.

After smoothing the mesh and closing the holes, we still can see how the colour hasn´t transferred as it should; then, we created a texture with depth maps extracting data from the base images with a mosaic blending to protect the surface. Results show how complex the base material makes the digitisation of the structure without post-production added to the main 3D model, as there are still some unclosed holes. This raises the question of whether post-produced 3D models are still useful for conservation since they have some features altered to fit reality but do not necessarily show the material state.

## 7. Conclusions

Although photogrammetry presents a few difficulties depending on the material the architecture is made of, as in Buren´s work with reflective and transparent surfaces, it can be fixed to a certain point afterwards in production and surely will be overcome in the future. The capacity to create models that deliver more information than digital elevation models, orthophoto and perspective views is valuable in recording before an intervention or tracking the qualities of a material.

In a large structure, as it is the cube, we would encourage using a drone to capture small details that might not have been caught by a camera set on a tripod from the floor level. Results show how light and transparency affect the creation of a readable surface for the software since there is no colour in some parts. Although the structure is in the middle of the city centre with a close airport and a hospital with a helipad, it´s situated in an area where you cannot fly a drone unless you go through a long and costly bureaucratic procedure. Regardless, the outcome might be enhanced by using a drone to capture the cube from the upper structure, allowing it to present a flatter and hopefully solid structure.

Ultimately, digital photogrammetry helps to create records and information about heritage in general and architecture in particular, making the process easier than before, more precise, cost-effective and accessible.

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# The churches of Alto Gállego

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**_Abstract_**

*The research focuses on the group of churches in the Alto Gállego region, north of the province of Huesca, known as "Iglesias del Serrablo". The uniqueness of the complex and its architectural value provide a very important asset to the architectural heritage of the area.*

*The "Amigos del Serrablo" Association, founded in 1971, has been valuing this heritage since its inception through its rehabilitation; however, the limited information and studies carried out on these properties mean that many of them are still unknown to the general public, despite the routes proposed by the Association for their dissemination.*

*The research that is being developed analyses this group of churches from different areas: geopolitical, historical, geographical, orographic, etc., and also provides an architectural study that helps technicians to address rehabilitation projects.*

*In order to develop the architectural analysis of the properties, a virtual model is created using tools such as a 3D scanner, drone flights and a camera; which, subsequently, through the application of techniques such as photogrammetry and point clouds, allow us to obtain the 3D model of the churches studied.*

*With the digital model of the church, the investigation will be approached in two lines: a more technical one in which the geometric documentation, lights, construction and structural elements, dimensions, etc., are analysed; that serves to establish hypotheses of virtual reconstruction of those churches that are in ruins, or that help to establish a line of action to rehabilitate. On the other hand, the digitisation of the building allows the creation of graphic representation support, such as virtual reality and augmented reality, that favours the dissemination and accessibility of this architectural heritage to a wider public, both in person and virtually.*

**Keywords:** *3D Scanner, Photogrammetry, 3D Modelling, Digital Surveying, Virtual Reality, Augmented Reality.*

## 1. Introduction

The research focuses on the group of churches in the Alto Gállego region, north of the province of Huesca, currently known as "Iglesias del Serrablo", a name that derives from the term coined "Iglesias Mozárabes de Serrablo" by Julio Gavín Moya and Antonio Durán Gudiol to refer to "this group of churches as one of the hallmarks of the territory" (Gavín J.; Durán A., 1969). The uniqueness of the complex and its architectural value provide a very important asset to the architectural heritage of the area.

The "Amigos del Serrablo" Association, founded in 1971, has been valuing this heritage since its inception through its rehabilitation. However, the information and studies carried out on these properties mean that many of them are still unknown to the general public.

The study of the churches as a whole has been approached from different points of view, from the field of history, geography, geology, sociocultural aspects, etc., but studying them from an architectural point of view is a good opportunity to be able to approach them as a line of research that allows analysing the entire set of churches and the effect that it had at the time of construction, as well as finding common elements that help us graphically reconstruct those that are not in a good state of conservation.

This set of churches was built in the Middle Ages, between the 10th and 12th centuries, and is made up of buildings in the Mozarabic and Romanesque styles, with Visigothic elements as well. The churches share common elements that homogenise the group and relate to each other throughout the territory (Gavín J., 1969); however, they present singularities that make some associate more with one architectural style than with another under the point of view of art historians who have studied these styles (Figures 1-2).

**Figure 1.** Lárrede church. Source: Muñoz, C. (2023).

**Figure 2.** Gavín church. Source: Muñoz, C. (2023).

The territorial, economic and temporal context of the churches makes this complex of special interest, since we must understand that they were built in the early stages of the Middle Ages in small municipalities, far from large population centres, with little economic capacity. to be able to tackle such important undertakings as the building of a church, much less so many churches in such a close territorial area; and in a context of wars for dominion and control of the territory.

In addition, the set of churches is distributed along the route of the Gállego River (Figure 3), with a changing and heterogeneous geography, with depressions and elevations that make it difficult to transport materials, which do not allow a visual relationship between the majority of them despite their physical proximity (Figure 4).

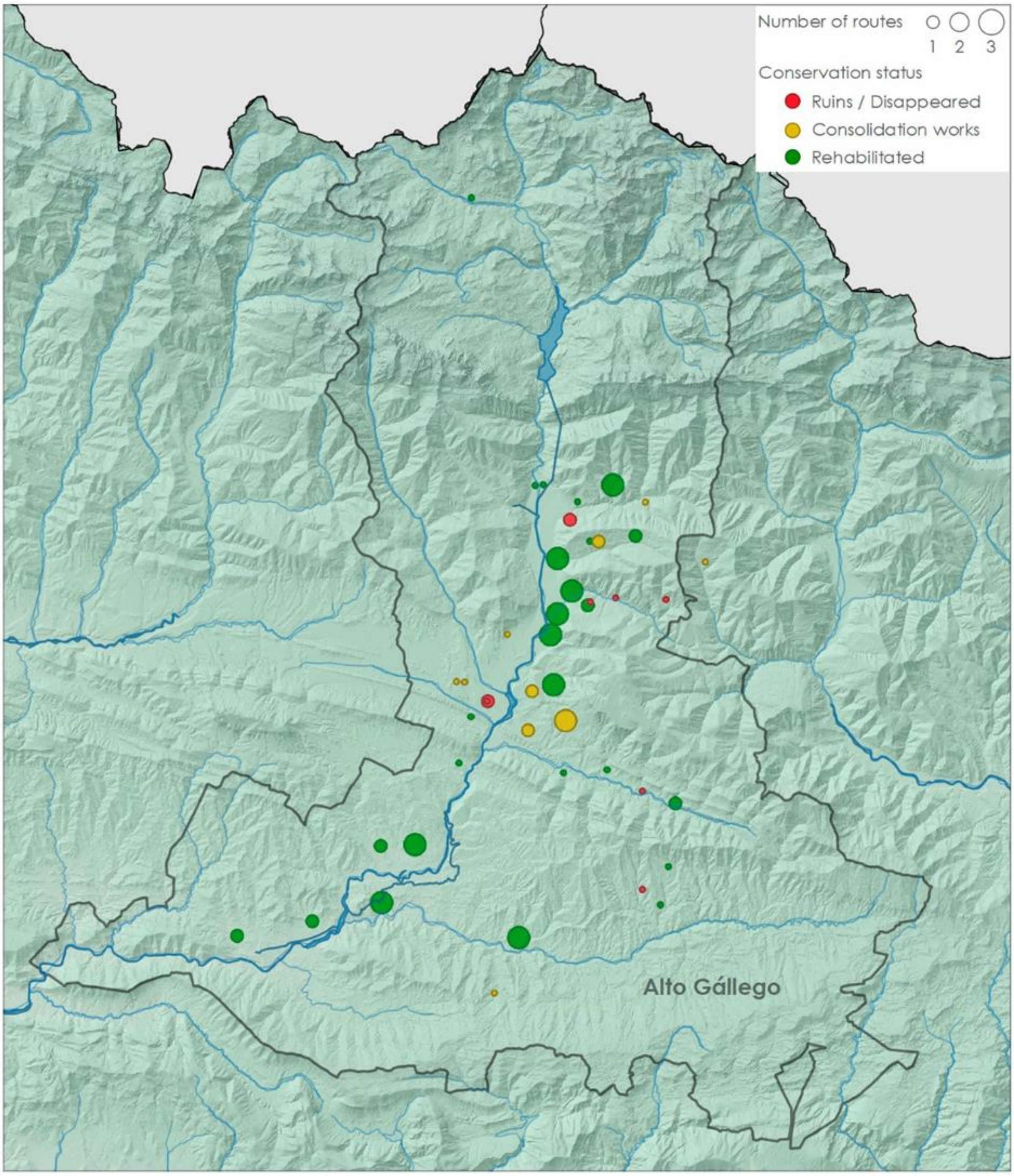



**Figure 3.** Serrablo churches map. Source: Muñoz, C. (2022).

*"The upper basin of the Gállego River is a space of great landscape diversity, with mountains, glaciers, rivers and lakes; to these physical and climatic peculiarities must be added its border character, its isolation, its unity and its autonomous organization as the support of an interesting and long history"*
(Biarge F. & Biarge A., 1999, p.2)

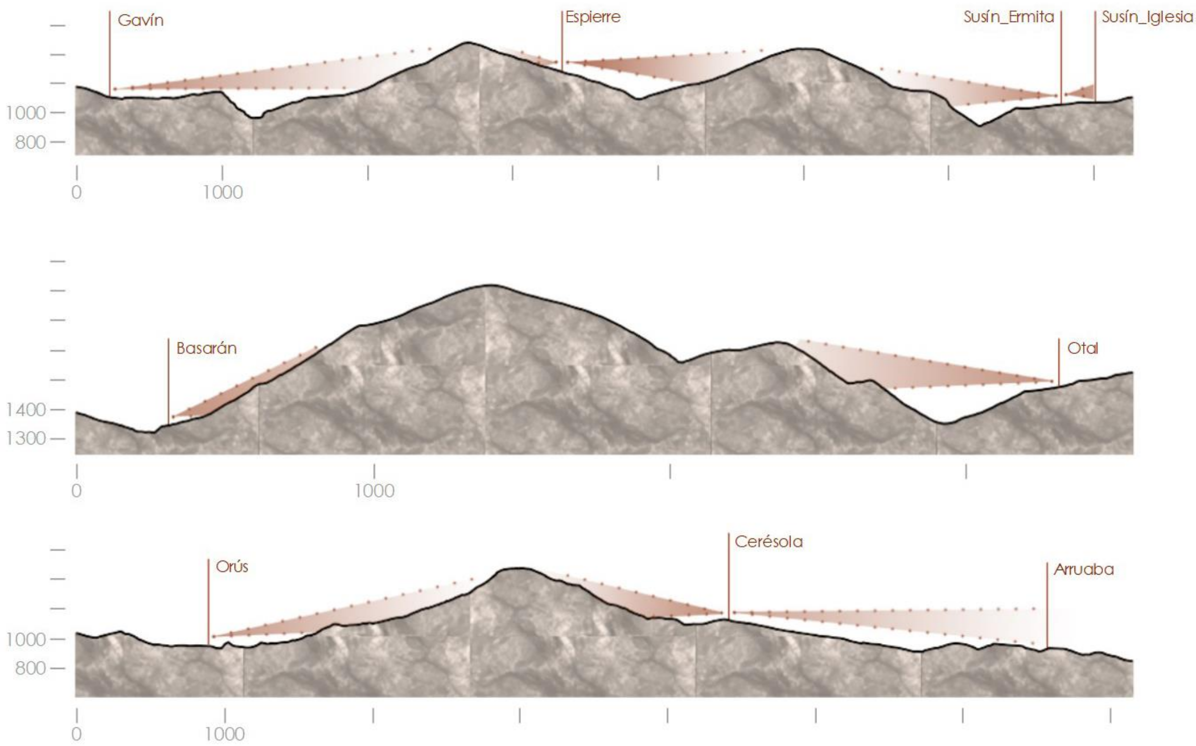



**Figure 4.** Terrain sections. Source: Muñoz, C. (2022).

## 2. Aims and objective

The main objective of the research is to revalue the architectural heritage found in this place by increasing its dissemination and accessibility while analysing more technical aspects focused on professionals in the sector. To achieve this, two lines of work have been established that complement and contribute to each other.

On the one hand, analysing the set of churches from a technical point of view allows us to establish hypotheses and conclusions that serve to relate and find common elements throughout the set with which to address future restoration, conservation and rehabilitation work carried out by the corresponding professionals.

On the other hand, it seeks to create a graphic representation support such as virtual reality and augmented reality that favours the dissemination and accessibility of this architectural heritage, both in person and virtually.

Photogrammetry techniques combined with the corresponding software are the vehicle that allows the construction of digital models of the churches with which to analyse and extract the construction, spatial, geometric characteristics, etc., in addition to adding elements of interaction, information and visualisation that help us achieve the aforementioned objectives.

## 3. Methods and procedure

### 3.1. Study work

The research is structured in different stages that provide information that is related to each other, which is why they are not closed work blocks with a defined beginning and end, but rather they support and provide data between them.

The first block focuses on studying and analysing all the written documentation about the churches, addressing different contexts, whether it is an anthropic context such as historical, social, economic, cultural, etc., or it may be a natural context such as orographic, geographical, geological, etc. As well as, the study of the graphic and digital context on the representation and cataloguing of architectural heritage. (Figure 5).

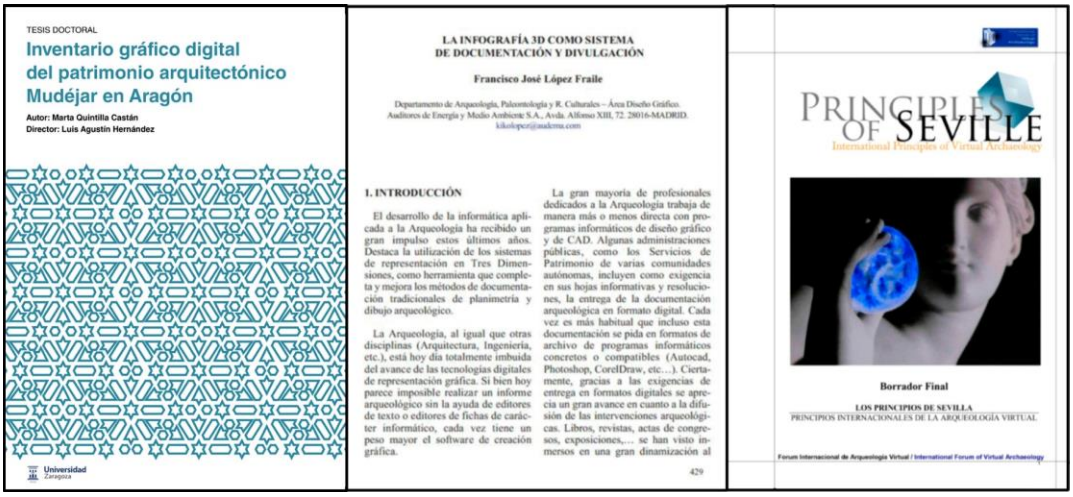
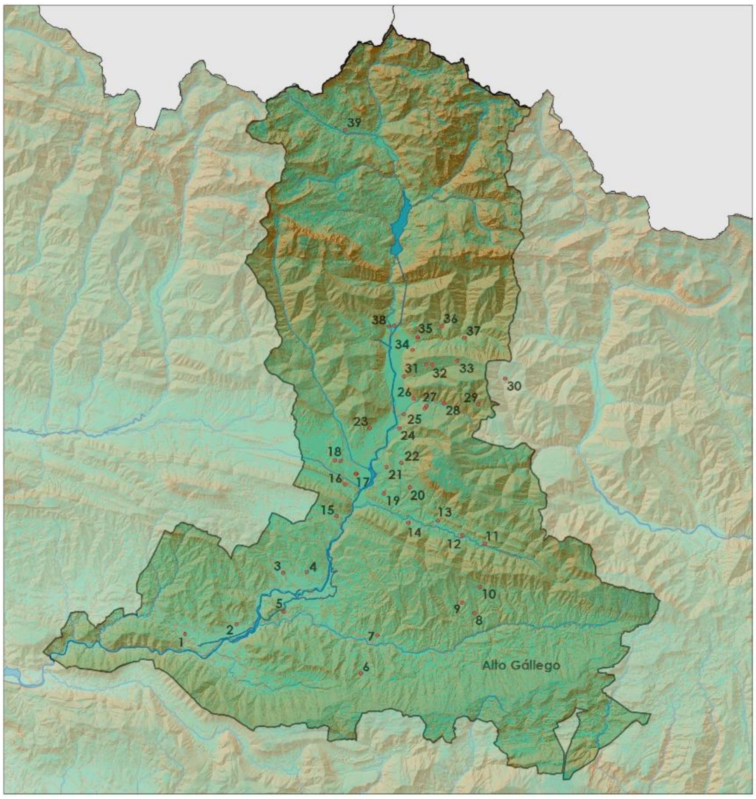



**Figure 5.** Books and articles for context. Source: Muñoz, C. (2023).

For the analysis of the analysed contexts, a study was carried out of the documentation available both in physical and digital format of each church, books related to the churches, their history and the Serrablo area, scientific articles from other researchers that explain the popular and religious architecture of the area, the history of the kings who had governed those territories at the time of the construction of the churches, etc. (Figure 6).


**Figure 6.** Books and articles for context. Source: Muñoz, C. (2023).

Another block of study of the Churches is developed prior to fieldwork. It involves the identification, geolocation, classification and documentation of each of the churches that are part of the complex being investigated. To do this, a list is prepared to indicate all the churches or hermitages located in the research area that are part of the group of churches with similar characteristics that can provide that character of unity (Figure 7).




**Catalogue of Serrablo churches**

**Region of Alto Gállego**

| | | |
|---|---|---|
| 1 | Javierrelatre | Iglesia de la Adoración de los Santos Reyes |
| 2 | Latre | Iglesia de San Miguel |
| 3 | Orna de Gállego | Iglesia de San Miguel |
| 4 | Arto | Iglesia de San Martín |
| 5 | Lasieso | Iglesia de San Pedro |
| 6 | Belarra | Ermita de San Ramón |
| 7 | Ordovés | Iglesia de San Martín |
| 8 | Arrruaba | Ermita de Santiago |
| 9 | Artosilla | Iglesia |
| 10 | Cerésola | Iglesia de la Purificación |
| 11 | Orús | Iglesia de San Juan |
| 12 | San Julián de Basa | Iglesia |
| 13 | Yebra de Basa | Iglesia de San Lorenzo |
| 14 | Allué | Iglesia de San Juan Bautista |
| 15 | Rapún | Iglesia de San Félix |
| 16 | Sabiñánigo Alto | Iglesia de San Hipólito |
| 17.1 | Sabiñánigo | Ruinas iglesia de Santa María de Gavín |
| 17.2 | Sabiñánigo | Ruinas iglesias y ermitas de Castiello de Guargo, Arasilla y Aineto |
| 18.1 | Cartirana | Iglesia de San Martín |
| 18.2 | Cartirana | Ermita de Santa Lucía |
| 19 | Sardas | Iglesia de Santa María |
| 20 | Isún de Basa | Iglesia de Santa María |
| 21 | Latas | Iglesia de San Martín |
| 22 | Satué | Iglesia de San Andrés |
| 23 | Sorripas | Iglesia de San Andrés |
| 24 | Lárrede | Iglesia de San Pedro |
| 25 | Lárrede-Oliván | Ermita de San Juan de Busa |
| 26 | Oliván | Iglesia de San Martín |
| 27.1 | Susín | Ermita de Nuestra Señora de las Eras |
| 27.2 | Susín | Iglesia de Santa Eulalia |
| 28 | Oliván | Iglesia de San Pedro |
| 29 | Basarán | Iglesia de San Miguel |
| 30 | Otal | Iglesia del Nacimiento de Nuestro Señor Jesucristo |
| 31 | Orós Bajo | Iglesia de Santa Eulalia |
| 32.1 | Espierre | Iglesia de San Esteban |
| 32.2 | Espierre | Ermita de Santa María |
| 33 | Espierre | Ermita de San Juan |
| 34 | Gavín | Monasterio de San Pelay |
| 35 | Gavín | Iglesia de Santa María |
| 36 | Gavín | Iglesia de San Bartolomé |
| 37 | Yésero | Iglesia de San Saturnino |
| 38.1 | Biescas | Iglesia de San Pedro Apóstol |
| 38.2 | Biescas | Iglesia de El Salvador |
| 39 | Formigal | Ruinas iglesia de San Miguel de Basarán |

**Figure 7.** Catalogue of Serrablo Churches. Source: Muñoz, C. (2022).

At the same time, some cards were made that complement the list and serve as a catalogue of the churches that make up the group studied in the research. For this, the "QGIS" software was used to prepare the graphic material of the cards, and that also allows to have the information of each georeferenced church (Figure 8).

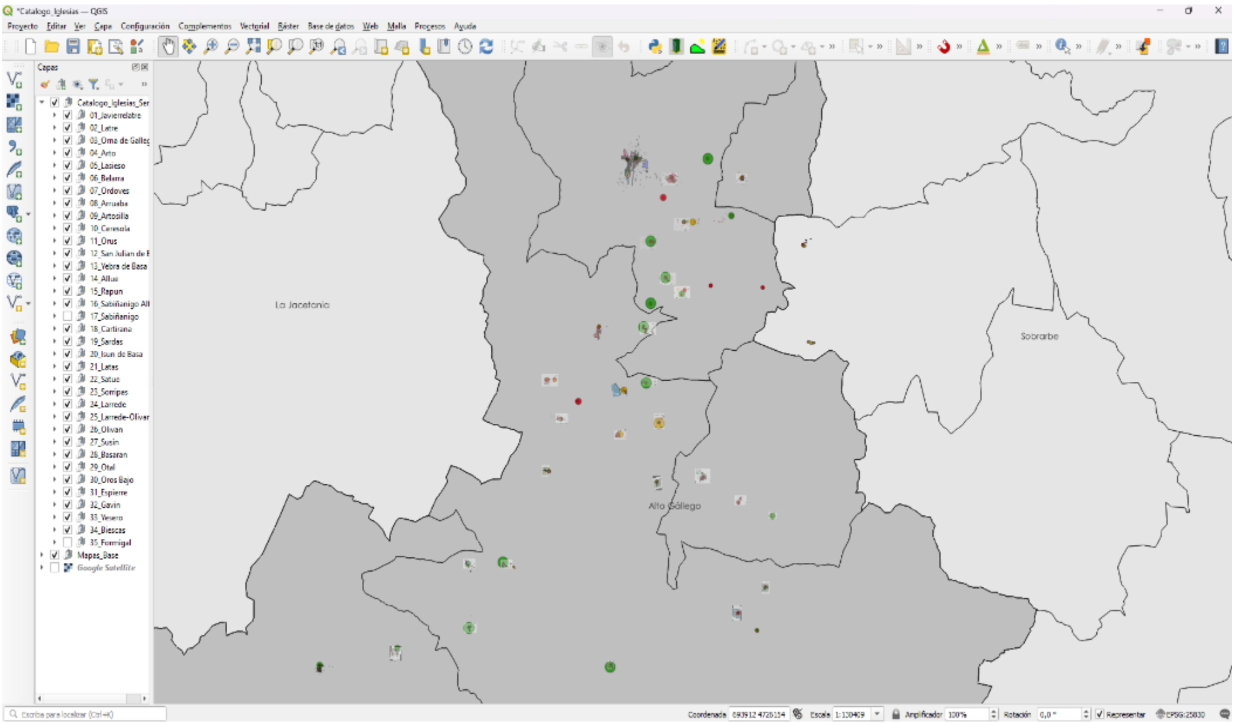



**Figure 8.** Geolocation of churches with QGIS. Source: Muñoz, C. (2022).

The files contain and graphically summarise the information obtained from the cadastre and the General Urban Planning Plans of each municipality; in this way, we can know the type of use of the plots, the classification of the land, if the church is protected by Heritage organisations, etc. also allowing a comparison to be established between them and also an example of cataloguing this type of property (Figure 9).

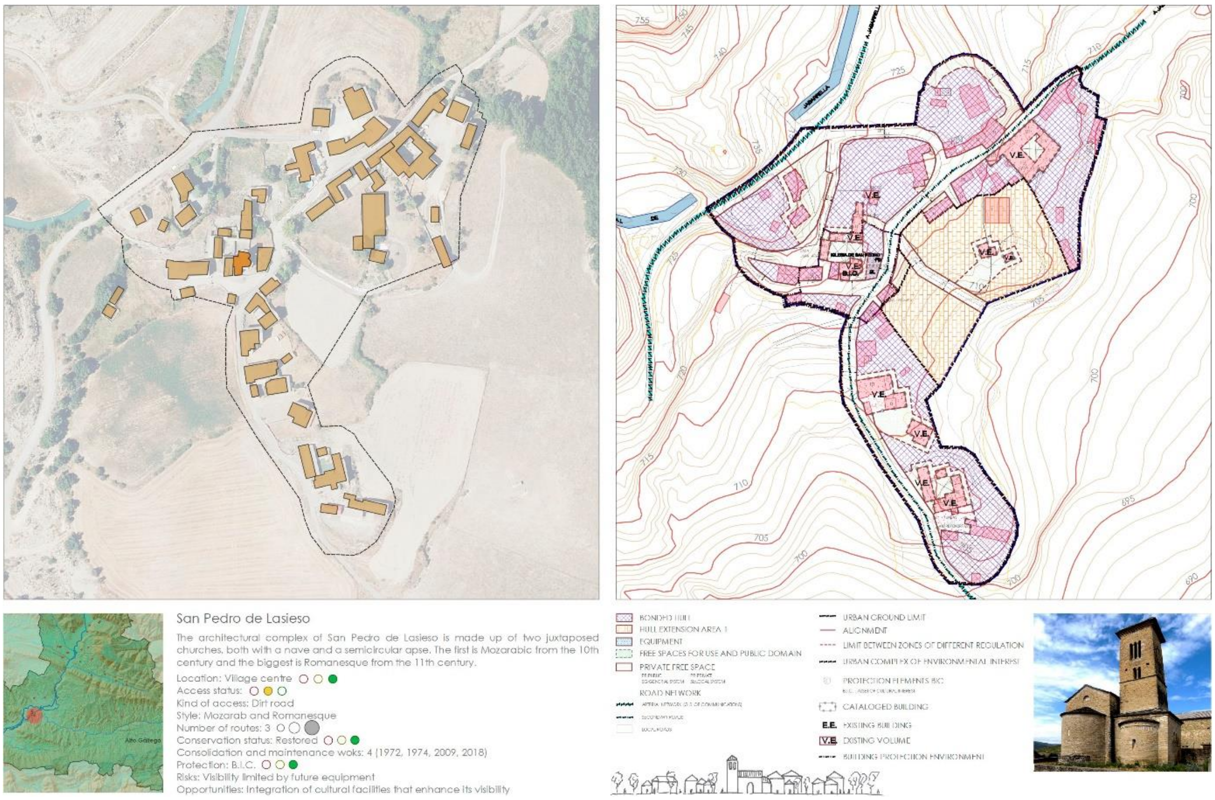



**Figure 9.** Type sheet of the Churches catalogue. Source: Muñoz, C. (2022).

Subsequently, with this catalogue of the churches and their corresponding files, a series of selection criteria is established (Table 1) based on the characteristics of the churches that will be used to make the decision to limit the number of samples to carry out the work of the field of research by reducing data collection to the most representative churches based on these selection criteria.

**Table 1.** Selection criteria

| Artistic | Technical | Divulgation |
|---|---|---|
| Architectonic style | State of conservation | Number of visitors |
| Compositional elements | Number of interventions | Number of tourist routes |
| Proportions and morphology | Heritage protection level | Accessibility and location |
| | Construction elements and materials | |

### 3.2. Fieldwork

Once the previous analysis has been carried out, we proceed to the individual study of the selected churches through in situ fieldwork whose work tools and procedures are the subject of this article. A digital survey of the selected churches will be carried out using different tools and devices.

On the one hand, prior to the visits, sketches of the property are made to serve as a basis for taking measurements that will help in checking the dimensions and scaling of the virtual models obtained. For this purpose, commonly used manual devices such as cameras, flexometers or laser meters are used. On the other hand, to obtain virtual models through point clouds, specific devices are used, such as 3D scanners, poles for remote access of photographic cameras, and drone flight by authorised personnel.

## 4. Results

After carrying out the fieldwork in the selected churches and obtaining all the necessary data from the on-site visits, we proceeded to process all the graphic information obtained.

Firstly, all the digital information obtained during the visit is downloaded, stored and organised in such a way that you can have quick and accurate access to the data needed at all times.

Subsequently, the photographs are processed using the *"Metashape"* software, specific for photogrammetry work. To do this, the coincident key points are identified in several photographs that allow us to relate the different positions of the camera in the process of virtual reconstruction of the church, obtaining a sufficient region to show us the church in its volume and textures.

After obtaining the point cloud of each church by processing the set of photographs taken in situ, the information is post-processed, that is, the selection of the points that we will use, as well as the discarding of those points that do not provide the digital model with the information that we want to obtain because they are not part of the scanned church. Once the point cloud with which we will work has been defined, we proceed to create the mesh and the rest of the elements that will be used to obtain the digital model of the church, such as the textures of the materials. Before finishing the process, the modelling must be cleaned, consisting of closing any possible gaps that the mesh created from the point cloud could not generate. (Figure 10)

**Figure 10.** Virtual reconstruction process of the model with photogrammetry. Source: Muñoz, C.; Piedrafita, J. (2015)

The same process of virtual reconstruction of the model will be applied to objects of special interest in the church environment. With the aerial images, we can create the exterior volume of the church, but the small details of the entrance porches, details of the bell tower, etc. They will not have the same presence as if we carry out these elements in detail with our own photographic scan for each element that we want to take out with a greater definition of detail (Figure 11).

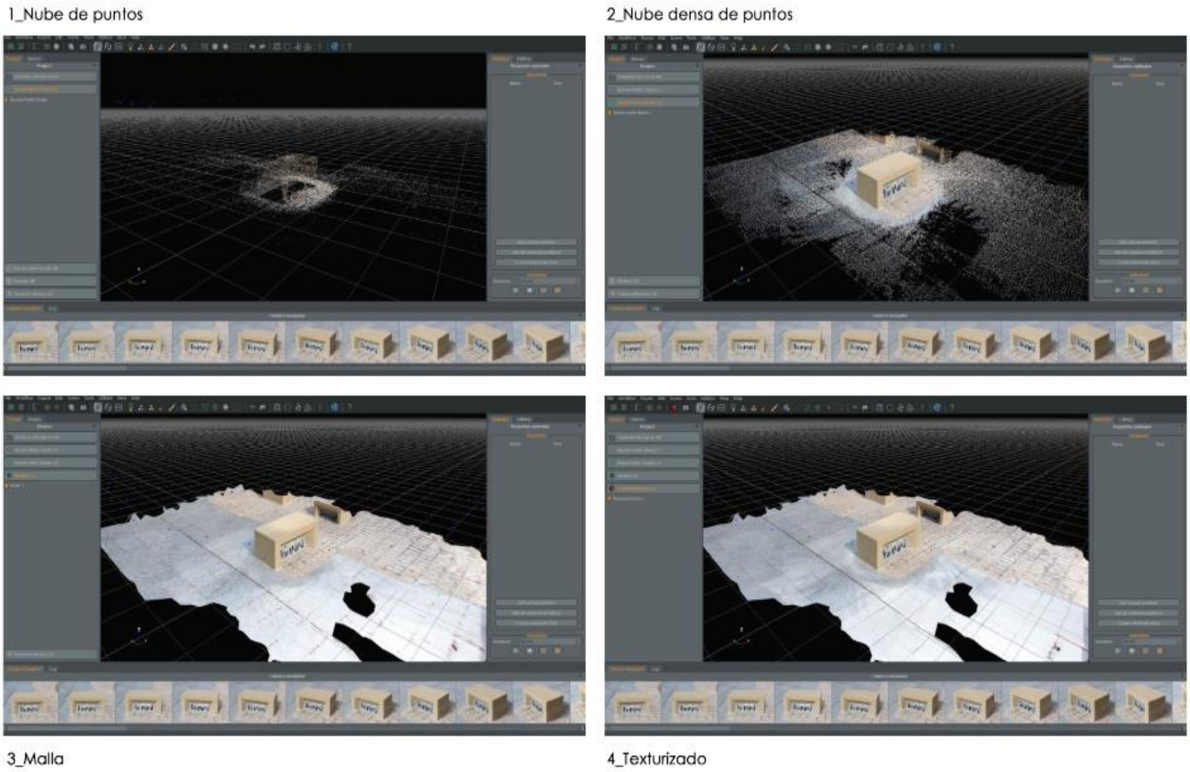



**Figure 11.** Photogrammetry of other elements. Source: Muñoz, C. (2022)

By processing the images taken during the visit to the church, either with the cameras or with the drone flight, a cloud of points of the exterior of the church is obtained. By processing the information obtained with the 3D scanner, we will obtain a cloud of points inside them.

To ensure that the proportions of the 3D modelling are correct, it is at this moment that we must check the dimensions of some of the elements, such as the length of the facades or of some of the openings, etc. This verification must correspond to the measurements that we have taken during the visit and that were noted in the sketches prepared previously; in this way, we will have a virtual model of the church correctly sized and geolocated to be able to work with it (Figure 12).

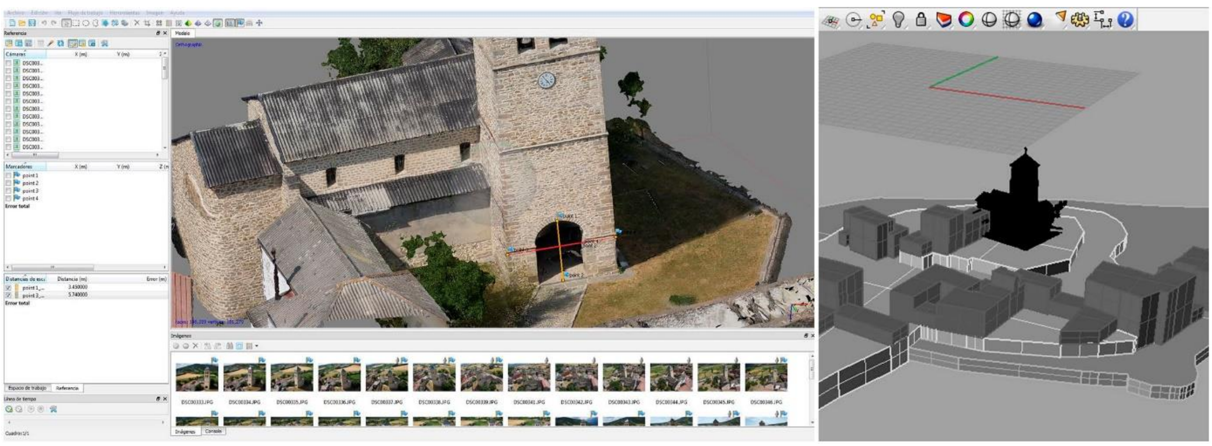


**Figure 12.** Virtual reconstruction of the church. Source: Muñoz, C.; Piedrafita, J. (2015)

Once the digital model of the church generated from photogrammetry has been created, we can obtain the 3D modelling in the usual format extensions to be able to work with it later. To do this, we must export both the mesh and the texture created in the format compatible with the 3D modelling program with which we are going to work.

You can also export the model in formats compatible with 2D drawing programs such as *"AutoCAD"* to be able to work with this information to prepare plans that serve to facilitate a possible intervention.

On the other hand, the correctly textured digital model allows us to create photomontages combining the real environment of the church with the virtual church with hardly any difference or be able to make other more creative photomontages focusing attention on the church and leaving the rest of the environment as volumes (Figure 13).

**Figure 13.** Volumetric photomontage with virtual church. Source: Muñoz C.; Piedrafita, J. (2015)

Finally, this virtual model of the church obtained will allow us to create a graphic representation to support the development of an interaction through virtual and augmented reality that helps disseminate the heritage that was proposed with the line of research.

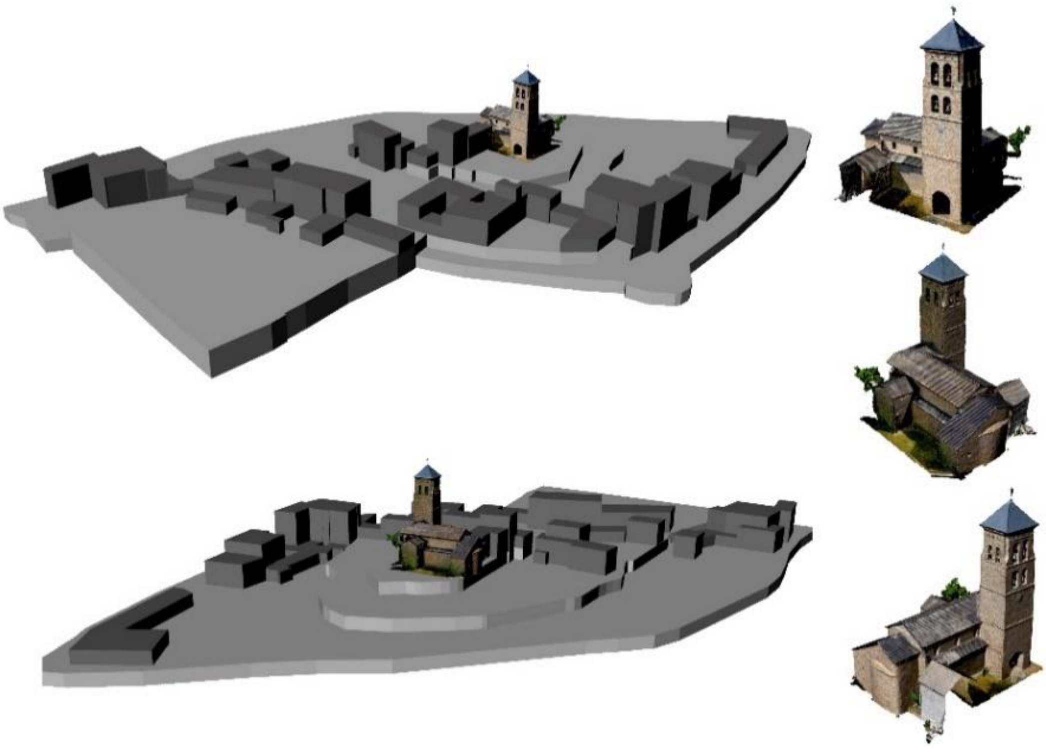


**Figure 14.** Virtual model of the church. Source: Muñoz, C., Piedrafita, J. (2015)

## 5. Conclusions

Photogrammetry tools have been used as a vehicle to obtain a digital model of the churches that are the object of the research in development and allow us to analyse their construction, architectural, volumetric and dimensional elements in order to establish a series of hypotheses about the common characteristics that define the group of buildings of the Alto Gállego churches.

On the other hand, the construction of a virtual model of the churches also allows the promotion of their dissemination digitally, helping to value the architectural heritage that this complex contributes to the territory, being able to bring the churches closer to a larger public through virtual visits, with the implementation of virtual reality and augmented reality that we will address in the final stage of the research, making these virtual visits an interactive and immersive experience with explanations, informative notes, etc.

In general, photogrammetry allows us to virtually reconstruct buildings that are part of our heritage; either to understand, analyse and delve into its construction process or to promote accessibility to its dissemination. Tragic events such as what happened in 2019 at Notre Dame de Paris or recently in 2024 at the Copenhagen Stock Exchange led to a serious deterioration of the architectural heritage of the place. The virtual reconstruction of these buildings through techniques such as photogrammetry allows us to have a basis of graphic, spatial, volumetric and technical information that helps the subsequent intervention to reconstruct the heritage. Likewise, new representation techniques such as virtual reality or 3D modelling allow us to visualise and interact with a building in ruins or with the result of the intervention in a heritage building prior to this.

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# Design for Cultural Cooperation. Interaction, Experience and Heritage Awareness

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***Abstract***

*The design of the museum experience can be improved through an innovative interaction framework that uses digital technology to digitise and make different types of cultural heritage accessible and improve awareness for the management of public and tourist use of heritage sites.*

*This research aims to protect cultural heritage diversity and enhance its accessibility and dissemination. It presents methods to digitise resources of various heritages and develop experiential design and interactive environments through advanced simulation and representation. The study addresses the development of an interaction design model based on real-time simulations of existing installations and experience environments for cultural sites and the evaluation of the process and design workflow, introducing modelling (CAD/BIM) and simulation environments (Game Engine/AI).*

*The objectives are to introduce an information model to manage the environment and exhibit design and to develop interactive installations that use diverse media to highlight cultural content and improve cultural attraction and communication efficiency. An itinerary and interactive display of tangible/intangible heritage will be presented and tested through the advanced simulation application to visualise immersive 3D environments. From the BIM, a live connection with the visual development tools of the game engine middleware is possible, which facilitates graphic simulation.*

*Field tests and process references will benefit from recent research on the Roman Theater of Amman as part of an international cooperation project on the experiential and interactive valorisation of the museum collections of the Popular Traditions Museum of Jordan.*

***Keywords:*** *cultural cooperation, cultural landscape, HBIM, simulation, interaction design, Jordan*.

## 1. Introduction

The cultural heritage of a society is a crucial component of its identity and plays a significant role in driving the local economy. As such, preserving and effectively managing this heritage is vital to ensure its longevity and to pass it on to future generations in good condition (Vecco, 2010).

The research aim is to protect the diversity of cultural heritage and enhance universal accessibility and dissemination of cultural contents; the process presents effective methods to digitise resources based on the different natures of various heritages and figure out experiential design and interactive environments through advanced simulation and representation of museum interiors.

Activities put into practice an operational procedure for the evaluation of the museum experience to foster cultural tourism management within international sites but also the use of a hypertextual model of a "simulated museum" for verification in the creation and design of museum displays and itineraries by institutional operators.

The *Faro Convention* (Council of Europe, 2005) presented the challenging concept of heritage communities (Art. 12, comma b), outlining a social context in which individuals are united by common values linked to a shared cultural heritage, embodying the concept of common good applied to the heritage. (Valiante, Oteri, 2022) The sense of belonging in the museography field develops through the interpretation of heritage, the generation of cultural meanings, and the design of museum installations, which occur through the transcription and communication of events, symbols, and expressions, often ritual, oral, and transmitted in limited geographical areas. The research traces a conceptual path which, starting from the objects considered in their uniqueness, displayed physically or in their digital equivalent, guides the user (or visitor) towards perception and restitution of a contextual nature, capable of integrating the stimuli coming from the objects, environments and those intangible elements characteristic of cultural landscapes.

The international collaboration project for the Museums of Folklore and Popular Traditions at the Roman Theater of Amman has facilitated the exploration of transforming museums into centres of knowledge and experience, utilising digital heritage methodologies. The project emphasises the importance of connecting individuals to their cultural heritage, highlighting the process of representation and dissemination. The Netherlands Museums Association has established a paradigm for museum values, including Collection, Connecting, Education, Experience, and Economics (https://museumvereniging.nl/). The most critical cluster is "Connecting," which operates across all organisational and functional levels of the museum, emphasising its role as a mediator between different social groups (Figure 1).

In the museums under study, digital transformation is implemented using technology to engage new audiences, promote cultural experiences, and attract young people of school age, their families, and foreign visitors. The strategy is developed through a co-planning process, integrating complex actions that address inclusion and intergenerational exchange. This involves transcribing the meanings of museum artifacts into new expressions through various multimedia technologies (Manovich, 2002).

In the museum sector, some of the main applications include:

1. Digitizing museum archives, libraries, and repositories, as well as creating multimedia exhibitions and 3D printing

2. Utilizing VR/AR systems in installations for greater interactivity and immersion, with more adaptable spaces for various uses

3. Introducing a variety of gamification and edutainment options, such as live broadcasts, online lessons, games, and quizzes

4. Employing algorithms and user preference analysis to create personalised visit paths and web-mentoring

5. Involving visitors in the design process through participatory design, co-design, prototyping, and simulation.

6. Providing ongoing training to museum visitors, both in-person and online, to extend the museum experience

 

**Figure 1.** The Museum of Popular Traditions at the Roman Theater of Amman. Source: author. (2022)

The experiential design of a cultural space promotes a mediation between environments, cultural content, intangible heritage (contribution of users, their testimonies, cultural practices but also the values of the territory), and the user community, allowing multiple forms of interaction and development (Amoruso, Mironenko, 2019).

Examining the global landscape of the creative industries, the digital museum's role and the need to adapt spaces and contents for a new functional audience is highlighted. The disciplinary consequences in representation and interactive design, technological innovations, and museographic strategies and solutions are illustrated.

## 2. Aims and objective

Technologies offer methods and tools for the conservation, analysis, and dissemination of heritage, as well as contributing to the creation of new representations of heritage itself. This innovation involves exploring new forms of sharing and disseminating knowledge, which becomes multimedia and interactive (Figure 2).

To fulfil their educational task, cultural spaces must overcome their spaces' physical and tangible dimensions to promote communication and sharing actions of their heritage permanently, also in intangible terms and services related to accessibility. The user is involved in activities and accesses interactive and personalised content, and this process makes our perception of cultural heritage different and the way we regenerate it through cognitive processes; in this regard, how it is made accessible use, for example, gamification and storytelling as tools and guides to connect content to users. The study seeks to enhance the utilisation of Building Information Modeling (BIM) for museum installations (Tucci et al., 2019) by introducing a design process focused on creating sophisticated multimedia and interactive representations using a Hyper-Model connected to the BIM.

The objective is to understand how digital media generates specific outcomes and implement solutions for universal design and accessibility. This approach simulates integrated interiors where visitors can engage with installations, interact with technological elements, and access multimedia content. This methodology facilitates a dynamic exchange of ideas by fostering collaboration among designers, curators, users, and exhibition spaces. To accommodate various design scenarios, such as incorporating digital elements into spaces, it is crucial to document the heritage of collections by transforming them into digital libraries and offering an interactive design tool for fittings, collection management, and museum route verification: the hyper model BIM. Through dynamic visualisations and representations, museum curators can leverage this graphical system to oversee all museum-related information efficiently.

In this research, the focus is on exploring the benefits of Building Information Modeling (BIM) in enhancing the design process for interior spaces, particularly in the context of museums.

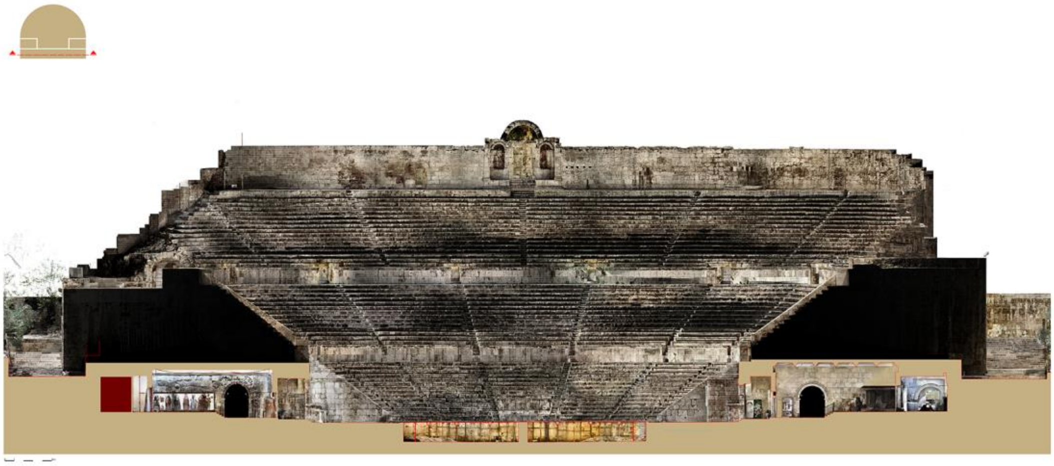

**Figure 2.** Architectural survey of the Roman Theater cavea, Amman. Source: author. (2022)

The study delves into how BIM facilitates collaboration among designers, curators, and digital media, emphasising its role in enabling interactive visualisation and validation of intricate projects tailored for various museum activities. These activities encompass the modernisation and digitisation of collections, interactive exhibits, environmental enhancements, and ensuring accessibility for diverse user groups. By utilising BIM for design simulations, it becomes feasible to assess the repercussions of modifications related to installation layouts, environmental features, and adaptable and advanced equipment, as well as to facilitate seamless information sharing. Furthermore, a key aspect highlighted is the capability of integrating architectural models derived from surveys and 3D scans with temporary interior design solutions to replicate the diverse requirements specified by museum curators. The research demonstrates how to put design strategies into practice, improve awareness through mock-ups and communication artifacts, and engage new audiences. Activities proposed an interaction design model for each museum, starting with the dynamic simulations of visits and engagement with the installations.

## 3. Methods and/or procedure

The study commenced by evaluating primary BIM parametric modelling and advanced simulation with game engine software. Notably, advanced simulation holds particular significance within the design and architecture field. This software framework is primarily tailored for creating interactive virtual environments and is validated through specific tools such as visors, glasses, caves, virtual theatres, and online platforms. Using specialised libraries and auxiliary programs, simulation enables assessing diverse design components. Furthermore, it innovatively incorporates functional parameters associated with individual physical and multimedia setups like showrooms, museum environments, home automation installations, hospital rooms, and temporary stands. This integration is achieved through novel advanced representation protocols and methodologies.

Experimentations benefit from the recent international cooperation project to valorise the museum collections of the Popular Traditions Museum of Jordan. The testing and verification process of the procedures took place at the Roman Theater site in Amman, where the Folklore Museum and the Popular Traditions Museum are situated. These museums have undergone a comprehensive reorganisation program based on experiential design and universal accessibility principles. The research focused on modelling environments using laser scanning survey data, checking the functionality of installations, simulating user experience, interacting with multimedia devices, and evaluating digital content related to the displayed objects (Figure 3).

The process follows an interaction design layout to enhance cultural content and improve cultural attraction and communication efficiency of exhibits, rather than just an isolated and interesting interactive entertainment device.

An itinerary and interactive display of tangible/intangible heritage will be presented to future visitors and tested in advance through the simulation application to visualise immersive 3D environments.


**Figure 3.** The Museum of Popular Traditions entrance with a view of the ground floor layout. Source: author (2023)

The concept that multi-sensory immersion can be used to engage audiences and heighten emotional experience is not new. In the past century, museums have used dioramas, film projections, sound effects, voice tracks, and the occasional smoke and mirrors to contextualise cultural artifacts and historical objects with immersive environments. They have drawn on the staging and mise-en-scene techniques commonly used in theatre and film. They have, at times, dared to use cutting-edge technologies, such as stereoscopic 3D when it was first popularised in the 1840s, to appeal to a wider audience (Stogner, 2011).

The BIM ARCHICAD software offers an enhanced hypertext model that can be exported to mobile or desktop applications, expanding its reach. This feature transforms the model into an interactive museum space by integrating technical visualisations and product datasheets. Users can access information about the museum's elements, such as finishes, dimensions, and quantities, in a hypertextual manner. The real-time navigation feature allows for a simulated virtual tour, enhancing user interaction with parametric objects. The hypertext graphic representation of the BIM model connects technical visualisations with interactive fruition, improving design component visualisation and understanding of spatial forms. This feature also consolidates all technical documentation related to performance, materials, and technical specifications into a single virtual model, a shared graphic database. BIM also enables the creation of custom objects and construction systems on a collaborative platform, prioritising and enhancing the 3D model's information characteristics. It facilitates communication among project participants by offering multi-scale, multi-dimensional design. Compared to traditional CAD design, BIM requires multidisciplinary knowledge of technological solutions to represent the model correctly, aligning with the technological standards of the professional and industrial sectors. The BIM model allows for flexibly managing advanced representation and interaction with the model. There are various ways to share, publish, and present the project through dynamic, immersive experiences, such as real-time simulation of interiors, photorealistic renderings, or NPR graphic filters. BIMx is an ARCHICAD tool that enables users to present the project in a dynamic and virtual visit mode, allowing them to verify paths and interactions with planned installations. The experimentation process allows for the definition of classification, properties, functions, and information on design elements that can be utilised for other specialised applications. The model, published through the wizard integration of its views, is intended for wide sharing, enabling even those who did not participate in the design to explore the project. The hyper model is beneficial for designers and curators in the interactive verification of installations, and also for visitors who visit the museum online. The main result of the experimentation was the verification of the user experience, the functioning of the museum setting, and the integration of the 3D model with historical documentation and the inventory of the museum collection. The physical structure of the museum building was simulated and reproduced through BIM modelling procedures, including parametric detail information and the main characteristics of architectural surfaces and materials. Environments are complex due to the incorporation of original structures belonging to the Roman theatre and the rich presence of museum collections, objects, exhibitors, and installations. Thanks to the hyper model, it has been possible to navigate in real-time and make checks that can assist in decision-making processes and cost evaluation. The Hyper-Model can contain the entire documentation of the project, including the 3D model, layout of elevations, 3D sections, axonometry, perspectives, datasheets, and the visit path (Amoruso, Mironenko, 2022).

From the BIM, it is possible to make a live connection with the visual development tools of the game engine suite, which provides functions that facilitate graphic simulation and audio, kinematics, and with the support of artificial intelligence (AI). The research tested the connection between the BIM model and the visual development tool included in the game engine suite. (Amoruso, Buratti, 2022) This suite offers features that simplify graphical simulation and provides tools for adding multimedia elements such as audio, motion simulation, and artificial intelligence applications for environmental design. These game engines, called "middleware," offer a flexible and reusable software platform that integrates all the functionality needed to develop an experiential application, thus reducing complexity and costs and providing predictions, verification, and solutions. TWINMOTION, a real-time rendering engine part of the Unreal Engine suite developed by Epic Games, was tested in a specific case. This tool supported the design of the Roman Theater exhibition, envisioning an experience with tactile, visual, and digital installations. Using Mixed Reality applications, digital prototypes were verified through advanced simulation in immersive environments using a virtual theatre-like infrastructure (Figure 4).

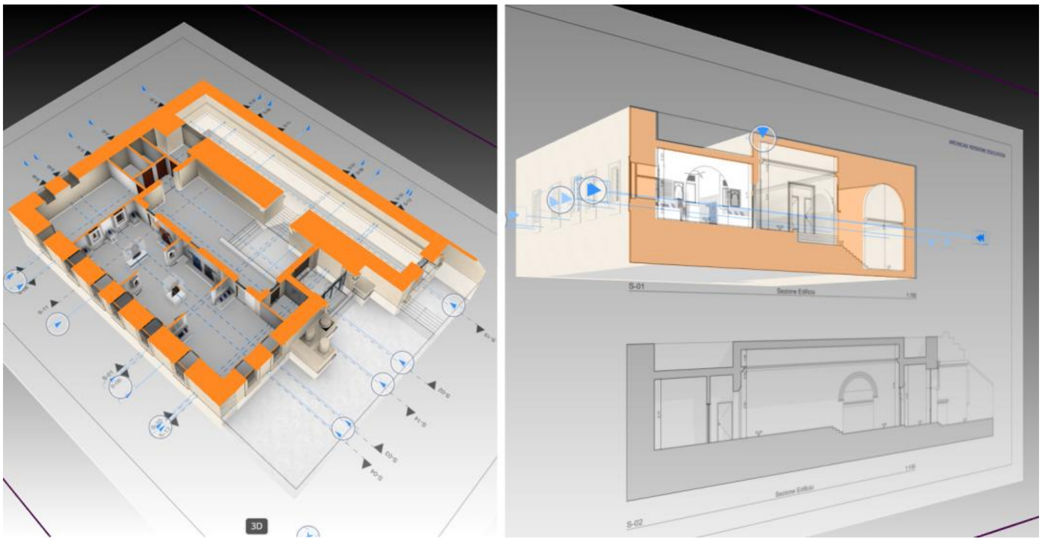

**Figure 4.** BIMx model and the interaction with the design layout from the BIM model. Source: author (2024)

 

## 4. Results

The new museological perspective for museums of cultures or, as defined by UNESCO, cultural landscapes, recognises the power of storytelling as a means of redefining the identity of cultural institutions, such as museums and libraries, often situated in peripheral and marginalised locations compared to large national galleries or art museums.

For instance, the project implemented experimental procedures for the Popular Traditions Museum, enhancing visitor engagement with the exhibits and promoting experiential learning dynamics.

Considering the unique nature of the museum's collections, which primarily consist of handcrafted objects produced through intricate and fragile techniques, special display conditions are necessary to ensure proper preservation and display. This includes appropriate lighting, furniture, displays, and accessories. To achieve the appropriate awareness, routine testing of visual and algorithmic programming was conducted utilising the parametric libraries of BIM software to verify the optimal setup solution and accessory provision for each artisan category. This ensures the exhibits' safe and effective conservation and display of jewels, dresses, and accessories.

BIM software's parametric and algorithmic components offer a specific application for the exhibition and interior design sector, enabling the museum to optimise the setup and accessory provision for each artisan category, thereby enhancing and preserving the exhibits' display.

The ARCHICAD design environment was used to develop an experimental application for museum installations and the digital museum in collaboration with curators and the Department of Jordanian Antiquities. In the context of Building Information Modeling (BIM), architectural objects, such as furniture, installations, and building components, play a crucial role in the design process, starting from the initial stages of architectural planning. These objects are not just visual elements but contain data and parameters anticipating their installation and usage over time. They serve as the interface between design and space functions, for example, forming a personal library for museum design, which contains all the components of a multimedia exhibition. The ARCHICAD Standard Library integrates many parametric elements that can be enriched with additional objects and textures from online catalogs. These platforms often offer parametric objects in the GSM format recognised by ARCHICAD, such as BIM Components and BIM Object, which can be accessed directly from the software (Figure 5).

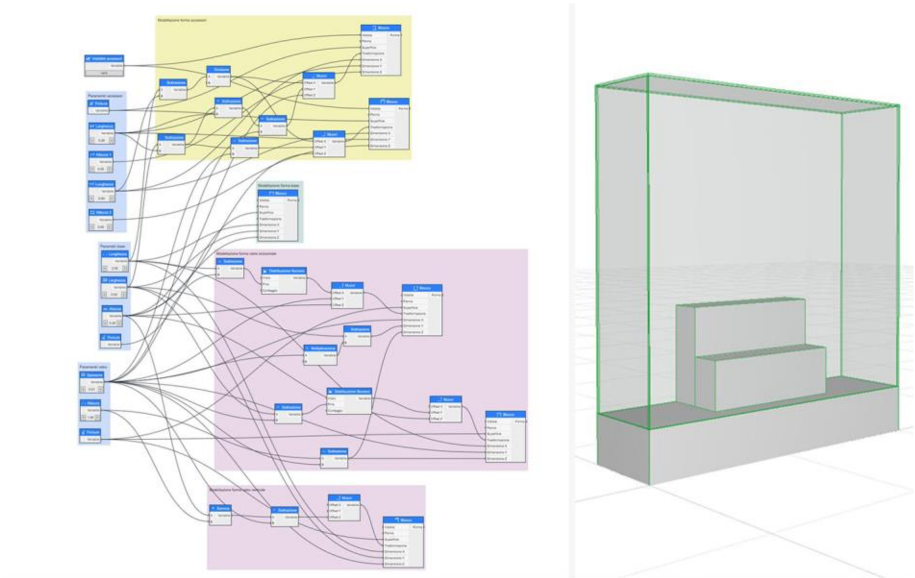

**Figure 5.** Visual algorithm for a parametric showcase at the Museum of Popular Traditions, designed with the PARAM-O ArchiCAD tool. Source: Amoruso, Mironenko (2021)

The main focus is the use of parametric programming in ARCHICAD to create customised libraries in BIM, specifically for the display of jewellery and traditional costumes. ARCHICAD's PARAM-O algorithmic tool has been tested to verify its parametric programming characteristics and how the visual node interface replaces scripts, integrating and extending the parametric modelling commands already typical of BIM, allowing users to create parametric elements of the library without directly writing the code in the Geometric Description Language (GDL).

The methodology involves fixing the "nodes," parametric modules, and their connections, leading to the complete installation of the structure, panels, plants, and accessories. The nodes allow the completion of the parametric and algorithmic model with its shapes, qualities, materials, colours, and accessories. The more parameters an object has, the more flexible it is. By saving the created object in PARAM-O, it becomes a native ARCHICAD library element. This tool provides infinite design variations and options for designers and curators, enabling them to dialogue through interactive simulations to test new outfitting solutions, choose collections, and refine the museum layout based on user experience. The research presents the models developed as an experimental set: on the one hand, the BIM model extended in the BIMx version to test its hypertextual and informative potential; on the other, the analogous simulation model, exploiting the Game Engine middleware, allows the advanced representation of set-up, experiential and satisfaction and accessibility verification actions and operations.

Visual information technologies, used for design and representation, offer an immersive experience of museum spaces. These can be used both to create multimedia content and to allow active interaction with the collections through displays and installations. The use of applications from video games allows us to verify, through iterative cycles of modelling, representation, and rendering in real-time, the accessibility, interaction, and general functionality of the museum environment (Figure 6-7).

The research concludes its critical path by examining the social context of the ongoing transformation, considering the digital products and services that the digital museum can offer for adequate cultural activity. In addition to the simple visit, often limited in space and time, research on the social impact of museums and libraries and the applications of technologies raise the question of experience and participation in the museum environment, an aspect that also concerns design, communication, and related cultural products.

A new interactive, universal, and flexible use is envisaged that responds to the different expectations of communities and visitors, who are increasingly cultural tourists, digital natives, activists, and creatives. The ideal experience of the user, visitor, and tourist is no longer limited to the cultural sphere of the "walls" or a single episode but extends the concept of the visit, including the planning phase, the use of resources available online, the consideration of pedagogical tools for school children, providing interaction and participation in events, initiatives and also continuous access to information and digitised collections.

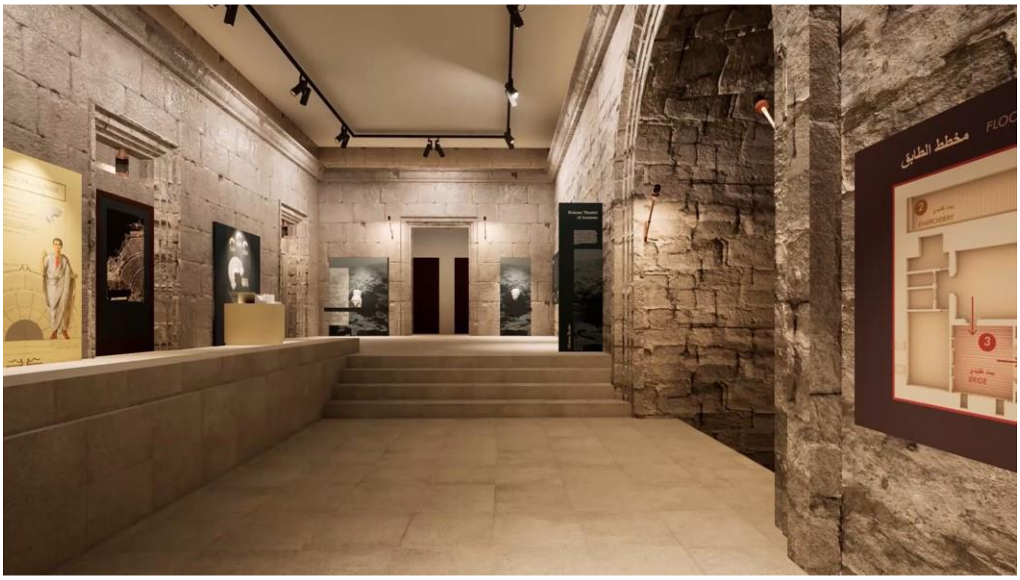


**Figure 6.** The Museum of Popular Traditions, the Roman Theatre exhibition entrance, infographics, and tactile replicas. Source: author (2022)


**Figure 7.** The Museum of Popular Traditions, the Roman Theatre exhibition, infographics, and a proposal for the tactile replica of the architectural model. Source: author (2022)

## 5. Conclusions

The application of Building Information Modeling (BIM) in museum design and management includes the introduction of an innovative workflow for the customisation and management of BIM models, reorganisation through digitisation and visualisation of collections, linking items to interactive visual environments, and the creation of an information archive and Hyper-Model.

The research methodology combines advanced methods of representation to address the various needs of digitisation in museum design with the scope to preserve memory and practices, enhancing the digital experience. Narrating heritage through digital media is an innovative strategy for preserving and sharing memories and practices with new content. The further step is to design a knowledge-based repository for gathering (workshop), maintaining (digital platform), and disseminating (augmented experience on site) the knowledge of the artisans and communities (Figure 8).

The BIM tool creates a seamless and efficient process for managing the technical design phases, from the preliminary stages to the final concept, while incorporating elements like disability issues and environmental safety parameters. The final Hyper-Model includes the technical and architectural layouts and information accessible to different figures operating in the museum system, promoting collaboration and inclusivity. This tool allows curators to link collections, usually listed by inventory cards, to an interactive visual environment. This environment contains the set-up solutions defined by parameters, libraries, and visual programming algorithms, providing a more engaging and accessible way to explore museum collections.

**Figure 8.** The Museum of Popular Traditions, the visual glossary of traditional dresses, an interactive installation with the pattern book of dress typologies and material board. Source: author (2023)

The ongoing experimentation aims to reorganise the museum, starting with digitising the inventory, promoting a more efficient and accessible approach to museum practices, and extending field visits to digital experience and remote access to web-based resources. The BIM model can be customised and oriented towards management, maintenance, and verification of environmental safety parameters rather than just exhibit design and content visualisation. Besides, the BIM procedure offers a representation environment that develops from the architectural survey and increases the model in the different levels of information required by the museum installations and maintenance. In conclusion, the introduction of BIM in museum design highlights its potential for improving efficiency, accessibility, and collaboration management in the museum sector.

The objective of this research is to foster a deeper understanding and appreciation of the artefacts displayed in the two museums and their connection to the Jordanian landscape. By achieving this, the research aims to create a continuous growth cycle in awareness of the rich and diverse cultural heritage. Ultimately, the goal is to inspire future generations to incorporate tradition into their lives through their thoughts, emotions, and actions.

 

## 6. Fundings

This work was developed under the cooperation project "Program for the definition of a strategic plan for the improvement and the enhancement of the Folklore Museum, the Museum of Popular Traditions, and the site of the Roman Theatre in Amman (2020-2023), funded by the Italian Agency for Development Cooperation in agreement with the Department of Antiquities of the Ministry of Tourism and Antiquities of the Hashemite Kingdom of Jordan and operated by the Department of Design of the Politecnico di Milano. Giuseppe Amoruso is the scientific director and project coordinator.

## 7. Acknowledgements

Giuseppe Amoruso is the author of the text and the supervisor of the survey, design, and final project outcomes. The author acknowledges Polina Mironenko for her support in illustrations and graphics design.

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# From Plan to HBIM in Zaragoza to Canfranc Passenger Buildings

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***Abstract***

*Graphic Expression, specifically architectural drawing, allows for the expression of the construction model and process, transitioning from the blank, two-dimensional plan to the actual constructed model.*

*Drawing is a tool in architecture to represent ideas, solutions, or projects we want to carry out. When studying Architectural Heritage, the potential of graphic expression to represent the existing, analyse its condition, and propose possible actions is undeniable.*

*Architectural heritage and other historical documents and objects from historical archives must be preserved to maintain history and culture.*

*The use of increasingly sophisticated tools and techniques allows for efficient optimisation of the level of detail of each graphic document for each situation.*

*Nowadays, we have tools and technology that enable new ways of working, facilitate data acquisition, representation of existing models, and preservation of existing documentation.*

*This document presents the different techniques for digitisation and the study of railway architecture from Zaragoza to Canfranc, focusing on passenger buildings at some stations.*

*Specifically, it refers to the work carried out, from the study of the documentation consulted in the AZAFT historical archive, the digital scanning of plans, redrawing of these plans, 3D surveys, photogrammetry work, and generating point clouds from laser scanning.*

**Keywords:** *railway, Canfranc, stations, passenger buildings, architectural drawing, graphic expression, 3D modeling, photogrammetry, scanning, laser scanner, HBIM, heritage.*

## 1. Introduction

The Zaragoza to Canfranc railway project, as a cross-border communication with neighbouring France, has been a long-standing aspiration advocated and defended by the Aragon region since the 19th century. Among other publications, these demands were recorded in 1853 in the text "Los Aragoneses a la Nación española" (Aragonese to the Spanish Nation).

This project was not without controversy due to technical, geographical, and orographic difficulties, different political and economic interests, and others beyond the scope of this document.

The study focuses on the final layout, specifically on the existing structures today, which allow us to trace the passage of history, which we can visit and touch, particularly in studying passenger buildings at train stations. "The passenger building is undoubtedly the most representative element of the architectural and logistical complex known as a railway station" (Martínez-Corral, 2019).

In the final layout, we can distinguish four sections. The first runs from Zaragoza to the town of Tardienta, connecting to the existing line to Barcelona. The second section extends from Tardienta, connecting to a branch line to Huesca, the provincial capital, and extending the line to Jaca. The third section reaches Canfranc, where the international station is located. The last section responds to French obligations to shorten the line, linking the Zuera station to the Turuñana station, bypassing Huesca and reducing the route by more than 40 km. The route crosses the border through the Somport tunnel to connect with France but is outside the scope of this study.

In the context of conserving and managing architectural heritage, the Canfranc Line presents a unique challenge. With its vast expanse, numerous structures, and rich history, preserving this masterpiece of the past for future generations requires a deep respect for its legacy and innovative tools and approaches that adapt to the demands of the present.

At this point, the convergence between the past and the future arises in the transition from traditional drawings to Heritage Building Information Modeling (HBIM). This article will explore how this technological evolution is transforming how we understand, preserve, and study the buildings between Zaragoza and Canfranc. From delineating their initial layouts to implementing advanced digital solutions, we will examine how HBIM has become an indispensable tool in preserving architectural heritage. Through concrete examples, detailed analysis, and reflections on the future, we will delve into the fascinating world where the past meets technological advancement, all in the unique context of this railway line.

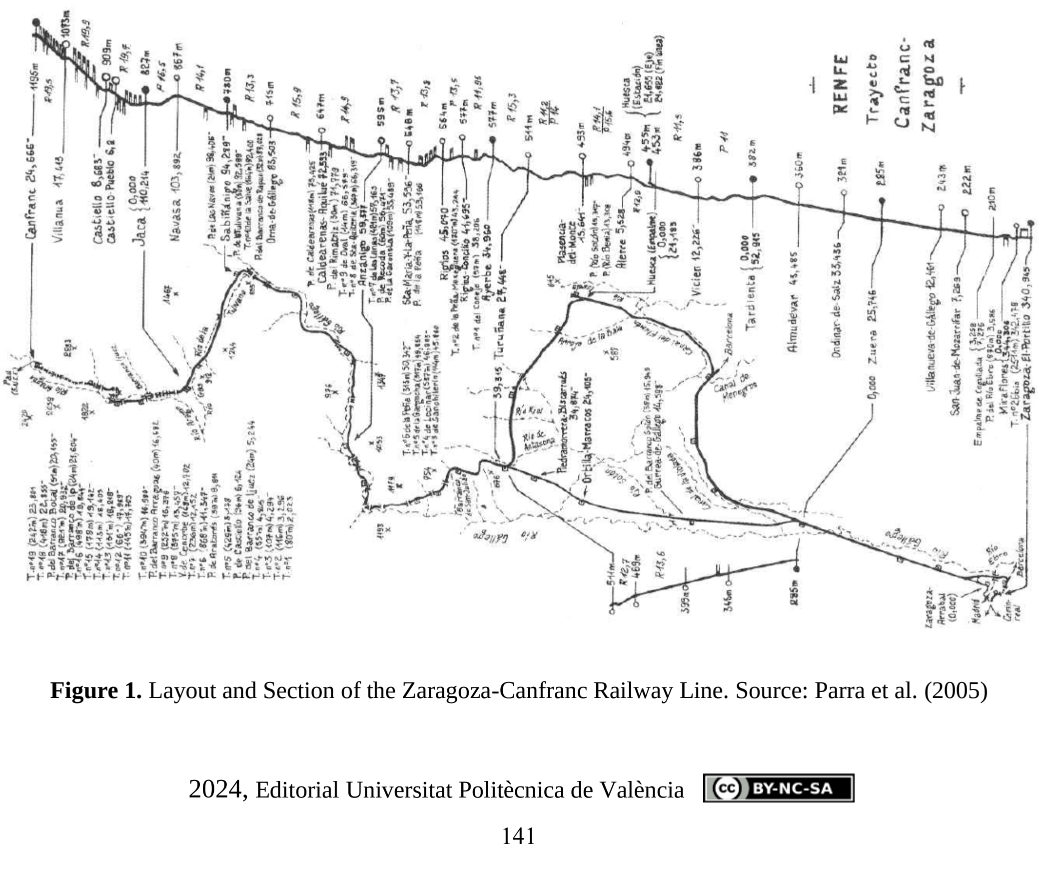



**Figure 1.** Layout and Section of the Zaragoza-Canfranc Railway Line. Source: Parra et al. (2005)

## 2. Study of Plans: Digitization and Redrawing

"With architectural drawing, we can surpass the flatness of a two-dimensional surface and represent three-dimensional ideas in a clear, understandable, and convincing manner. Developing this skill requires experience both in the execution and interpretation of the graphic language of drawing. Drawing is a matter of technique and a cognitive act involving visual perception, good judgment, and logic of dimensions and spatial relationships" (Ching, 1974).

The plan represents an essential graphic document in work and, therefore, in studying architectural or heritage work. Spaces, structural systems, construction systems, and other solutions that will be carried out and executed in the work are reflected in the drawing. They also serve us to depict and study existing spaces.

Plans become graphic documents in themselves, with the ability to express. To understand them, learning to read and interpret them is necessary. Each stroke on a plan has rigour; it has a way of being and speaking in its graphic language.

In an initial approach to this study of the railway line between Zaragoza and Canfranc, access is available to original documentation of the layout, construction, and projects of the line, as well as of the stations, specifically the passenger buildings. The Zaragozana Association of Friends of the Railway and Tram (AZAFT) preserves in its facilities an archive with plans, scrolls, and other graphic documents, texts, letters, etc.

The condition of these documents, their preservation, the history of these documents, and this archive are the subject of another study. With the affection and value they have, not only as a document but also as heritage in themselves, they have been consulted and studied, preserving their condition.


**Figure 2.** Photo of the Consulted Plans. Source: Author.

The original plans consulted and studied were in a delicate conservation condition, and after consultation, they were catalogued and preserved. To facilitate the consultation and study of the found graphic documentation, as well as to preserve the condition of the original documents, digitisation was carried out through scanning as they were studied. The digitisation of plans "aims to:

- Increase citizens' access to archive documents through the use of the internet;
- Disseminate historical heritage;
- Safeguard original documents by avoiding manipulation;
- Create backups of unique and valuable materials;

- Create a common repository for the dissemination and preservation of historical heritage" (Generelo, 2017).

Scanning historical plans from the 19th and early 20th centuries is not easy. It is truly an exciting task because it involves handling historical documents. However, their manipulation must be careful due to their delicacy and conservation status. The format of the plans, with large dimensions, also presents certain challenges when handling and digitising the documents. Likewise, the logical intention of AZAFT's archive property to preserve the documentation in its facilities to avoid the loss of any copies does not facilitate solutions for moving the plans for digitisation. The same applies to the lack of economic resources allocated for this purpose.

Given all these circumstances, the decision was made to acquire a scanner for plans with guides, which allows scanning by successive passes over the surface of the plans to be digitised, as well as assembly and editing of the images afterwards.

The characteristics of the Senniao Track Scanner for plan digitisation are as follows:

**Table 1.** Laser Scanner Characteristics

| | | | |
|---|---|---|---|
| **Model number** | SN900STA0H | **Colour depth** | other |
| **Scanner amplitude** | A4 | **Type** | Escáner de superficie plana |
| **Interface type** | USB 2.0 | **Scanning element type** | CIS |
| **Scanning speed** | 600*600dpi <6cm/s | **Optical resolution** | 300 x 600 |
| **Brand name** | LZHZXY | **Origin** | CN(Origen) |
| **Product Model** | SN900STA0H | **with English Manual** | Yes |
| **File Format** | JPG & PDF | **canner size** | 265X42X24.5 mm |
| **Product weight** | 1.6KG | **Standard battery** | 2*AA alkaline five batteries |
| **Resolution** | 900 * 900dpi \| 600 * 600dpi \| 300 * 300dpi | **Memory** | Micro SD card, up to 32G |
| **Scan track length** | A0H (a scan length of about 1.5 meters) | **Product number** | DL0158 |

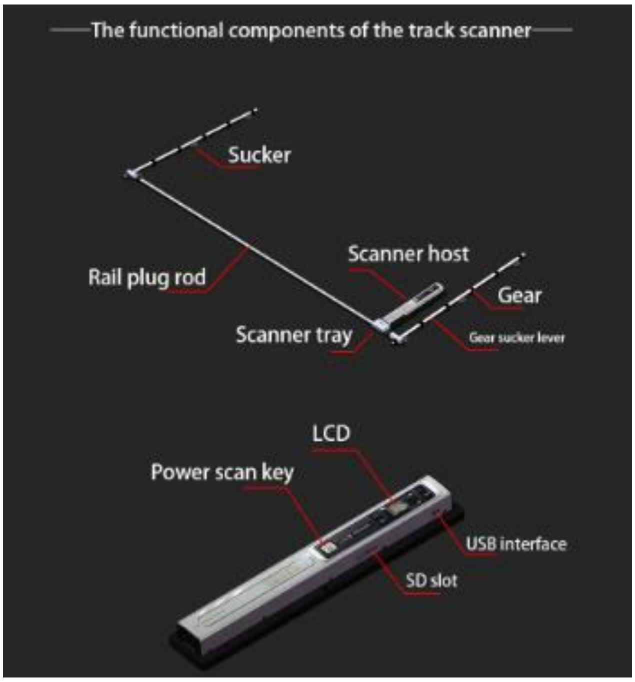



**Figure 3.** Photo of Plan Scanner. Source: Aliexpress.

"As a reference, we will consider that an appropriate resolution for opaque graphic supports will be between 300 ppi and 600 ppi" (Generelo, 2017).

**Table 2.** Minimum Suitable Resolution Levels for Each Support. Source: General, 2017

| Support | Type | Resolution (PPI) |
|---|---|---|
| Opacity | Up to 18x24 cm | 600 |
| | Above 18x24 cm | 300 |
| Celluloid Transparent | 35 mm and 16 mm | 2,600 - 4,200 |
| Glass or Celluloid Transparent | 4x5 cm, 4.5x6 cm | 1,800 |
| | 6x6 cm, 6x7 cm, 6.5x9 cm | 1,200 |
| | 9x12 cm, 10x15 cm | 800 |
| | 15x20 cm and larger sizes | 600 |

Due to the dimensions of the plans and graphic documents, the scanning resolution is set at 300 dpi. The IMADARA document is taken as a reference.

"The purpose of this document is to establish a protocol of action and standardised guidelines for all Archives of the DARA system that are easily assumable by all centres, whether or not they have specialised technicians in digitisation, thus unifying criteria and facilitating the dissemination and conservation of historical documents. Although DARA allows the incorporation of documents of all types, such as moving images or sound documents, the present recommendations will focus only on still images of textual documents. Some guidelines for graphic documents (photographs, engravings, drawings, cartography, etc.) are included. It should be noted that these recommendations are aimed at digitising documents of a historical nature and/or declared to be of permanent conservation, as well as documents of an exceptional nature" (General, 2017).

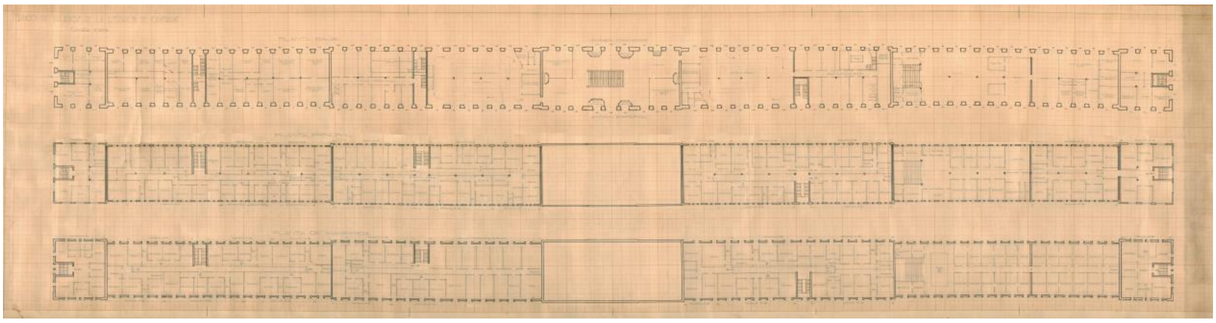


**Figure 4**. Digitised Plans of the Passenger Building at Canfranc Station. Source: Author.

The digitisation of the original plans enables quick, secure, and easy access to the sources while preserving the document. However, the digitised document does not serve as a working document, allowing direct modifications. Instead, it serves as a basis and reference point to gather the necessary documentation and information to accurately represent spaces and construction elements using drawing techniques in computer-aided design programs.

During the digitisation process, a sufficient approximation for documentary work is achieved. However, despite meticulous scanning and subsequent image assembly and editing, there is always some loss of definition and precision. Therefore, it is considered beneficial and necessary to create precise drawings where measurements, spaces, construction solutions, and all kinds of details can be verified.

"A drawing is a two-dimensional static document responsible for communicating and transferring information to a recipient. In the field of architecture, drawing can serve various intentions. Within an analytical, descriptive, or design process, there may be developmental stages where drawings have different expressive and informative levels: more abstract, synthesised, and geometrised, emphasising colour, shape, composition, luminosities, details, movements, etc. The final drawings (those that conclude the ideological stage and offer the possibility of construction) are the ones that meticulously guide the 'faithful' construction of a work, based on a vocabulary and syntax of architectural graphic expression" (Gomes et al., 2017).

**Figure 5.** Floor Plans, Elevations, and Sections of the Passenger Building at La Peña Station. Source: Author.

The detailed and meticulous drawings allow for much greater precision and observation of details and construction elements. Furthermore, they serve as a basis for subsequent work in various fields that may arise, whether it be study, analysis, conservation, or even intervention.

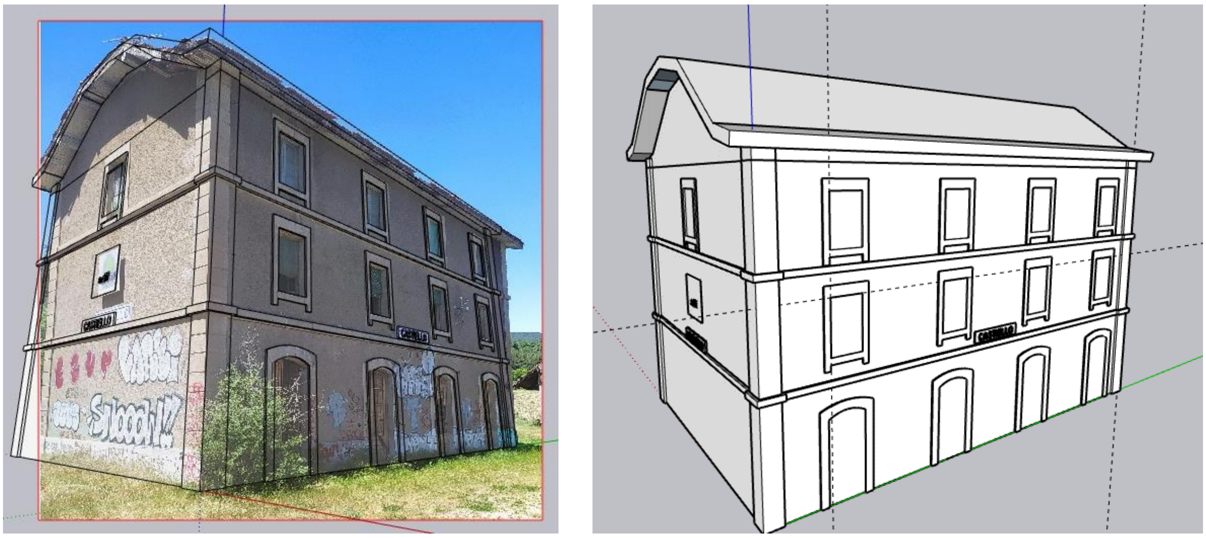
Referring to the original documentation also allows for comparing what was projected with what was executed. It also enables the observation of the condition of existing elements and the status of what has been preserved. Redrawing the plans using CAD methodology based on the original plans and comparing them with the existing conditions provides a valuable working document.

## 3. 3D Model

3D modelling has become an essential tool in the preservation and management of architectural heritage, allowing for the creation of precise and detailed digital representations of historic structures.

The process of 3D modelling begins with collecting data about the building to be represented. Once the data is gathered, 3D modelling software is used to create a digital model. Specifically, 3D models have been developed using SketchUp software, a dynamic and powerful architectural 3D modelling software that enables the creation of scenes and geometric models with comprehensive information agilely. Using a 3D modelling tool allows for the transition from two-dimensional plans to three-dimensional, obtaining a digital model of any building or architectural and heritage work.

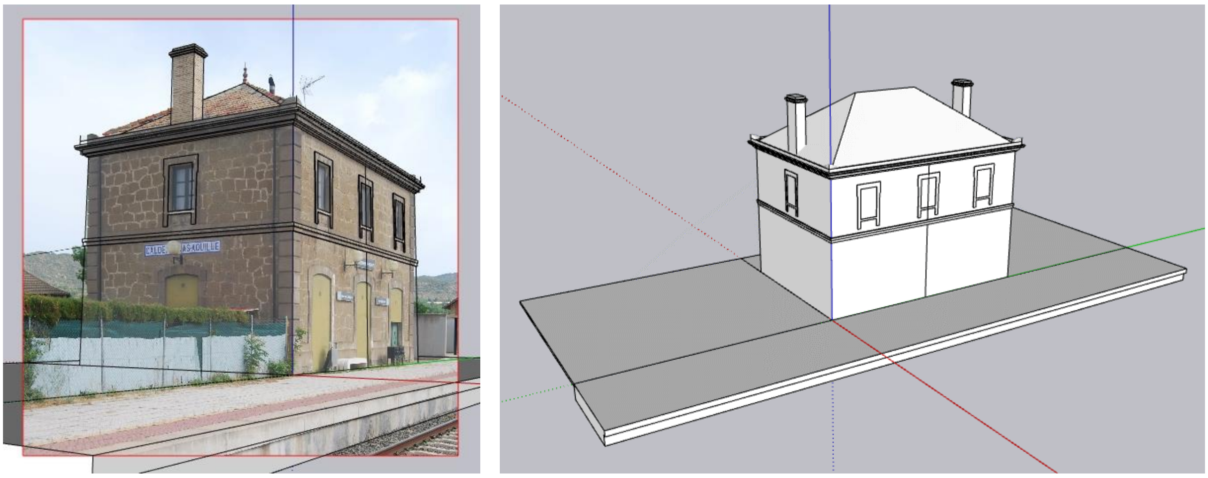
"Increasingly, SketchUp is being used to significantly enhance spatial perception... In the technological world we live in, innovation and communication are fundamental, making it essential to draw in three dimensions" (Calle, 2016).



**Figures 6 - 7.** 3D Model of the Passenger Building at Castiello Station. Source: Author.

These models can be manipulated and edited, adding additional details and refining the geometry to create an accurate and realistic representation of the original structure or landscape. Additionally, 3D modelling allows for creating interactive virtual models that can be explored and analysed from any angle, providing a new way to interact with the history and architecture of the Zaragoza to Canfranc Railway Line.

3D modelling has been used to document various buildings along the route between Zaragoza and Canfranc, focusing on the passenger buildings of some of the stations on the line. These digital models provide a precise visual representation of the line in its current state and serve as a tool for planning restoration and conservation projects.



**Figures 8 - 9.** 3D Model of the Passenger Building at Caldearenas Station. Source: Autor.

Additionally, 3D modelling allows researchers and conservators to simulate the evolution of structures over time, anticipate potential conservation issues, and efficiently plan future interventions.


**Figures 10 - 11.** Proposed Urban Development Infographic for Canfranc Station. Source: Urbanism Department, School of Engineering and Architecture, University of Zaragoza.

## 4. Photogrammetry

Photogrammetry has become an indispensable tool in the conservation of architectural heritage. It allows for precise capture of historical buildings in their current state. Photogrammetry uses high-resolution photographs to create accurate three-dimensional models of objects or environments. This involves taking detailed photographs of buildings and their architectural features from different angles and perspectives.

These photographs are then processed using specialised photogrammetry software, which employs advanced algorithms to identify common reference points in the images and calculate the three-dimensional geometry of the scene. The result is a detailed and accurate digital model that captures the essence of the observed buildings. It is possible to quickly generate a point cloud as the basis for further work and study.

In addition to being a quick process, photogrammetry is relatively inexpensive because we can capture the snapshots using a digital camera, even those incorporated into our mobile phones, for subsequent production using specific software. Specifically, we have worked with RECAP from Autodesk.


**Figures 12 - 13.** Point Clouds Obtained through Photogrammetry of the Passenger Buildings at Castiello and Plasencia Stations. Source: Author.

## 5. HBIM

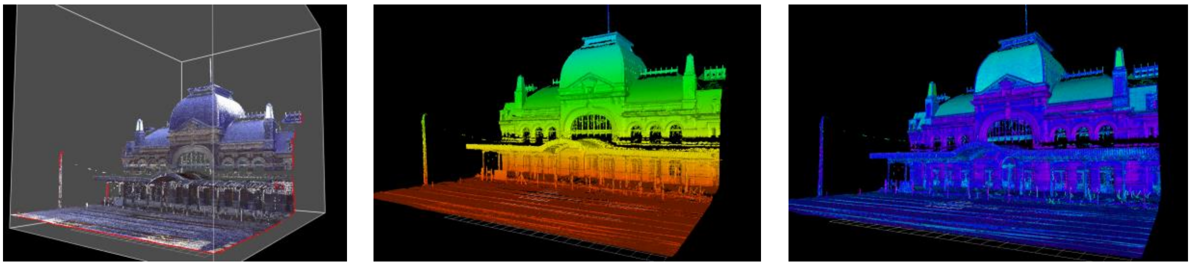
Building Information Modeling for Heritage Management (HBIM) represents an innovative approach to conserving and managing historic buildings. Unlike traditional models, which primarily focus on the visual representation of architecture, HBIM incorporates detailed digital information about the geometry, structure, materials, and other relevant aspects of a building, structure, or detail etc.

This wealth of information allows visualising the structure in its current state and simulating its evolution over time, anticipating potential conservation issues, and planning interventions more efficiently. Additionally, HBIM facilitates interdisciplinary collaboration and interconnectivity by providing a common platform for architects, engineers, conservators, and other professionals involved in heritage preservation.

Among the advantages offered by this working methodology are (VVAA, 2018):

- Real-time interoperability of all users;
- Workflow optimisation;
- Greater precision in measurements and budgets;
- Enhancement of visualisation and dissemination.

The digital models created using this technology provide an accurate representation of existing structures. Furthermore, integrating historical information into these models provides a more comprehensive understanding of the line's past, enriching our understanding of its cultural and historical significance.



**Figures 14 – 15 - 16.** Point Clouds were obtained via laser scanning of the passenger building at Canfranc Station. Source: Mora.

## 6. Conclusions

The railway line between Zaragoza and Canfranc remains a symbol of connection and encounters between cultures and eras. From a collective standpoint, it is essential to protect and preserve this legacy for future generations. Preserving what exists and disseminating the history and architectural heritage is necessary in architecture. By consulting existing sources and documents based on the AZAFT archive, we have compiled an important catalogue of reliable documentation of the originally projected plans and contrasted it with what exists today. This study provides a repository where we have:

- Original documents;
- Digitised documents through scanning;
- 2D plans;
- 3D modelling;
- Point clouds from photogrammetry;
- Point clouds obtained through laser scanning.

As is the case in most situations, heritage management faces a series of challenges. Among the most prominent are limited funding, lack of specialised human resources, and the need to reconcile heritage preservation with contemporary demands for development and tourism.

However, the future of heritage management on the Canfranc line is full of promises and possibilities. Using new technologies and work methodologies, such as HBIM as a fundamental tool, is expected to enable effective heritage management, thus guaranteeing the preservation of architectural heritage.
The transition from traditional plans to the HBIM methodology, through other digital design, modelling, and information management tools, marks a significant milestone in heritage preservation. When we look to the future in terms of development, sustainability, and prosperity, there must be a commitment to heritage preservation, in this specific case, the architectural legacy provided by the passenger buildings of the railway stations between Zaragoza and Canfranc, ensuring that it continues to be a symbol of connection and encounter throughout the centuries.

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# The Common Data Environment in Monument Master Plans

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***Abstract***

*This contribution addresses the digital twin's Common Data Environment (CDE) role in Master Plans of Monumental Buildings. The essential objective is the preservation of immovable properties for future generations. Researchers in the cultural heritage field have used digital tools to document historic buildings and preserve them infinitely digitally. The question is whether the digital twin and its application can help achieve sustainable building and environment management.*

*The primary document will always be the building itself. However, within conservation, restoration, or maintenance, it is necessary to have an extensive documentary archive where interventions are recorded. The older the monument, the greater the knowledge of the built element must be acquired before any intervention, which requires much time in previous research. Technological advancements and digital repositories make it easier to create digital platforms within Heritage Building Information Modelling (HBIM) because we work with historic buildings.*

*The digital twin is a shared data environment and is a management and recovery tool for architectural heritage. To develop this work, it has been necessary to collaborate with expert stakeholders involved in the management of buildings throughout their life cycles.*

***Keywords:*** *environment data, master plans, heritage, culture, architecture, digital twin.*

## 1. Introduction

Cultural heritage is not just a link between generations but a vital thread that weaves our past, present, and future together. Protecting and valuing this heritage is not just crucial but imperative for preserving our identity and legacy. Effective conservation demands profound knowledge and well-established preservation criteria.

Digital tools, such as Heritage Building Information Modelling (HBIM), have revolutionised the documentation and management of historic buildings. These technologies allow the creation of detailed 2D and 3D geometric models, facilitating interdisciplinary study and conservation of heritage sites. Additionally, the interoperability of HBIM with Geographic Information Systems (GIS) enhances the accuracy and comprehensiveness of these models, providing a complete view of the current state of monuments.

It is possible to assimilate a Common Data Environment (CDE) BIM-GIS structure to the framework of a master plan, as both approaches share the objective of centralising and managing information in an integrated and coordinated manner. A master plan, which guides a heritage site's long-term planning and management, can significantly benefit from the precision and detail offered by a CDE BIM-GIS platform, ensuring more effective and sustainable conservation.

The digital twin, a precise virtual representation of a physical building, emerges as a vital tool. It acts as a Common Data Environment (CDE) that centralises all relevant information and as a management and recovery instrument for architectural heritage. By simulating environmental phenomena and situations that affect the deterioration of buildings, the digital twin aids in developing sustainable conservation strategies.

## 2. Applicability of a CDE in a BIM-GIS Environment for Master Plans

A master plan is a fundamental strategic document for planning the conservation and management of heritage buildings. This document provides a broad and detailed vision of a monument or heritage site, addressing contemporary management and conservation needs. It should be designed to be precise and versatile, allowing its application in diverse circumstances and contexts. The Alhambra Master Plan, for example, reflects this complexity and versatility by providing a contemporary perspective necessary for acting upon the monument, with direct involvement of the managing body and public participation, making it a well-anchored management instrument in a democratic society (Villafranca Jiménez, 2015).

In Spanish, the National Plans for Architectural Heritage (PN) emphasise the importance of unifying knowledge and documentation about these buildings. Since the first National Plan for the Protection of Cathedrals in 1999, the need to coordinate conservation and restoration activities has been established. The National Conservation Plans are a synthesis of two key figures: the National Information Plans outlined in the Historical Heritage Law, under the competence of the Heritage Council, and the Conservation and Restoration Plans. National plans, in particular, set the groundwork for Master Plans (MP), which are essential as they define the long-term strategy for conserving and restoring heritage buildings. These documents schedule investments according to identified needs and coordinate the involvement of various stakeholders (MECyD, 2015).

A master plan is conceived as an integral tool for the comprehensive management of heritage, involving the programming of necessary actions and interventions, allowing proper coordination among the agents involved in the protection, conservation, restoration, study, research, interpretation, and dissemination of the monument. In this sense, it can be said to function similarly to a Common Data Environment (CDE), where efficient integration and collaboration between different disciplines and actors are also sought. A CDE must gather the knowledge obtained during the plan's development and accumulate it throughout the building's life cycle. Its purpose is to improve the efficiency and coherence of future actions, ensuring information interoperability among disciplines. Often, it involves a platform that integrates construction information models (BIM) with geospatial data (GIS) in a familiar environment. This integration enables more efficient and collaborative management of construction projects and asset management, providing a comprehensive and detailed view of spatial and non-spatial information related to physical assets.

In the context of a monument master plan, a BIM-GIS CDE plays a decisive role by enabling a comprehensive understanding of the plan's structure and its relationship with the monuments and their surroundings. This integration of geospatial data and HBIM models is crucial, as a master plan requires a detailed understanding of the monuments' location, structure, and geospatial context. It provides an accurate and detailed representation of their location and geometry within the protection environment. Additionally, it facilitates the visualisation and analysis of spatial and non-spatial information related to the monuments and their surroundings in a shared digital environment. This is fundamental for identifying spatial relationships and complex patterns, contributing to planning and decision-making in a monument master plan.

Another significant advantage is its capacity for data management and fostering collaboration. It provides a centralised environment for storing, managing, and sharing data and models related to the monuments and their surroundings, facilitating stakeholder collaboration. This collaboration is essential for effectively developing and implementing the master plan.

Implementing a BIM-GIS CDE is helpful for impact analysis and simulation, allowing for analyses of the monuments and their environment, which is crucial for evaluating the impact of potential interventions proposed within the framework of the master plan.

### 2.1. BIM and GIS for Heritage Management

The use of BIM strategies in the lifecycle management of heritage buildings is one of the main objectives of providing effective CDEs. The integration of BIM and GIS can function as a centralised digital repository, bringing together various types of information accessible to any stakeholder interacting with the building throughout its lifecycle. This approach is a collaborative paradigm whose main objective is efficient building management. Integrating BIM and GIS in a CDE offers a holistic approach to heritage management, combining architectural and construction details with geospatial and environmental context data. A BIM environment applied to heritage allows for comprehensive management of heritage buildings' legal, architectural, and cultural aspects. Implementing HBIM leads to new methods, protocols, and processes for the building's intervention, conservation, maintenance, and lifecycle management (García-Valldecabres, J.L. et al., 2022).

There are similarities between HBIM and GIS as they share a common goal of representing geospatial data and properties, albeit with slightly different approaches. While HBIM focuses on the three-dimensional representation of data, GIS works primarily in two dimensions. What unites these platforms is their importance on data and its presentation. The key lies in connecting these databases to achieve effective integration, regardless of whether the representation is 2D or 3D. Significant changes have been experienced in work methods in recent years, moving from application and result-centered approaches to a more management-oriented and automated information approach. In this sense, 3D representation is not always necessary in GIS; what is fundamental is having a well-structured and connected database that allows access to relevant and updated data when needed (Colucci et al., 2020).

GIS files are primarily characterised by using points, lines, and polygons to represent geographic entities. In contrast, HBIM requires a high level of geometric complexity due to the need for greater detail in the information. This can pose challenges in integrating both platforms and the need for a connected database. In recent years, the benefits of HBIM for recording and documenting the current state of cultural building assets have been demonstrated, positioning it as the best repository for managing the documentation of a Master Plan. The 3D-HBIM model generated can also be used during cultural studies, including analysing the surrounding environment, describing the building's particular properties, and the construction history.

For this reason, most research asserts that the model must remain open to new uses and requirements, such as preventive conservation, dissemination, diagnostics, and maintenance. This flexibility ensures that HBIM serves current needs and adapts to future demands in managing cultural heritage.

## 3. Methodology

The implementation procedures of the BIM methodology ensure the quality of the information repository by allowing the testing of the generated model or models. It must be possible to test the model information and its federation. This BIM management involves creating a centralised system around the information models, which must be comprehensive, traceable, and accessible according to defined roles and responsibilities.

The HBIM model is created and updated proportionally throughout the project's development, and deliverables are generated from this model and linked to external documents, thus documenting the traceability of each deliverable.

Specifically, the conditions of the HBIM methodology in a Cultural Interest Property (BIC) are as follows:

1. Procedures must be defined through a working protocol that promotes knowledge of the heritage building, its conservation and restoration, and enables proper management. These pieces of information must be reflected in the BEP.
2. There must be procedural continuity in developing proposed actions for the MP, considering foreseeable requirements in future actions that enrich the information model. These objectives should reflect those outlined in the Master Plan of the building.
3. The model must adapt to the capabilities of the managing entity of the heritage asset to facilitate its continued use throughout all phases of the building's lifecycle.
4. A CDE linked with all BIM-GIS models must be established.

These zone models can be subdivided into disciplines, delineations, or federated models. This division can be based on criteria such as the building's size not exceeding a certain number of units. The organisation of native working files is defined in the BIM Execution Plan (BEP) for each required BIM use. Likewise, deliverables must be produced as specified in the BEP. Necessary testing and adjustments must be made so that the information structure of native models can be exported to open BIM formats.

The model organisation must have a previously agreed-upon coordinate origin. The definition of model categories, subprojects, the interference matrix, and the process map to obtain specific BIM should be included in the overall connection process diagram. It should also include the connection of documentation with deliverables and the deliverable and people review process. Finally, it should include tables with adequate information organisation by categories previously detailed according to a standardised classification such as UniClass.

Once the different HBIM models of the historic building, which may be linked to different sub-models, are generated, a linkage to a GIS database is created. This is made possible by linking IFC files with software such as ArcGIS Pro or QuantumGIS (QGIS). Within this database lies the building's environment, enabling the incorporation of general information and topographic parameters, visual tours, etc.

The integration of HBIM and GIS can be comparable, for example, to the methodology proposed by the National Cathedrals Plan through the fundamental steps outlined in the action method. Firstly, it addresses identifying cultural assets by providing technological tools for developing detailed inventories and catalogues of cathedrals, which can be perfectly achieved with HBIM. Then, regarding asset protection, the protection environment can be incorporated into GIS to provide a deeper understanding of the state of historic buildings and their surroundings. This technological approach allows for precise diagnostics of the conservation status of monuments, which in turn facilitates the formulation of general conservation and management strategies. The application of this methodology promotes the implementation of continuous projects for documentation, preventive conservation, and dissemination of cultural heritage. This aligns with the long-term vision that a Master Plan must-have, which seeks to conserve these monuments and promote their valorisation and understanding by the general public.

Below, we present a table illustrating the adaptation of the structure of a monument master plan in a CDE using HBIM and GIS. This approach combines the rigour and integrity of the master plan with the effectiveness and versatility of advanced digital tools.

 

**Table 1.** Phases of an MP in a BIM-GIS CDE Environment.

| Phase | | Data base |
|---|---|---|
| 1 | Degree of protection of the monument and its surroundings, along with protection proposals. | GIS |
| 2 | Comprehensive description of the monument in all its aspects. | CDE |
| 3 | Historical and chronological memory of the monument. | CDE |
| 4 | Memory of previous interventions. | CDE |
| 5 | Legal analysis on ownership and other legal aspects. | CDE |
| 6 | Architectural and structural description of the monument. | BIM |
| 7 | Compilation and cataloguing of graphic, archaeological, bibliographic, etc., documentation. | CDE |
| 8 | Evaluación del estado de conservación y situación urbanística del monumento. | BIM |
| 9 | Intervention proposals with economic evaluation. | BIM |
| 10 | Description of movable heritage. | CDE |
| 11 | Compilation and cataloguing of graphic and bibliographic documentation on movable heritage. | CDE |
| 12 | Study of movable heritage and its conservation status. | BIM |
| 13 | Description of intangible heritage linked to the monument. | CDE |
| 14 | Compilation and cataloguing of graphic and bibliographic documentation on intangible heritage. | CDE |
| 15 | Risk analysis and assessment. | BIM |
| 16 | Diagnosis and general intervention criteria. | BIM |
| 17 | Protection plan and preventive conservation. | BIM |
| 18 | Periodic maintenance plan for the monument. | BIM |
| 19 | Conservation and restoration plan for the monument and movable heritage. | BIM |
| 20 | Documentation and research plan for the monument. | BIM |
| 21 | Plan of training, accessibility, and dissemination proposals. | CDE |
| 22 | Management proposals plan for the monument. | BIM |
| 23 | Schedule for the implementation of proposed plans. | BIM |
| 24 | Planimetric, photographic, sound documentation, and other relevant documents. | BIM |
| 25 | Historical and archaeological research, analysis of socio-economic context, community participation, budget and financing, legislation and regulations, monitoring and evaluation, environmental sustainability, and inter-institutional collaboration. | CDE |

## 4. Results and conclusions

Creating a CDE in a BIM-GIS environment offers numerous advantages for managing Master Plans. Firstly, it facilitates interoperability and collaboration among different disciplines and tools. Architects, engineers, conservators, cultural managers, and other stakeholders can work efficiently, exchanging information and coordinating efforts without obstacles often arising from the lack of communication between disparate platforms.

Centralised data management is another critical benefit. Integrating BIM and GIS data into a single centralised repository allows easier access and more coherent information management throughout the building's lifecycle. This simplifies data handling and ensures that all involved parties work with the same up-to-date information.

A CDE enhances data-driven decision-making and provides a solid foundation of accurate and updated data, enabling more informed planning and execution of conservation and restoration interventions. With access to detailed and relevant information, stakeholders can better assess needs and effectively prioritise actions.

The combination of BIM and GIS in a CDE allows for detailed spatial and contextual analysis, which is essential for understanding the environment and conditions affecting heritage buildings. With more profound and more precise analysis, interventions can be designed to address current issues and anticipate and mitigate potential future challenges.

Finally, efficiency in planning and execution is significantly improved with a CDE. The availability of integrated information reduces the time and costs associated with data duplication and lack of coordination. This translates into faster and more cost-effective planning and execution of Master Plans, ensuring that resources are used most effectively and that conservation and restoration projects are completed on time and within budget.

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# Large-scale photogrammetry: the case of the Roman baths of Alange, Badajoz (Spain)

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***Abstract***

*Photogrammetry applied to heritage documentation has undergone significant development in recent years. The research objective we present is to synthesise the result of the work carried out by employing and studying the application of large-scale photogrammetric techniques in an integrated manner coherently and exhaustively. This research has been applied in the Roman Baths of Alange case, which was declared a World Heritage Site (UNESCO, 1993). This significant ensemble lacks detailed planimetric documentation and archaeological interventions. This research has established a comprehensive overview of the difficulties affecting the characteristics of the photogrammetric technique and its development in architecturally complex, narrow, enormous, and data collection-challenging places. This has been reflected in a point cloud of the surveyed site. Thus, the aim is to understand the scope of the technique and analyse each of its characteristics.*

***Keywords:*** *photogrammetry, heritage, photogrammetric survey, Roman baths of Alange, world heritage.*

## 1. Introduction

Although photogrammetry is widely used in heritage preservation, such as in historical monuments, culturally significant properties, archaeological remains, small objects, etc, the difficulty of its application in complex natural environments requires extensive knowledge of the technique and instrumentation used.

This work is part of the ongoing themes in the Master's Thesis in Architecture and Historical Heritage at the University of Seville, by David Conejero, supervised by Pablo M. Millán, and conducted with the assistance of Margarita Infante and Concepción Cantillana on fieldwork. It arises from an interest in photogrammetric surveys in exceptionally unusual and complex cases, sometimes successfully employing this technique and simple and low-cost instrumentation to survey locations with difficult access and/or peculiar geometries and characteristics (Conejero, 2023).

In the case at hand, the difficulty lies in the Project's scale and the presence of wáter in the chosen site, the Roman Baths of the Alange Spa, Badajoz (Spain).

### 1.1. The Photogrammetric Technique in Architectural Heritage

Henri Bonneval defines Photogrammetry as the "...technique for studying and precisely defining the shape, dimensions, and position in space of any object, using measurements taken from one or more photographs…" (Bonneval, 1972, p. 35).

It originated in the 19th century, thanks to the research of Laussedat with Metrophotography. The German architect Meydenbauer, from 1867, carried out numerous interventions in architectural heritage using this technique with the novel photography, henceforth calling it Photogrammetry (Buill, 1997; Herrero, 2006). From its origins, Meydenbauer employed this technology, which was quite novel for preserving historical monuments in his country (Pereira-Uzal, 2016), later expanding and extending his work throughout Europe and abroad (Albertz, 2001).

Over the years, thanks to the technological advances throughout the decades, new instrumentation could be employed in photogrammetry, expanding its working horizons. Currently, with digital technology, photogrammetry employs innovative devices such as UAVs (Unmanned Aerial Vehicles) or drones (Ruiz et al., 2015; Buill et al., 2016; Palacios, 2023), digital cameras or even satellites, as well as the use of fast data processing software, offering a very effective and convenient working method.

Understanding the subtle relationship between the analytical and analogue photogrammetry methods is essential. New technologies and devices that aid data collection are useful and necessary as long as the theoretical foundations and trigonometric principles are understood. It's also crucial to master drawing as a tool to achieve architectural and archaeological details and High-quality representations (Latorre & Cámara, 2010).

In recent works carried out with photogrammetry, it has been used "Close-Range" or "CRP", a technology that consists of closet o surface photogrammetry (around 1.20 m near the surface), which takes around a hundred photographs (Domingo et al., 2024). In heritage dissemination, there are various publications on preserving tangible heritage through virtual models, with works of varying magnitude, some of which involve several hundred photographs taken (Caro & Hansen, 2015; Leija-Román et al., 2022; Sala, 2022) or in some cases, up to a thousand photographs (Conejero, 2023).

### 1.2. The Roman Baths of the Alange Spa

Declared a World Heritage Site in 1993 (UNESCO, 1993), the Roman baths of the Alange Spa (Badajoz) date back to the 3rd century AD, a period revealed by a Roman inscription found in their vicinity (Álvarez, 1973).

These Roman baths consist of two large elevations with domes, both finished with an oculus that allows sunlight to enter. They are connected by a narrow corridor where natural light barely penetrates, which links on one end to the rest of the spa facilities through a set of stairs and on the other end to the exterior garden.

 

Throughout history, the Roman baths underwent various transformations and occupations. At the end of the 7th century, they had a monastical use during the Diocese of Aquis in Lusitania in the reign of Wamba (Carmona & Caletero, 2016). It also declined and neglected for almost a millennia (Madoz, 1846). It wasn't until the 16th century that the Roman baths' first interpretations appeared, as Ambrosio de Morales noted in 1575, referring to them as an "ancient temple from Roman times, round like the Pantheon of Rome" (Salas, 2010). Subsequently, other archaeology scholars (De Laborde, 1806; Canto, 2001) and medicine scholars (Colodrón, 1838; De Villaescusa, 1850) highlighted the value of these baths due to their Roman structures and the very rare but beneficial mineral-medicinal properties of the waters. Thus, the Roman baths evolved and transformed into a thermal complex with innovative techniques up to the present day (Carmona & Caletero, 2013).

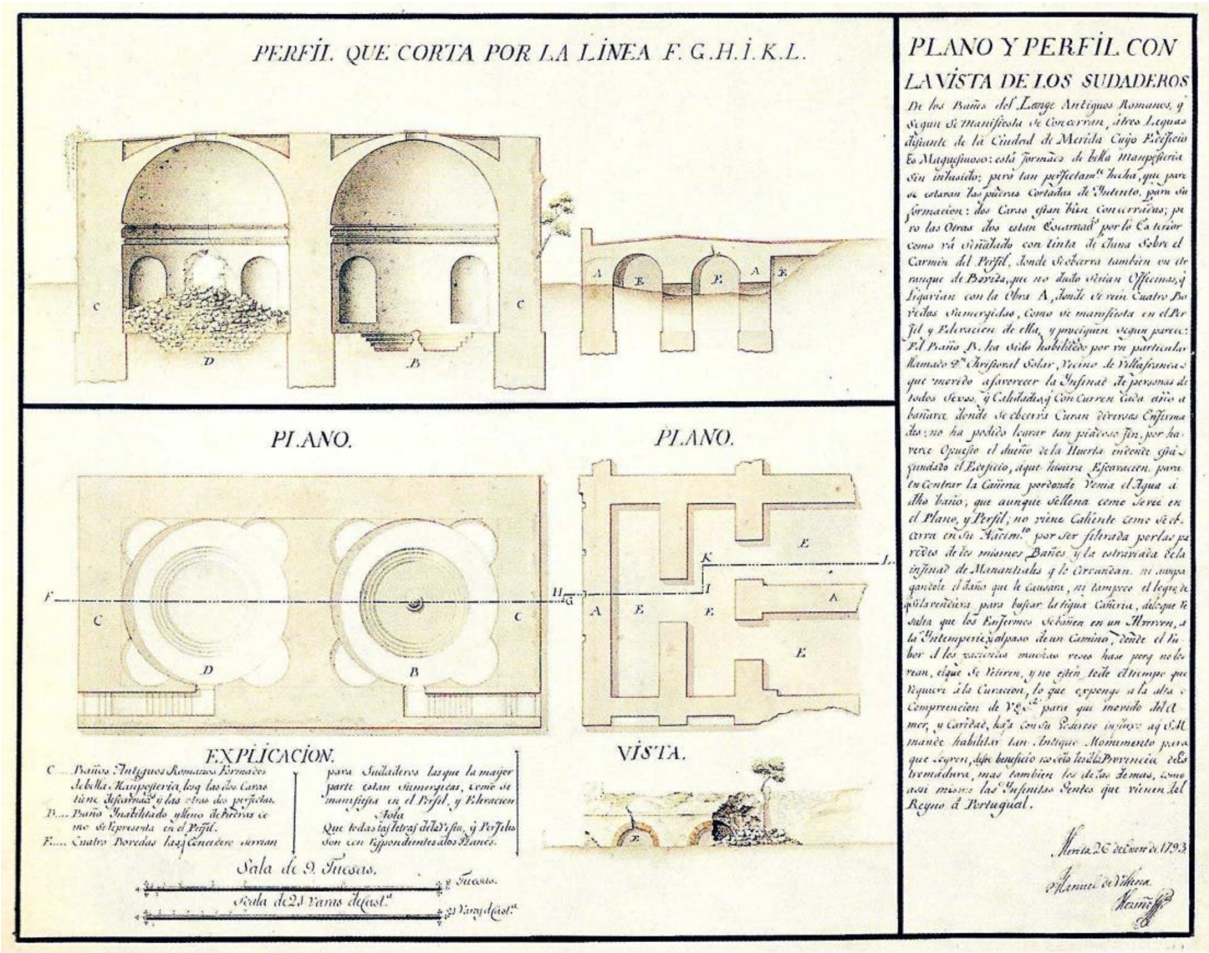


**Figure 1.** Plate No. 8 - "Baths of Alange" by Manuel de Villena y Moziño, 1793.
Source: Canto and De Gregorio, A.M.. (2001)

## 2. Objectives

This communication aims to address and develop the complexities and difficulties of using photogrammetric techniques within the surveyed site, explaining the necessary foundations and knowledge required to achieve the best possible result. It aims to understand each necessary step for creating useful and precise documentation, both for characterising the materials of the chosen heritage site and for its dissemination.

The other objective of this project is to reflect the qualities of data collection in photogrammetric surveys and topographic work in a point cloud. This aims to raise awareness about the value of the work done with this technique and its professional rigour in research projects or any other type of work.

## 3. Methods

### 3.1. Planning

The work plan was devised during several preliminary inspection visits to the site, during which the geometric and architectural complexities of the building were analysed.

Due to their archaeological significance, it was decided to focus the survey not only on the interior of the two baths and the stairwell and corridor area providing access to them but also on their roofs and exterior walls. Given the scale of the task, simultaneous data capture of the spaces was proposed using two cameras with different characteristics.

Fieldwork begins with selecting camera parameters based on the dimensions and lighting conditions of the different work areas. Firstly, the focal length must be decided, which is the ratio between the distance from the focus to the optical centre of the camera lens. For data capture of the oculi of both domes, the cameras are set to their maximum focal distance, 32 mm, to allow for greater precision in the information from photographs near this area and to optimise the connection between exterior and interior data. The rest of the photographs are taken with a focal length of 12 mm to achieve a wider field of view and capture as much data as possible with minimal photographs, to obtain a thorough understanding of the interior of the domes and the connecting corridor and stairs, which are very narrow (some áreas are less than 1m in width), making image capture challenging.

Before taking the photographs, the ISO speed parameter must also be configured. This determines the amount of light the digital camera sensor is sensitive to. Lower values, around ISO 100-200, are used in well-lit places, while higher values, ISO-400 or more, capture as much light as possible in poorly-lit areas. In this case, since tripods were available, very low ISO values of 100 and 200 were chosen to avoid digital noise in photographs and enable data capture even in areas with dim lighting conditions, such as the interiors of the domes, shaded areas, and corridors.

Another consideration is the Aperture Priority Mode, in which the Automatic option is chosen to regulate the amount of light entering the digital camera sensor when the surrounding light is constantly changing and moving. This is crucial because the fieldwork extends for many hours, during which natural light, entering only through the domes' oculi, undergoes slow but constant changes over time, resulting in moving shadows and changes in lighting and colours.

Finally, the Aperture setting is selected, closely related to the depth of field when obtaining information. A higher aperture setting results in a greater depth of field. Despite the walls being mostly smooth and lacking pictographic or archaeological information in most cases, the aim is to capture as much data as possible. It was considered that an aperture of F8 was the optimal working value, as it represented an intermediate aperture that provided good depth of field for the available light both indoors and outdoors, achieving good sharpness and quality in the shots taken.

Regarding topographic data collection, the work environment was thoroughly inspected, and the required number of stations and suitable locations were determined based on visibility between stations and between these stations and the selected control points. A series of coded targets were placed on these control points, forming a network of points that would facilitate the orientation of different parts of the future 3D model and provide it with good geometric rigidity and scaling. The targets used are marked with geometric patterns automatically recognisable by the chosen software for subsequent office work. These targets are numbered and captured using a total station along a necessarily open itinerary. In pursuit of maximum reliability and precision, the itinerary is repeated several times, verifying its validity and averaging errors.

### 3.2. Procedure

Once the processes and working characteristics are understood, data collection begins. Walkable areas surround the Roman baths, as each centre has a circular pool. Data is collected from the oculus areas with focal distances of 12 and 32mm alternately, while the rest of the domes and rooms are captured only with a 12mm focal length.

Before starting the survey, photographs were taken in various locations in the surveyed area using white balance cards. This is done to calibrate the white colour in the digital images that will be taken, considering the various lights produced in the areas depending on solar incisions and shadows present in the property at different times. This helps to balance the light for photographic exposure.

The survey should be conducted to capture data where the photographs overlap by a minimum of 60%. This means that when taking a photograph, the next one should have at least 60% of the information from the previous photograph so that later, the computer software can correctly align the photographs.

Three types of photographic shots were considered based on the angle formed between the camera's optical axis and the photographed surface:

The first pass is as orthogonal as possible, aiming to obtain the highest possible quality in texture and colours.

The second pass is at an approximate angle of 45º to the surfaces. This is to capture depths and points that are less visible from an orthogonal view.

The third pass is also at an approximate angle of 45º, but in the opposite direction to the previous one, to gather maximum information about the relief.

Finally, data is collected in the corridor and stairs in one direction and then in the opposite direction. This is due to the barrel vaults, arches, and skylights found in the high areas, which need to be considered for a complete survey due to the reflection of light on the digital camera and the architectural complexity.

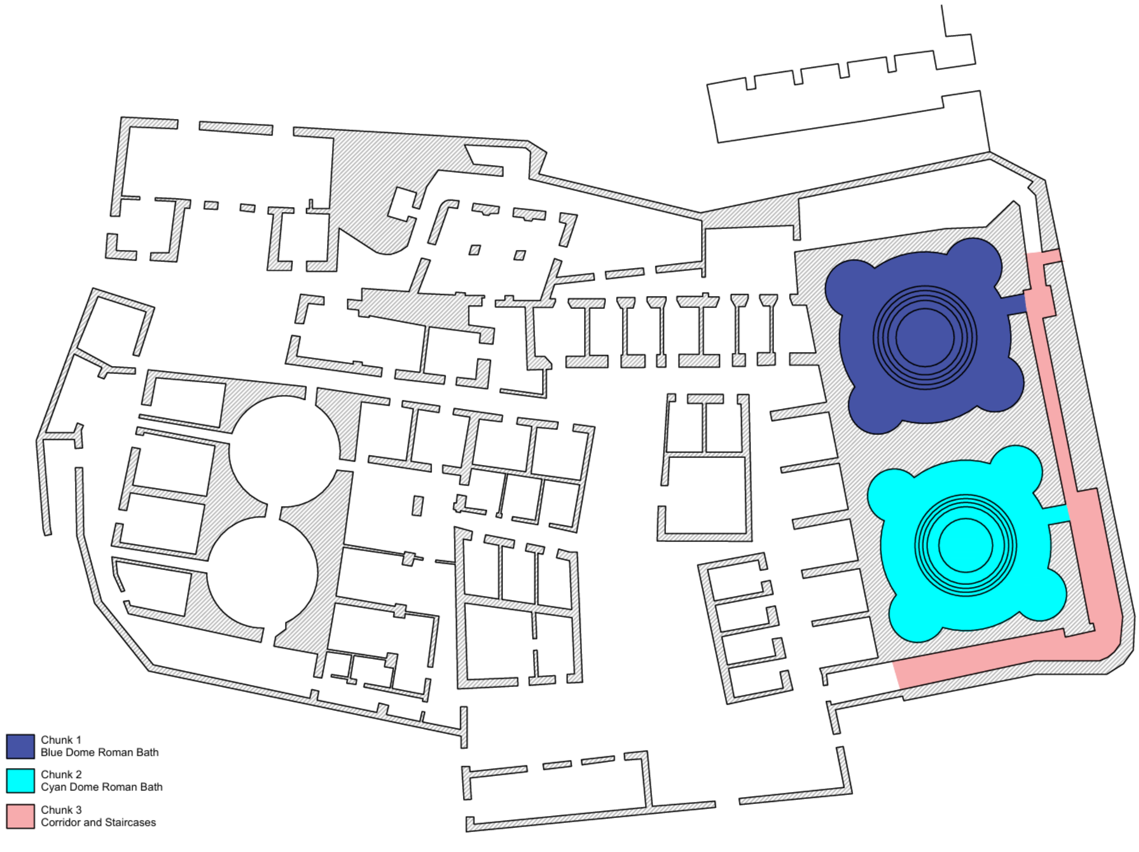


**Figure 2.** Areas of Action in a Sketch of the Alange Spa. Author's work.

### 3.3. Instrumentation

The instrumentation used in this project consists of equipment that does not require a large initial budget. The aim is to present photogrammetric techniques as an accessible working method that provides professional and rigorous results with affordable instrumentation.

Most of the field equipment used belongs to the authors of this research, while some were provided for this work by the Department of Graphic Engineering at the University of Seville.

**Table 1.** Instrumentation Used in Photographic Work

| Instrumentation | Models and Features |
|---|---|
| 2 Digital Cameras | -Panasonic DMC-GX80KEGK with 4K Ultra HD quality and 16 MP resolution<br>-Panasonic DMC-GX80K LUMIX G VARIO with 4K quality and 16 MP resolution |
| 2 Photographic Tripods | -Manfrotto Compact Advanced (44 – 165cm) with a three-way head<br>-Cullman Primax 380 (62 – 160cm) with a three-way head and quick-release coupling system |
| 2 White Balance Cards | Calibrated white reference card for light balance and photographic exposure |
| 2 Memory Cards | 128 GB SD Cards |

**Table 2.** Instrumentation Used in Topographic Work

| Instrumentation | Models and Features |
|---|---|
| 1 Total Station | Leica Flexline TS02 with FIRMWARE v.2.31 software and leveling base |
| 1 Tripod | Leica GST20-9 Heavy Wooden with a maximum height of 180cm |
| Targets | Circular targets of 12 bits |

**Table 3.** Instrumentation Used in Informatic Work

| Instrumentation | Models and Features |
|---|---|
| 1 Computer | OMEN by HP Laptop 15-duplex:<br>-Operating System: Windows 11 Home 64 Bits<br>-Intel Core i7-9750H processor<br>-CPU 2.60GHz (12 CPUs)<br>-BIOS F.19<br>-DirectX12<br>-16 GB RAM<br>-NVIDIA GeForce GTX 1650 graphics card |
| Specific Software for Photogrammetric Data Processing | AGISOFT METASHAPE 2.0.1. PROFESSIONAL EDITION |

## 4. Results

After data collection in the field, a fairly accurate point cloud of the study object is obtained using AGISOFT METASHAPE PROFESSIONAL software. Given the extensive nature of the work, these point clouds are divided into three different sets, as over 2,000 photographs are processed in the software. This divided working mode is referred to as *chunks*.

The photo-alignment process is conducted with maximum precision, using 40,000 key points per frame and 4,000 tie points per photo, resulting in a sparse point cloud of 362,409 points in the blue dome chunk, 228,634 points in the cyan dome chunk, and 514,595 points in the corridors and staircases chunk. These point clouds are then aligned and merged using the topographic work performed, thanks to the itinerary taking the targets as scaling and orientation points for the model. This allows for creating a complete model, generating the mesh using depth maps and an 8K RGB texture map, ultimately resulting in a virtual 3D model of the ensemble.

Regarding the captured images, they are also of great value as a result of the photographic dating of the property. This work, 2,244 photographs are processed, each with a quality of 4592 x 3448 pixels. Additionally, each photograph generates two files, one in JPG format and another in RAW format. The RAW format is particularly useful for photographic editing tasks, as it contains many uncompressed and unprocessed data and details from the digital image.

**Figure 3.** Dense Cloud in Agisoft Metashape Professional of Blue Dome Bath. Author's work.

**Figure 4.** Point Cloud in Agisoft Metashape Professional of Cyan Dome Bath. Autor's work.

**Figure 5.** Point Cloud of Corridor and Stairs. Author's work.

## 5. Conclusions

This project has had a steady but slow process due to the enormous amount of data that needs processing, the hours, and dedication in the fieldwork since each photograph was taken carefully. However, the significant effort in project data planning greatly sped up the work.

Overall, the time required for surveying such a large ensemble with photogrammetry is a disadvantage compared to other surveying methods, which offer more agility in work time, such as 3D scanning. On the other hand, the photogrammetric technique offers greater economic accessibility; it can be performed with lower-cost instrumentation, providing a professional-quality product if used correctly. It's essential to emphasise the explanations and actions outlined in this article to address the architectural complexities and photogrammetric technique challenges. Having all these factors addressed in this article is crucial to starting a photogrammetric survey project in heritage buildings of similar scale, complexity, and technical challenges.

This is an ambitious project, and even though we've obtained the point cloud, future lines of work are left open to create a complete model of all the Roman baths, indoors and outdoors, and to form a complete 3D virtual model.

Regarding heritage, photogrammetry offers many possibilities for any type of research. Some of its utilities include, for example, gaining a better understanding of its geometric and architectural characteristics, helping to date heritage assets or parts of them, monitoring the state of conservation through the comparison of point clouds and virtual models to detect defects or deterioration in the asset over time; facilitating multidisciplinary and international work teams thanks to the possibility of sharing the 3D model with specialists from different fields via the internet; likewise, the 3D model serves to disseminate our architectural heritage and enhance its value to tourism and society.

Finally, the quality obtained from the work is very satisfactory, despite the disadvantage in working speed. The set objectives are achieved, and we look forward to further developing this well-studied property's survey, archaeological, and research studies.

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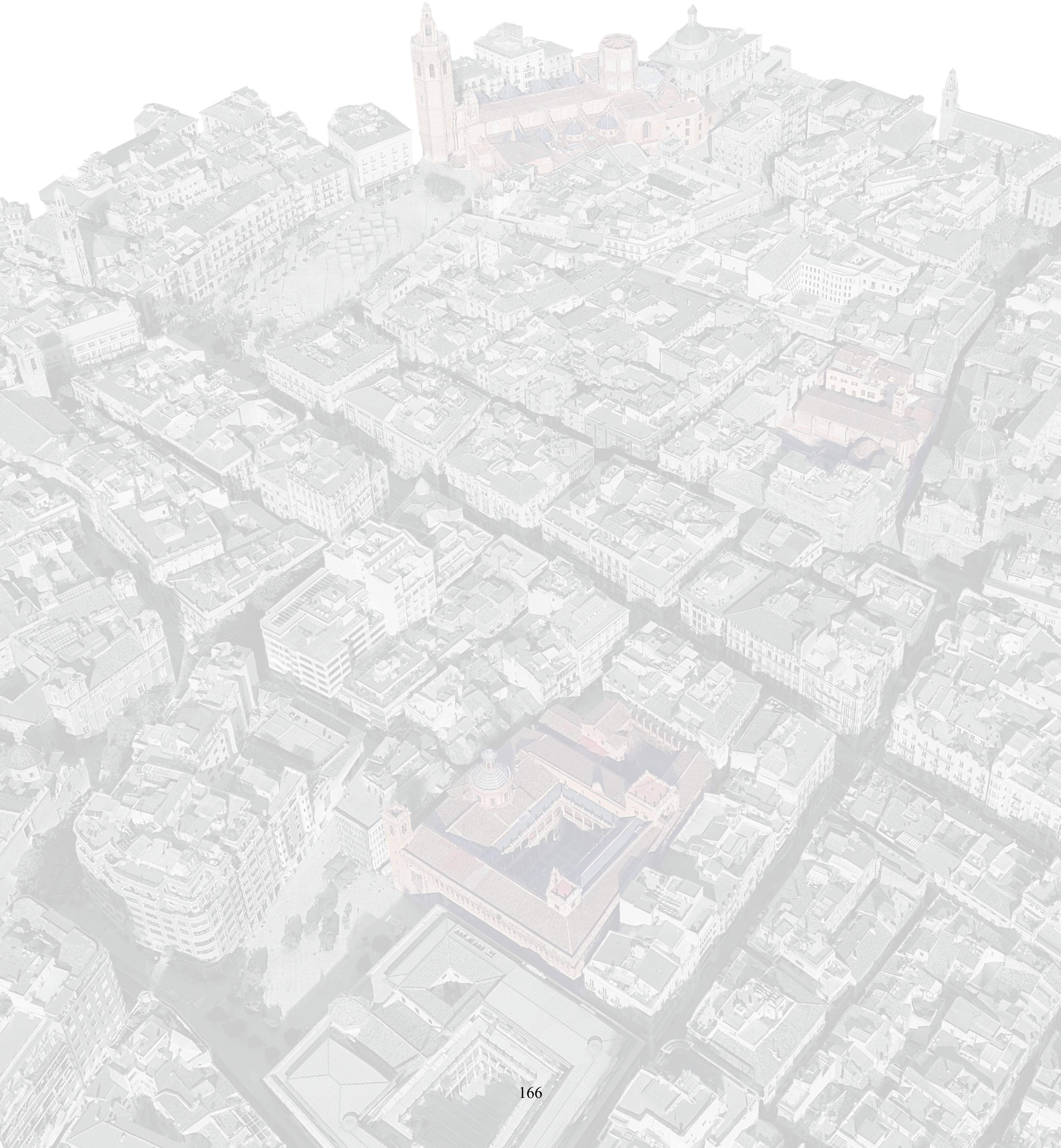
# TOPIC 2

*DIGITAL TOOLS FOR THE CONSERVATION AND ENHANCEMENT OF HERITAGE*



International Congress for Heritage Digital Technologies and Tourism Management
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# Interactive and Immersive Dynamic Perspectives: A Case Study of Piazza Castello in Turin

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## Abstract

*This contribution describes an interesting experience of reconstructive digital modeling related to a project of significant documentary relevance attributed to a young Alessandro Antonelli (1798-1888). During his training period in Rome, the architect proposed an intervention project for Piazza Castello in Turin. The proposal's outcome is contained within six crafted panels accompanied by extensive archival, graphical, and textual material, currently shown at the exhibition "Neoclassicisms in Turin. From the 18th century to the young Antonelli" at the Accademia delle Belle Arti in Turin. The static nature of the original representations can be overcome by defining new digital environments that track Antonelli's proposal and the current configuration of the urban space. The proposed solution enables a virtual tour inside a navigable and immersive space equipped with the architect's original drawings. In the second part of the experience, participants find themselves immersed in the unusual space of Piazza Castello, with the possibility to move within the urban scene, capturing unconventional viewpoints that technical representations in mongian projections cannot convey. The experience also serves as an opportunity to critically reflect on the definitions of interactive and immersive dynamic perspectives, analysing their various components, from presence to immersion to embodiment, about modes of spatial exploration and the combined use of movement and orientation. These elements complement the visual perception of three-dimensional digital environments. These strategic activities shape the definition of the image in virtual reality environments based on three-dimensional models. The objective is twofold: firstly, to enhance the visitor experience at the Accademia by integrating original drawings with new multimedia content to supplement the physical experience; secondly, perhaps even more relevant from a disciplinary point of view, to identify a balance between user action and the adopted narrative model.*


***Keywords:*** *reconstructive modeling, VR, navigable environments, Antonelli, digital storytelling.*

## 1. Introduction

The exhibition "*Neoclassicisms in Turin: From the Eighteenth Century to the Young Antonelli*", held in the rooms of the Pinacoteca Albertina, allowed exploration of some treasures usually kept in the depots of the Accademia Albertina di Belle Arti. Specifically, the focus is on the boards depicting the decoration project of Piazza Castello in Turin, produced by Alessandro Antonelli, at the time an architecture student of the Savoy capital of the early 19$^{th}$ century, after his "*pensionato*" at the Accademia di San Luca in Rome (Accademia Albertina di Belle Arti di Torino, 2022).

After winning the scholarship competition in 1826, the architect, originally from Ghemme, immersed himself in the historical and architectural richness preserved by the Eternal City, finally having the opportunity to observe classical models that were previously studied directly. He consolidated his approach to neoclassical architecture in Rome, fully manifesting it in the architectural proposal he sent to the sovereign in September 1831. The influence derived from the two cities where Antonelli developed his education is indeed of fundamental importance: the studies conducted in Turin and Rome offered the architect a multitude of suggestions, foremost among them are the Pantheon and the Chiesa della Gran Madre di Dio by Ferdinando Bonsignore, his master (Ciattaglia, 2022; Rosso, 1989).

The Piedmontese architect's drawings, preserved in Accademia di Belle Arti depots in Turin, describe the grandeur of the idea he developed. He proposed a revolutionary version of the Turin command centre, justifying the demolition of the medieval castle of Palazzo Madama and the Beaumont gallery; he suggested constructing a new cathedral of monumental dimensions placed in the centre of the square. The latter aims to represent a worthy substitute for the Renaissance-era cathedral, now unsuitable for the role of capital bestowed upon Turin. The ambition was to transform the appearance and presence of the city's heart, reorganising it according to a strict symmetry that can confer the ideal mould sought by the architect. For this reason, the small square in front of the royal palace was duplicated on the opposite side, towards the East, thus replacing the secretariat's wing, which was also demolished with the castle and the gallery. The long portico connected the design system and the uniformity of the facades, punctuated by the spans of the above-ground first-floor arches and by the giant Ionic pilasters that envelop the context of the church, including the sovereign's residence. Indeed, a new facade was applied to the royal palace, hiding the original front behind an imposing colonnade and displacing the royal palace from the role of the main subject of the square. The communicated ambition hidden in the drawings shows how the symbol of power, King Carlo Alberto, steps back to renounce the search for dynastic glory: the heart of the capital becomes the stage of the sacred space at the service of the people.

Six drawing boards recount the magnificent project that describes the cathedral and the context of the square. A three-dimensional model faithful to the drawing project was developed, using these elements and rich in precious details. New technologies related to digital modeling and the creation of immersive virtual environments can be considered exciting resources for enhancing this academic exercise, which, as such, has never been realised. The only drawing board testimony remains difficult to understand when addressed to a broad audience. The urban scene modelled in three dimensions becomes the protagonist in the development of the immersive experience, which allows the end user to perceive the conceived spaces through a new, more personal, and immediate key, exploiting the tools of virtual reality vision.

The exhibition project is an opportunity to investigate the relationship between the museum environment and the new tools for developing communication and user engagement through spatial digital media. The contribution reflects on the use of digital innovations, specifically those related to Virtual Reality (VR), capable of favouring the recontextualisation of the object of knowledge and consequently multiplying the potential of its narrative. According to this thought, E. Bonacini's words in describing museums as "an architecture in continuous evolution, giving rise to a rethinking of collecting and exhibiting significant objects" (Bonacini, 2020) remain current.

To address this reflection, other traditional boundaries of the Drawing discipline must be overcome by incorporating codes previously integrated by other disciplines such as photography, cinema, or video games. This broadening of perspective allows, on the one hand, the identification of a taxonomy referring to this specific research area; on the other hand, this approach lets the identification of the codes that characterise it: orientation, stereoscopy, interactivity, and sensory involvement (Rossi, 2020).

## 2. Aims and objective

The contribution critically reflects on the possibilities of using digital technologies to represent, understand, and communicate characteristics and information belonging to a work that is part of the cultural heritage. The identified work is a project that remains unrealised, characterised by rich documentation consisting of wonderful technical representations in orthogonal projections and a fascinating perspective at a human scale that enhances the power of Antonelli's revolutionary proposal. It also includes a technical report that motivates the proposed choices and integrates the graphic elaborations preserved in the archival collection of the Accademia Albertina. The immersive experience aims to relate to the museum environment in the Accademia called “Pinacoteca”, reflecting on the significant role these digital tools have assumed within museum spaces, particularly during the pandemic and post-pandemic period. This revolutionises the relationship between the collections on display and the visitor, with evident repercussions on the proposed communication methods and the definition of exhibition paths that involve hybrid forms of interaction between physical objects and multimedia content.

The medium identified within this digital revolution consists of systems capable of positioning and interacting between real and virtual environments. The first theorisation of the hybridisation through these two different worlds and the identification of a specific lexicon capable of representing the variables identified within these two extremes is the Reality-Virtuality Continuum by P. Milgram and F. Kishino (Milgram & Kishino, 1994). As often happens in the academic field, researchers rework and adapt some technologies used in sectors other than those they investigate or specific disciplinary scientific sectors to particular contexts, sometimes very distant from their original purposes. For instance, a couple of years after the taxonomy proposed by Milgram and Kishino, id Software developed and published Wolfenstein 3D, a first-person shooter video game in which the player fights against the Nazi army. Later, it was made available for many other platforms after its initial release for MS-DOS by Apogee Software. This video game constitutes the first example of a navigable three-dimensional scenario where the user/player can move within a three-dimensional model and interact with it, albeit using very different functionalities from those proposed in a museum context. The video game draws inspiration from the older Castle Wolfenstein (1981), which adopted a more traditional top-down view. Another exciting element was the presence of brief sequences of digitised voices, which is rare for a home computer video game of that time. Over the years, first-person video games have experienced exponential development in graphic quality and computing power.

It is precisely from the video game industry sector that some immersive experiences designed for educational purposes draw inspiration: the proposed experience uses the same applications used for the entertainment world, imagining fruition that can employ augmented reality visors to represent with greater effectiveness the evocative power of this unfinished work, offering the public the opportunity to explore and understand it in a new and engaging way while also receiving some notions about the training and professional life of the architect Antonelli through interaction with certain parts of the digital model. Video games, but more broadly the concept of “gamification,” allow for an experience defined as “story doing,” in which the user takes on the role of an active protagonist in the proposed story, making continuous decisions that can influence the outcomes (Izzo, 2017).

## 3. Methods and procedure

### 3.1. Analysing, reading, and digitising sources

Before starting the reconstructive digital modeling activity, it is essential to analyse the drawings meticulously. The architect's legacy comprises six boards dated September 15, 1831, drawn with ink and watercolours by Antonelli himself (excluding the perspective panel engraved by Alessandro Angeli). Since the project included three different versions of the cathedral, two in a Constantinian style and only one referencing “ the most famous cathedrals in Europe," it is necessary to identify which versions have the richest representations to provide helpful information for developing the immersive environment The proposal of the new cathedral, crowned by the central hemispherical dome, which excludes the preservation of the Beaumont gallery and has a more international vision, contains the most details among the received illustrations; therefore, we have identified it as the object of study. Scans are made from the original panels preserved in the Academy di Belle Arti, generating high-resolution image files that, adequately scaled and positioned in the workspace, form the basis for developing the three-dimensional model.

### 3.2. Reconstructive digital modeling

Digital scans of Antonelli's drawings are imported into the model space of Rhinoceros software and then correctly scaled by converting length measurements from piedmontese trabucchi to meters (1 trabucco = 3.082596 meters[1]). The panels are aligned in three-dimensional space, and the modeling phase can start through a "trace" of the drawings, serving as graphical references for generating surfaces and solid geometries from those drawn on paper (Figure 1). Almost the entire square was recreated following the traces of the illustrations produced by the young Antonelli. However, some small areas of the project inevitably result in less metric reliability, such as the rear part of the cathedral. This part is not visible from the perspective panel, which is the most detailed.


**Figure 1.** The proposed workflow, from left to right: 3.1: Digitizing sources; 3.2: 3D Modeling; 3.3: Geometry retopology; 3.4: Interoperability between Rhinoceros and Unreal Engine. Source: Vanni, E.

In the experience, the user can compare the two versions of the square: the one imagined by the author and the current one. For the 3D modeling of Palazzo Madama (Viano, 2002) and the remaining architectural structures that characterise Piazza Castello, a similar process was followed. Through the drawings from surveys conducted for the restoration of Palazzo Madama, the model of the medieval castle and the juvarriana staircase were defined. Finally, the square is completed by defining the facades of the entire perimeter. To maximise the potential of the technologies allowing the use of the model in virtual reality, a narrative path is conceived to accompany the visitor throughout the experience. It is articulated in a series of rooms representing a hypothetical depiction of the architect's studio in 1831. Various objects are arranged within this space, referring to topic moments and concepts directly related to the project for the decoration of Piazza Castello. The entire apparatus is realised through digital modeling.

[1] According to the official conversion factor adopted for the Piedmontese trabucco in the province of Mondovì before 1818 (as indicated in the Tables of Equivalence of weights and measures already in use in the various 'province' of the Kingdom with the decimal metric system. Approved by decree on May 20, 1877), (Novello & Piumatti, 2012).

 

### 3.3. Geometry retopology

Next, the step involves transforming the modelled geometries, known as “polysurfaces”, into meshes, allowing the multitude of elements to be exported in a .fbx file format for use in subsequent stages of work to complete the development of the immersive application. Another necessary process involves optimising the meshes, which, through transformation, acquire an excessively dense and disorderly polygonal structure, making the digital model excessively heavy and, therefore, difficult to manage. In this case, the “QuadRemesh” command, specific to the Rhinoceros software, was used to reconfigure the geometry structure and simultaneously lighten the mesh by organising its shape using quadrangular faces. This allows the desired level of detail to be maintained while drastically reducing the number of polygons present in the model.

### 3.4. Importing the model into the graphics engine used to define the immersive environment

In the following stages of developing the immersive experience, the focus shifts to the Unreal Engine graphics engine, where a working project is created from the Games's virtual Reality template.

Then, import the geometries produced in Rhinoceros into the Editor. At this stage, it is essential to highlight the choice to utilise the recent Nanite technology. This algorithm allows the import and display of large 3D models while maintaining high-performance thanks to automatic and real-time management of the Level Of Detail (LOD).

The different modelled parts are imported into the virtual space and arranged neatly. Various materials are assigned to the surfaces of these elements, along with a thoughtful arrangement of light sources, to enhance the realism of the experience and increase visitor engagement.

Once we complete this phase, the environment will be structurally and aesthetically ready, but we will need further modifications to support the user's presence. To facilitate movement within the modelled spaces, we define collision attributes in the imported meshes, rendering the geometries solid and enabling them to behave like physical objects: impassable, providing a surface for visitors to walk on, etc. Specifically, we consider geometries related to floors, walls, handrails, etc., and we exclude meshes that users are unlikely to interact with from this process for optimisation and file lightweight purposes.

Another crucial aspect is the movement system for the user participating in the experience. The Meta Quest 3 headset is the selected hardware for the application and is compatible with the teleportation locomotion system, already present by default in the Games Virtual Reality template. With the joystick on the suitable controller, users can point and choose their movement position, while using the joystick on the left controller allows them to rotate their view by pointing it left or right.

The decision to maintain this movement system is due to its ease of use and minimal risk of inducing motion sickness, even for users who are inexperienced or unaccustomed to virtual reality.
To complete the work, interaction types between the user and the environment in different areas of the experience are defined and implemented through the Blueprint visual programming language native to the Unreal Engine:

- Box collisions trigger animations once a particular area is crossed (for example, when pressing buttons, automatic door opening, or text and pop-ups appear);
- The ability to grab, carry, and release various objects in the environments (to observe details up close and to define small puzzles distributed along the narrative path).

The application is then completed and ready to be exported and used.

## 4. Results

The immersive experience involved various figures from different scientific-disciplinary sectors: the group coordinated by Prof. Lo Turco (Drawing) together with Dr. Enrico Zanellati (Curator of the Accademia Albertina) and Prof. Elena Gianasso (History of Architecture). This collaboration allowed for the definition of a multidisciplinary and engaging experience capable of addressing highly heterogeneous themes. The initial concept phase was the first step in undertaking an operation of this magnitude, which involved the design of a storyboard for visual aspects and the storytelling to delve into narrative aspects. Both were useful in clearly defining the setting of the proposed virtual experience. We identified two main scenarios, each with different morphology, configuration, and proposed levels of interaction.

### 4.1. The "studiolo"

The first virtual environment, Antonelli's "studio," serves as a filtering area, a primary mediation zone guiding the visitor through the transition between the real and virtual worlds without straying too far from the former. The proposed digital environment attempts to evoke the physical-real space through simple and familiar forms, hypothetically placing the experience fruition within the rooms of the Museo della Pinacoteca dell'Accademia Albertina. We configure the new virtual space as an additional room to add to the current visitation path established within the museum spaces for the exhibition "*Neoclassicisms in Turin: From the Eighteenth Century to the Young Antonelli*".
The space thus configured is an indoor environment characterized by:

a. A designated area for introducing and demonstrating the fundamental commands required to navigate the immersive environment;
b. An exploratory space resembling the architect's "*studiolo*", where visitors can delve into the cultural interests of the author (Figure 2).

This intimate space contains objects to evoke some of the architect's fundamental life stages, with specific interactions highlighting their importance. These elements facilitate understanding and closeness between contemporary visitors and the past author, achieving an immersive experience capable of transcending spatial and temporal boundaries and focusing the viewer's attention on the multifaceted and complex figure of architect Antonelli. The spatial boundaries are overcome by connecting and overlaying two distant cities, Rome and Turin, which are the main scenarios for the author's education and biography. The temporal boundaries are overcome by placing elements from crucial moments in the architect's life within a single space. This allows for a cohesive narrative that reveals the significant stages to visitors, enabling them to understand Antonelli's personal and professional growth. The central identified life moments include:

- The "*pensionato romano"* corresponds to the subsequent five-year training completed in Rome after obtaining the title of architect and engineer, mainly focusing on the grand civic (Pantheon) and religious (Basilica San Pietro) architectures of the past;
- The apprenticeship was when the young architect acquired his language and characteristics, developing his strong personality;
- The earlier projects for the city of Turin influenced the young Antonelli's proposal for a new Cathedral in Piazza Castello, referencing illustrious figures such as Juvarra, Alfieri, and Canina.

**Figure 2.** The interior environment is reminiscent of Antonelli's "studiolo" (foreground) and the introductory space to the experience (background). Source: Vanni, E.

The interactive aspect plays a crucial role, engaging two critical figures in the museum ecosystem: the visitor, who explores and acquires new knowledge, and the content, which carries a diversity of hidden meanings waiting to be revealed. This interactive process plays a significant role in the real/physical museum environment, where certain elements may act as barriers or filters to ensure the proper protection and conservation of content. This relationship also gains relevance in the virtual environment, where digital tools allow overcoming physical interferences inherent in the real world, enabling a sophisticated and increasingly intimate connection.

Interaction is realised through touch controllers, allowing interaction with crucial elements and activating puzzles/micro-games. Completing these challenges enables the acquisition of multimedia content to enrich and consolidate the experience and a portion of a plastic model. Assembling this model allows for the visualisation of the entire Cathedral project for Piazza Castello, unlocking and providing access to the subsequent immersive scenario (Figure 3).

**Figure 3.** The space dedicated to the collection and completion of the model depicting Antonellini's Cathedral project (light) and its location within the city of Turin (dark). Source: Vanni, E.

### 4.2. The cathedral

The second virtual environment represents Antonelli's project for Piazza Castello, the Cathedral, in its urban dimension and is visitable at a human scale. In contrast to the previous environment, this one visualises an imaginary open space, traces only found in the tables preserved at the Pinacoteca. Repairing the architect's never-realized project on a 1:1 scale allows for discussions and evaluations that are not possible priori through only iconographic sources. Compared to the static nature of the boards, using an environment that enables immersion in a dynamic space allows visitors to capture new perspectives of Antonelli's work and the surrounding urban configuration (Figure 4). The realisation and crystallisation of this project from a specific historical period, translated into a digital environment, also allows for temporal parallels between the imagined configuration by the young architect and the current situation. These historical overlays are visualised through interactions, which occur through specific points within the urban environment. These elements are placed mainly along the city's most critical historical axes or at specific optical cones capable of capturing the essence of the Cathedral project and its relationship with the context. To be explored and experienced fluidly, an environment of this size requires specific navigation aids, such as the teleporter using touch controllers.

**Figure 4.** The external environment recalls the imaginative design of the Cathedral, which Antonelli designed for the city of Turin. Source: Vanni, E.

Teleporting is one of the possible variations of spatial cognition investigated in gaming concerning the relationship between embodiment and environment (motion perception). Our body needs to be involved through its three physical sensors (visual, vestibular, and proprioceptive systems) to respond naturally to the movement instilled by the digital medium. Teleportation lets visitors move quickly between specific points within a vast virtual space (Figure 5). These points, called Points of Interest (P.O.I.), must be identified in advance, and their representation must follow specific graphical rules, such as shape, colour or size. A specific purpose guides these choices: they must be easily recognisable yet discreet to attract and maintain the visitor's focused attention. This way, the participant in the experience receives guidance and direction to follow a specific visual narrative, as seen in the case of the magnificent, never-realized work of young Antonelli, even though it may seem unconscious. However, there is no pre-established path to complete the itinerary, which remains at the user. The individual might be driven by the Fear Of Missing Out (F.O.M.O.), prompting them to repeat the experience multiple times to ensure they see all its parts. (Rossi, 2020).


**Figure 5.** Navigation of the virtual environment using the teleporter with the joystick. Source: Vanni, E.

## 5. Conclusions

In the 1930s, the Science Museum of London unveiled the "Children's Gallery," an innovative area designed to spark curiosity among youngsters about science: a pioneering example of blending education and entertainment. Sir Henry Lions, the museum's director, prioritised engaging primarily with ordinary visitors rather than exclusively targeting specialists. Fast forward to today, one cannot overlook the experience of the Archaeological Museum of Naples with the video game Father and Son, designed by Fabio Viola (Viola & Cassone, 2017), which has garnered over 4 million downloads worldwide.

The illusory image of a dimension other than the real one has always accompanied creative processes, including those closest to us, such as those used to envision architectures, cities, and worlds projected into an apparent or unattainable ideal future. Contemporary visual culture, fueled by the film and gaming industries, has benefited from new technological opportunities capable of enhancing the perceptual experience of the observer. Since the pandemic, these processes have further strengthened, prompting us to reflect on the use and importance of such devices for scientific, educational, and leisure purposes. Thus, the words of William Gibson (Gibson, 2014) become relevant again when the protagonist of the science fiction book Case navigates data cities and infiltrates archives as if they were fortresses to conquer. In this case, the proposed technology can be applied in speculative or design contexts and extended to educational purposes aimed at less qualified users, supporting practical efforts to valorise existing knowledge through interactive observation, primarily stimulating visual learning (Basso, 2020).

New technologies related to digital modeling and the creation of immersive virtual environments can be valuable resources for enhancing the cultural heritage of architectural projects never realised, of which only paper documentation remains, consisting of a report and some highly detailed technical drawings, many of which are difficult to understand for a broad audience. Essentially, what changes concerns how we perceive things: from a static view, heavily influenced by the canons of perspective representations, we have transitioned to a continuous and changing view, altering cognitive conditions and expanding investigation spaces from a dynamic interactive perspective. Riccardo Migliari, who first coined the term (Migliari, 2008), acknowledged the debt that representation culture owes to the gaming sector, attributing to it the crucial role of remediating the perspective device. The three-dimensional modelled urban scene becomes the protagonist in the development of the immersive experience, allowing the end-user to perceive the spaces conceived through a new, more personal, and immediate key, leveraging virtual reality viewing tools.

The developed application offers an alternative to traditional modes of experiencing museum exhibits: participants in the immersive experience can visit a series of unexplored and fully explorable locations. Active participation is required inside these locations to interact with the elements present and solve puzzles related to the project's theme and author. This way, curiosity about exploration and discovery drives visitor engagement, allowing them to experience a digital yet immersive journey firsthand. When the dimensions of the virtual environment necessitate bodily movement, the perceptual modes of sight integrate with those inherent to the human body and its neuro-cerebral apparatus. One thing is sure: the plastic intelligence of a three-dimensional space cannot be exhausted in a two-dimensional representation, or the construction of scale models alone (Antinucci, 2004), but digital models can enhance it. Suitably arranged models allow firsthand experience through virtual navigation tools that integrate visual perception stimuli with those induced by our body's movements relative to the environment (Rossi, 2020).

## 6. Acknowledgements

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Although the contribution was conceived jointly, M. Lo Turco is the author of paragraphs “5. Conclusions”; J. Bono of paragraphs “2. Aims and objective” and “4. Results,” and E. Vanni of paragraphs “1. Introduction” and “3. Method and/or procedure.”

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# Graphic restitution of the Four Seasons Hall of the Marquis of Benicarló's House

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***Abstract***

*The Marquis of Benicarló's House is one of the foremost examples of 18th-century civil architecture in the Valencian region. Within its walls, it safeguards ceramic panels from the esteemed Conde de Aranda Factory in Alcora, possessing significant historical and heritage worth.*

*However, akin to many other instances, before its designation as a Cultural Interest Property (BIC) in 2008, the structure underwent the removal of several architecturally valuable components, such as the flooring of the Four Seasons Hall. Thankfully, the original tiles from this flooring have been rediscovered within the collection of the National Museum of Ceramics and Decorative Arts González Martí.*

*This paper presents the graphical restoration efforts applied to the flooring, utilising the pieces sourced from the museum's collection. It also details the process of digitally restoring the flooring to its original location through advanced digitisation techniques. This enables the visualisation of the hall's authentic state using virtual reality methods, thereby facilitating its appreciation and dissemination as a heritage architectural space.*

**Keywords:** *Marquis of Benicarló's House, ceramic flooring, architectural heritage, graphic restitution, virtual reality.*

## 1. Introduction

The Marquis House, also known as *Casa dels Miquels*, located in Benicarló, Castellón province, is a remarkable example of Valencian civil Baroque architecture. Erected in the late 18th century by Joaquín Miquel Lluís, it replaced the former Encomienda House, once the headquarters of the Commander of the Order of Montesa. The building comprises a ground floor, mezzanine, main floor, and attic, organised around a grand entrance hall (Figure 1) and gallery (García Lisón et al., 1983).

**Figure 1.** Entrance Hall and gallery. Marquis of Benicarló's House.

Notable features include a magnificent staircase, decorative ceramic coverings in the chapel and the kitchen, and decorative paintings and ceramic flooring in the noble rooms. The ceramics were crafted at the Conde de Aranda factory in Alcora (Gil-Saura, 2002; Pérez-Guillém, 1999). Designated as a singular BIC (Cultural Heritage) by the Valencian Government in 2007 (Consell de la Generalitat Valenciana, 2007) and definitively listed as such by the Ministry of Culture in 2008, it holds 1st category Real Estate with Monument status (Consell de la Generalitat Valenciana, 2007). A section of the original flooring of one of the main halls on the first floor has been replaced with modern white ceramic tiles, contrasting with the original perimeter tiles of different colours and sizes (Figure 2).

**Figure 2.** Hall of the main floor. Marquis of Benicarló's House.

Recovering this hall, including these decorative ceramics, presents a significant challenge, requiring the preservation of historical and stylistic authenticity while safeguarding their original properties and characteristics. Digital modelling techniques allow us to graphically restore these architectural elements in their original buildings and visualise and contextualise them using virtual reality (VR) techniques (Puyuelo-Cazorla et al., 2011).

## 2. Aims and objectives

The main objective of this work is the graphic restitution of this hall. To achieve this objective, the following aims have been proposed:

- Data collection of the hall using laser scanning and photogrammetry techniques;
- Generation of a point cloud of the hall;
- Meshing and texturing of the hall;
- Documentation of ceramic pieces;
- Graphic assembly of the ceramic pavement;
- Restitution of the pavement in the 3D model of the hall;
- Visualisation of the Hall using VR techniques.

## 3. Methods and procedure

Within the methodology, we must differentiate between the graphic survey work conducted within the building itself, the data collection performed in the museum, the graphic processing based on the initial information, the integration of the flooring within the digital model of the hall and its visualisation using VR techniques (Rodriguez-Navarro et al., 2022).

### 3.1. Data collection of the hall

Cutting-edge tools such as 3D scanners and photogrammetry systems are used for in-situ data capture in architectural research, enabling the creation of detailed 3D models without altering the physical structure (Guerra, 2029; Murcia-Soler et al., 2020). A Leica BLK360 3D Imaging Laser Scanner has been employed, featuring precise measurements and high-resolution imaging capabilities. Fieldwork involves planning the number of stations for scanning each floor and using Cyclone Field 360 software for real-time visualisation and alignment (Roldán-Medina et al., 2020). To collect data, the southeast area of the palace's main floor has been scanned, carrying out nine stations (Figure 3).

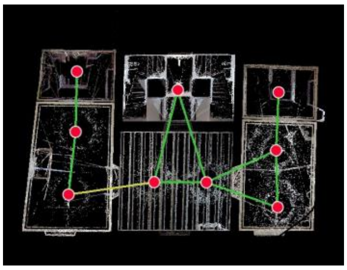

**Figure 3.** Site plan. Oriented point clouds of the floor.

Additionally, a photogrammetric model of the main floor has been created using a RICOH THETA Z1 360º photographic camera and MATTERPORT software. The resulting 3D model can be accessed online (Figure 4).

**Figure 4.** QR code of the 3D model of the building.

### 3.2. Generation of the point cloud

To process the point clouds acquired from the scanner, we utilised LEICA GEOSYSTEMS CYCLONE REGISTER 360 software. This software facilitated the recording and integration of the nine-point clouds by importing .blk files from the scan and aligning them to identify three common points in each cloud, resulting in a consolidated point cloud. Furthermore, the software offered capabilities for refining and orienting the point cloud.

Using this unified point cloud data, we generated a digital model of the southeast hall, the location of the original pavement.

To enhance the clarity of the point cloud, we employed the “smooth surfaces" tool, which effectively eliminated excess points, focusing solely on the walls and floor. Any unselected areas were highlighted in red and subsequently removed automatically (Figure 5).

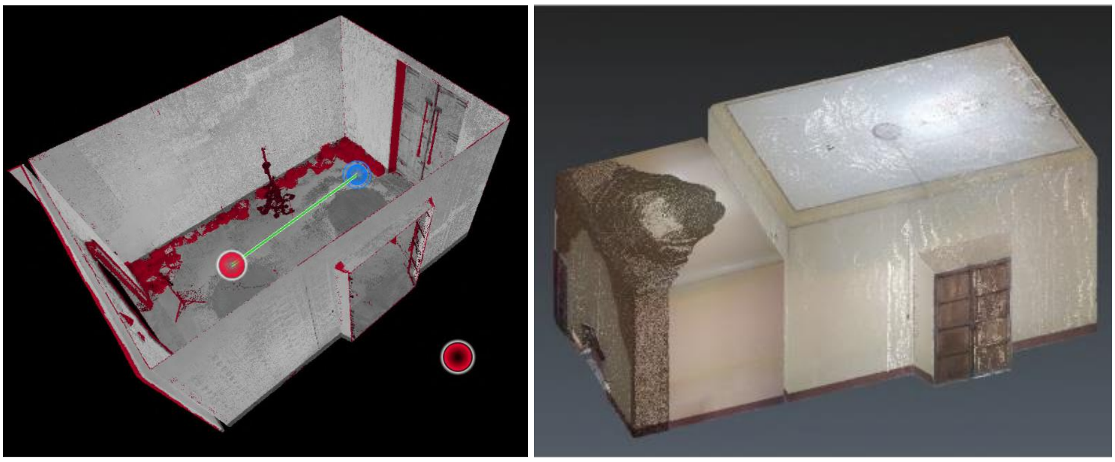

**Figure 5.** (a) Cleaning of the point cloud of the Hall. (b) Colourpoint cloud of the Hall.

### 3.3. Meshing and texturing of the hall

The point cloud has been imported into the Cyclone 3DR program in an e.57 format to create the mesh. Then, the "3D mesh creation" tool was selected, and the "two-step meshing" option was chosen (Figure 6).

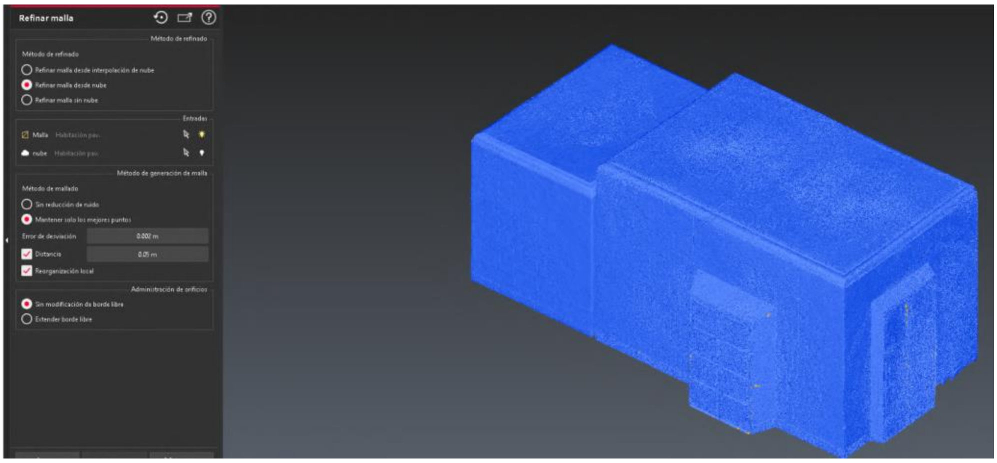


**Figure 6.** 3D mesh unrefined

The next step has been to select "refine mesh from the cloud." From this process, a mesh of the Hall has been obtained. The next step has been to improve the mesh for subsequent texturing.

Afterwards, the "global smoothing" tool was used, and the "smooth noise" tool was selected, thus achieving a more homogeneous model. However, several errors in the mesh still need to be corrected using different modelling tools.

Using the "clean/separate," "bridge," "fill holes," and "smooth mesh" tools, all poorly modelled parts have been eliminated, and the mesh has been adjusted. To delineate each part of the room for subsequently applying each texture in its correct place, a polyline has been created on each one of the edges, its projection onto the mesh has been performed, a constrained mesh has been created, and subsequently, the "sharp edges" tool has been applied (Figure 7).

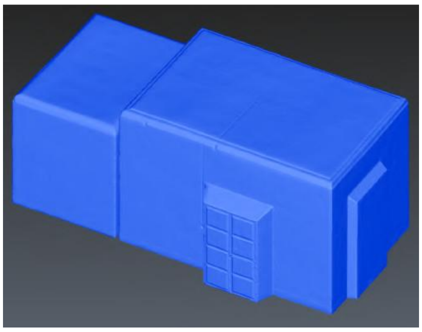

**Figure 7.** Tight and refined mesh

With the GIMP software, the three spherical images captured by the scanner itself have been edited to texture the room. The main edits focus on fixing the lights generated on the walls and ceiling, removing the stacked tiles on one side of the hall, and eliminating the bed's headboard (Figure 8).

**Figure 8.** (a) Original spherical image of the Hall. (b) Edited spherical image of the Hall.

The adjusted and refined mesh has been textured using different spherical images of the room once edited. With this procedure, a fully textured mesh of the room has been obtained (Figure 9).

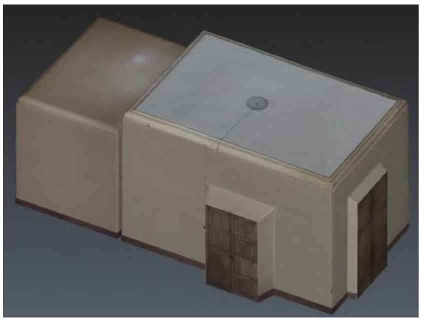

**Figure 9.** Mesh textured using spherical images.

### 3.4. Documentación of ceramic tiles

To capture photographs of the ceramic tiles, we utilised Nikon D-80 and Nikon 5200 cameras equipped with conventional lenses (18-135 mm, f/3.5-5.6 aperture) as well as a Sigma wide-angle lens (8-16 mm, f/4.5-5.6 aperture). These cameras were securely mounted on an adjustable support system to ensure precise focus and alignment of orthogonal images. The tiles were positioned on a millimetre template to facilitate accurate adjustments.

To minimise any potential lens movements, remote triggers via the SnapBridge application were employed (Figure 10). Each tile was photographed from both the obverse and reverse sides, and additional data collection included weighing and measuring each piece using a calliper.

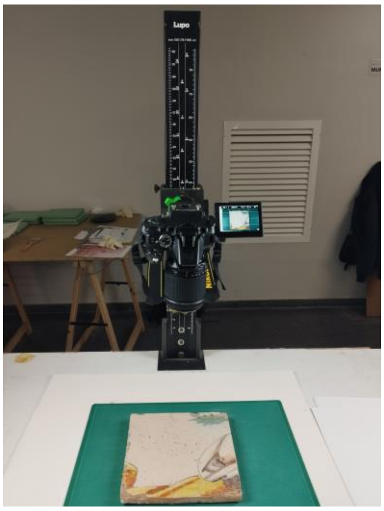

**Figure 10.** Capture of images of the ceramic pieces.

### 3.5. Graphic assembly of the ceramic pavement

In this subsection, the graphic process carried out based on the images captured of the ceramic pieces located in the museum will be presented.

The tiles were labelled and numbered based on the initials of each set, following the methodology outlined in the graphic restoration work of the Sanjoans Palace (Julián-Querol, 2010). To correct fisheye lens distortion, also known as "barrel distortion", the images underwent rectification using PTLENS software. This rectification process was generally effective, especially considering the capture conditions with orthogonal support to the pieces. However, in instances where warping occurred, further rectification was conducted using ASRix software. Once rectified, the images were cropped to eliminate the background using the GIMP photographic retouching tool.

Subsequently, the cleaned and retouched images were assembled into different decorative panels using GIMP software on a 21.5 x 21.5 cm grid. Each subset represented a different pattern, such as Spring, Summer, Autumn, Winter, Chronos, corner border, brown border, blue border, and white panel. The Four Season panels consisted of 16 tiles, the Chronos panel of 44 pieces, and the border and white panels of 9 tiles each (Figure 11).


**Figure 11.** Digital reconstruction of the Winter ceramic panel.

After obtaining the individual patterns, a grid of 33 x 21 tiles was constructed, each containing a distinct decorative pattern. The panel was then finalised by incorporating a segment composed of undecorated white pieces.

Subsequently, the edited photographs were applied to the mesh using the "texture from image" tool. However, due to inadequate software adjustment, manually adjusting each room area with the desired photograph was necessary, accomplished through the "texture adjustment" tool (Figure 12).

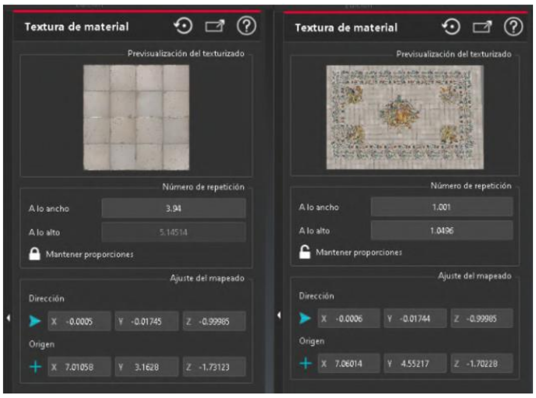


**Figure 12.** "Texture adjustment" tool.

### 3.6. Restitution of the pavement in the 3D model of the hall

Two textures were created from scratch for the flooring creation: one depicting the fully decorated flooring for the main room and another one featuring a module of 4 x 4 white tiles for the adjacent room.

To facilitate the flooring placement, the flooring has been divided into two parts and separated from the rest of the room, leaving a mesh of the walls and ceiling, one mesh on one floor and another on the other. Each texture has been applied separately by importing each image into the program, and using the "texture adjustment" tool, both textures have been applied; by adjusting the values of each image, we position the photos in their place.

By adjusting the values of each image, the images have been placed in their correct positions. The final result can be observed in Figures 13 and 14.

**Figure 13.** Pavement texture adjusted to the mesh. Floor view.

**Figure 14.** Pavement texture adjusted to the mesh. 3D view.

### 3.7. Visualisation of the Hall using VR techniques

To upload the model to the Sketchfab platform, the .obj file size has been reduced using MeshLab software as follows: Filters -> Remeshing, Simplification, and Reconstruction -> Simplification: Quadric Edge Collapse Decimation (with texture) -> Target number of faces 500,000.

The model has been uploaded to the Sketchfab platform, where it is possible to perform a 3D visualisation of the model and navigate through it (Figure 15).

**Figure 15.** QR code of the 3D model at Sketchfab web.

## 4. Results

The efforts have created a comprehensive digital model of the room, allowing for in-depth exploration from historical and heritage viewpoints and facilitating its cultural dissemination in a virtual environment. This digital model provides a visualisation of the architectural space as it existed before the removal of the decorated ceramic pavement, thereby enriching our understanding and appreciation of the space (Figure 16).

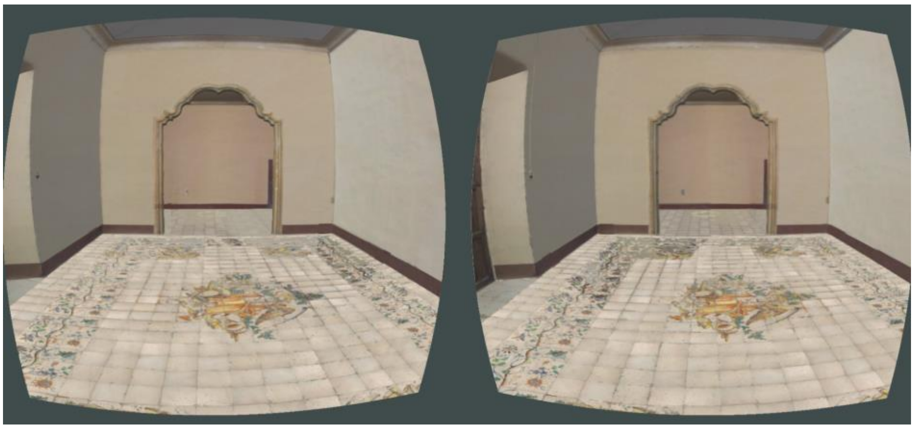

**Figure 16.** Visualisation of the Hall through VR.

## 5. Conclusions

Virtual Reality (VR) offers significant advantages in preserving architectural heritage that may be threatened, destroyed, or difficult to access. By creating virtual models of historical buildings, VR enables digital documentation and preservation, ensuring these monuments can be experienced and appreciated by current and future generations. This approach safeguards cultural heritage and facilitates its global dissemination, overcoming physical and geographical limitations.

VR has emerged as a groundbreaking tool for visualising architectural heritage, providing various benefits from sensory immersion to digital preservation. Its capacity to recreate historical environments, promote interactivity, and grant global access to cultural treasures positions it as a potent tool for conserving and disseminating architectural heritage.

The Marquis of Benicarló's House stands among the four unique Cultural Interest Properties (BICs) in Benicarló today, boasting significant heritage and historical value. It holds immense potential as a cultural landmark within the province of Castellón, particularly in the region of Bajo Maestrazgo.

Through digital modelling and VR technology, we've been able to digitally restore the splendour of one of its distinctive architectural spaces, named the "Four Seasons Hall." Utilising this technique, we've created an immersive journey back to the late 18th century, offering a glimpse of this space in its original conception (Figure 17). This methodology holds promise for similar case studies, providing a means to restore damaged or missing architectural elements.

**Figure 17.** View of the flooring in the 3D model of the Hall.

## 6. Funding

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# The use of Digital Twins for heritage conservation: the Church of San Juan del Hospital as a case study

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***Abstract***

*The evolution of new technologies in construction is opening up new possibilities in the process of information management that encompass all stages of a building's useful life, design, construction, and operation. In this sense, the tools of the Building Information Modelling (BIM) environment are very useful, consolidating themselves in the management of new buildings. They are currently beginning their introduction to the management of historic buildings through HBIM.*

*Among the utilities that facilitate the management of historic buildings is the simulation of their behaviour in order to develop the most appropriate strategies to guarantee the conservation of their heritage assets. Among the tools that guarantee a correct simulation of the building behaviour are digital twins that, based on HBIM models and duly provided with real data, allow the generation of dynamic models that facilitate the decision-making process for the maintenance of the building.*

*This paper describes the creation and validation of the digital twin developed for the church of San Juan del Hospital in Valencia, where the importance of data collection to bring the behaviour of the simulated building closer to the real behaviour has been proven.*

***Keywords:*** *Digital Twin, BIM, HBIM, Simulation*.

## 1. Introduction

The evolution of new technologies in construction is opening up new possibilities in the information management process that cover all stages of a building's useful life. The databases that are generated, in many cases through BIM (Building Information Modelling) strategies, are offering optimum results in new buildings, and their implementation is being consolidated.

One of the areas in which the implementation of BIM technologies is lagging is that of heritage buildings, where this technology is known as HBIM (Heritage Building Information Modelling). The efficient management of building information in historic buildings is being tested because of its great potential, as information in these buildings is often dispersed and incomplete. However, it has been shown that there are no robust strategies and that most published experiences are case studies reflecting different tests that require further validation (García-Valldecabres et al., 2022).

As in the case of new buildings, the use of HBIM strategies allows the centralisation of information, which, when applied to historic buildings, becomes a repository where geometric, constructive, and historical information can be collected, facilitating collaborative work and the coordinated exchange of information between multidisciplinary teams.

In the case of historic buildings, these multidisciplinary teams must be in charge of ensuring their conservation and, at the same time, guaranteeing their correct exploitation in order to bring culture closer to society without putting the heritage at risk. In this sense, the Master Plans (MP) play a very important role. They must be drawn together with Preventive Maintenance Plans (PMPs) to guarantee a correct maintenance strategy and to program actions over time that must be flexible and adaptable (Liu et al., 2022).

The interest in preventive conservation and understanding the factors that can condition heritage conservation generates several lines of research. The research proposes the use of non-destructive testing (NDTg) for the diagnosis of heritage buildings, proving to be one of the most sustainable approaches in the field of preventive conservation (Hidalgo-Sánchez et al., 2023). In the same vein, studies on the mechanical behaviour of historic structures and the assessment of expected service life are also carried out using non-destructive techniques (NDTs) (Kilic, 2015). Integrating the data into the 3D model has also been studied (Kukela & Seglins, 2013), which has enabled several conclusions to be drawn about potential stability threats, contributing to the development of a methodology for preserving and conserving monuments.

However, these preventive tasks based on the periodic control and maintenance of buildings require reviewing not only the state of the structural and functional elements but also the state of conservation of the materials (Gutierrez et al., 2009). Stone materials can be altered by the surrounding environment so that the presence of atmospheric oxygen favours oxidation processes, and humidity favours hydration and dissolution processes (Fernandez París, 1975). Similarly, paints can be affected by efflorescence due to the appearance of continuous condensation (Bellido Márquez, 2016).

In the process of generating MPs and their PMPs, HBIM technologies play a major role since they enable the generation of three-dimensional digital models where it is possible to collect the history and evolution of the building and, at the same time, design strategies for the future maintenance of the building through Digital Twins (DTs).

A DT is a virtual model designed to reflect a physical object accurately. The object under study is equipped with various sensors related to vital areas of functionality. These sensors produce data on different aspects of the physical object's performance, such as humidity, temperature, or CO2 emissions. These are transmitted to a processing system and applied to the digital copy, allowing adjustments and supporting decision-making for its preservation.

DTs assist in the preventive maintenance process by allowing adjustments over time through data obtained from building monitoring. This technology has been widely used by industry and is now being implemented in the management of buildings, especially new construction. In the world of construction, the digital information revolution has led to BIM technologies changing the processes of design, construction, and management of buildings (Tulenheimo, 2015). Existing investigations evaluate the structure and management of information that DTs store to understand the functioning of buildings (Gordo-Gregorio & Guéna, 2021).

These DTs have started to be applied, through case studies, in historic buildings and sites, confirming that the use of sensors installed in historic sites allows for safeguarding the site's integrity and acting preventively (Jouan & Hallot, 2019). In addition, new digital technologies offer many solutions capable of delivering a digital replica of objects of interest so that a reduction of uncertainties in analysis models can be achieved. A rational approach to preserving and protecting artistic heritage is based on traditional approaches supported and integrated by novel technologies so that qualitative and quantitative indicators of the current condition of artistic heritage can be defined and validated in an interdisciplinary framework (Marra et al., 2023).

As in other areas of BIM and HBIM, through case studies, it is possible to find experiences where the use of DTs, with the aim of improving the interior conditions in historic buildings, has allowed relating HBIM models with Computational Fluid Dynamics (CFD) allowing the evaluation of the amount of ventilation required and reducing the amount of equipment (Zhang et al., 2022). At the same time, the use of DTs supported by HBIM strategies has enabled the integration of both technologies around a Decision Support System based on Artificial Intelligence (in this case, Machine Learning techniques) for the management of museum collections in historical architectures (La Russa & Santagati, 2020).

Nevertheless, it can be stated that the use of DT based on HBIM strategies applied to historic buildings is incipient and that the need for further research is confirmed to consolidate the findings and to be able to develop working strategies applicable to other case studies. Recent publications confirm that simulation tools applied to an HBIM model make it possible to simulate the characteristics and behaviour of the real building. However, it is a very young technology, and no consolidated strategies have been found. It is necessary to work with case studies (Niccolucci et al., 2023).

## 2. Aims and objective

Given the need for new research that allows the development of DTs integrated into PMPs based on HBIM technologies that evaluate the behaviour of historic buildings, the aim of this research is to describe the process followed for the creation and validation of the DT developed for the church of San Juan del Hospital in Valencia.

The church of San Juan del Hospital is the oldest church in Valencia. It began as a small Romanesque church, and at the end of the 13th century, three bays were added, turning it into the church we see today. The two doors and some magnificent paintings, recently restored, remain from the Romanesque church. The side chapels located between buttresses on the gospel side were added in the 15th century. The first of these was made by Pere Balaguer, the author of the well-known Serranos Towers, the gateway to the Christian wall and symbol of the city. On the epistle side, the side chapels are enclosed by thin stone walls (15 cm) due to the later construction of cemetery arches outside. The large quantity of archaeological remains found in the subsoil of the cemetery area has led to the creation of a museum located in adjoining rooms. It should not be forgotten that beneath this architectural complex are the remains of the different towns that have developed in the city since the Roman period when the city was founded (138 BC): Visigoths (5$^{th}$ Century -714 AC), Arabs (714-1238 AC) and Christians (from 1238 AC to the present day).

The geometry of the church has a single nave with chapels between the buttresses (Figure 1). The main nave is characterised by the small size of its openings to the exterior, with only three doors that can be opened. In terms of natural lighting, the windows located in the hierarchy, which are made of alabaster, stand out. In terms of openings to the exterior, the church only has three openings that correspond to the three access doors: one facing the north courtyard, another to the south courtyard, and a third one that acts as the main access located on the west side of the nave.

**Figure 1.** Interior of the church of San Juan del Hospital. Source: Own preparation.

## 3. Methods and procedure

### 3.1. Methodology

The methodology followed in this research for developing and validating the DT is as follows:

- Preparation of a DT with DesignBuilder v7.0.2.6 software starting from an HBIM model generated with Autodesk Revit 2023;
- Design of a building monitoring system. A monitoring system is designed to collect the necessary information for the evaluation of the building's situation and to define strategies for action;
- Preparation of climate files to allow simulations with the same weather conditions;
- Data will be collected from the monitoring system and introduced into the Digital Twin;
- Carrying out simulations and validating the results obtained by comparing the simulated and the real data obtained from the monitoring.

### 3.2. Preparation of the Digital Twin

The DT has been generated from a 3D geometry made with Autodesk Revit that belongs to the Master Plan of the Church of San Juan del Hospital. The starting point was a point cloud that allowed us to obtain accurate data on all the architectural elements (Figure 2).

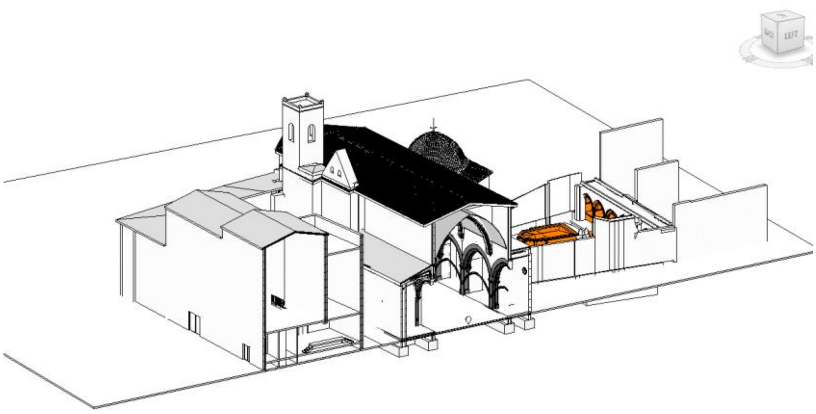

**Figure 2.** Point cloud scanning-based model. Source: own preparation

 

From the HBIM model, the geometry is exported to a .gbxml file in a format used for the exchange of information between building behaviour simulation programs. This .gbxml file is imported into DesignBuilder, where the quality of the imported geometry is evaluated, and the necessary adjustments are made. In the case of the church of San Juan del Hospital, it has been necessary to simplify geometries and adjust the communication between the different spaces of the model. At the same time, the surrounding buildings are virtually constructed so that the simulation of the building's behaviour considers the urban obstacles that condition sunlight and ventilation (Figure 3).

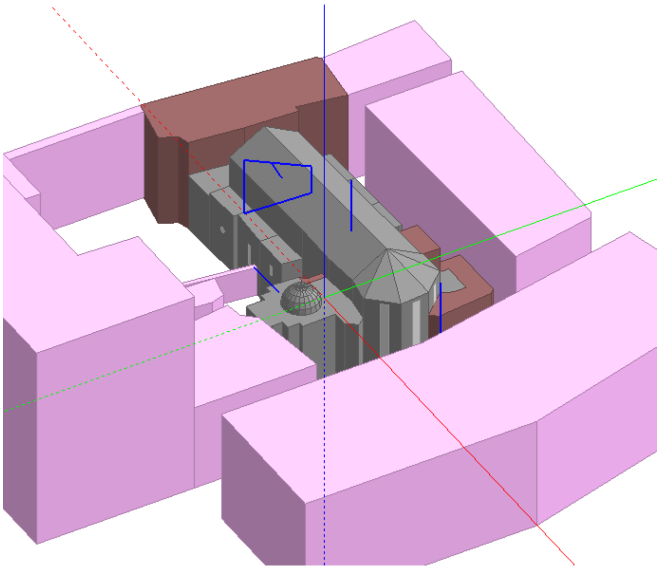

**Figure 3.** Calculation model with its environment. Source: own preparation

Among the parameters to be defined in the DT are the characteristics of the enclosures, construction materials, and joinery, which are obtained from the HBIM model and include the construction characteristics of the building. The church has the main windows located in the presbytery, which, as it is made of alabaster, has been configured with minimum solar gain.

In addition to the construction characteristics, the ventilation ratios to be used in the calculations must be defined. It should be noted that the air renewal capacity of the church is very limited, as its windows can't be opened. Only two doors on the sides of the church produce natural ventilation. Their opening schedule has been replicated in the model based on data provided by the church managers.

In the case of infiltration ventilation, as no in situ measurement of the real infiltration ventilation capacity of the church was available, simulations were carried out until the ppm and ºC data obtained were similar to reality. The result obtained is that the church renews air 0.067 air renewals per hour, a very low ventilation rate.

The heat generation values per installed device are set at 5W per $m^2$, a reduced value given the very low equipment and lighting load in the church and obtained from the equipment installed in the building.

The heat generation rate per individual is set at 0.90 (1.0 men, 0.85 women, and 0.75 children) while the activity is set at 'seated quiet' (108 W/person) because the activity carried out is sedentary and of low heat generation. These values are taken from the ASHRAE standard. The radiation emitted by the occupants is the only significant heat source for the model, apart from the outside temperature. Finally, the building has no HVAC equipment to condition the space, so the conditions depend entirely on the building, the climate, and the activity carried out.

On the other hand, it is necessary to introduce occupancy profiles (Figure 4) to calculate the influence of people on the behaviour of the building. To generate this information, a visitor count is carried out during the study period, defining a maximum capacity of 230 people, which is only reached during large celebrations such as weddings.

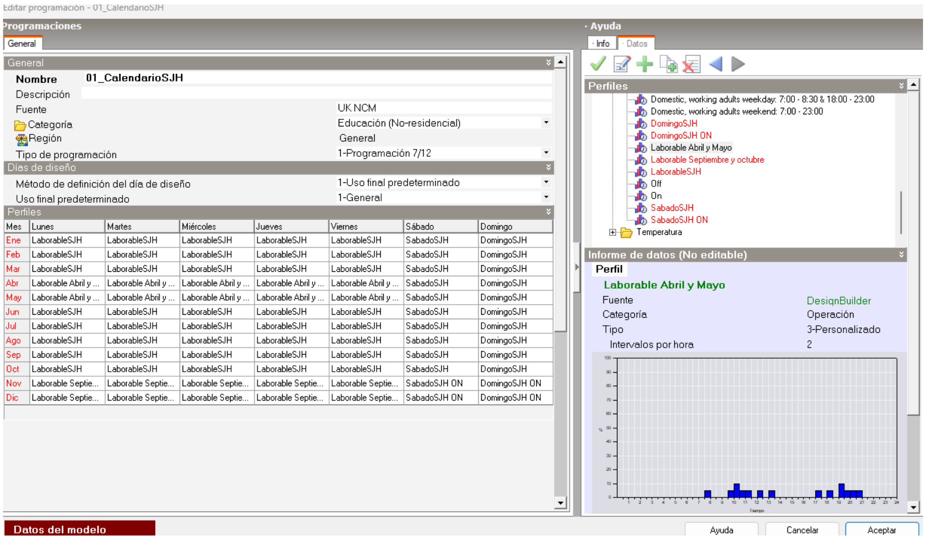


**Figure 4.** Occupation profile Schedule. Source: own preparation

### 3.3. Monitoring System Design

For collecting the data used in the DT generation process, a monitoring system is designed based on autonomous Testo 160 IAQ sensors installed in the church in different positions. The sensors are battery-powered and wireless and collect data on relative humidity (RH), indoor temperature, atmospheric pressure, and $CO_2$ concentration every 15 minutes. Calibration of these sensors is carried out periodically by means of a portable Testo 435-2. The accuracy of the measurements made with these sensors is shown in Table 1.

| | Model | Measuring Range | Accuracy |
|---|---|---|---|
| Humidity/temperature/$CO_2$ probe | Testo 435-2 | −20–+70 °C | ±0.3 °C |
| | | +10–+100% HR | ±2% HR |
| | | 0–+10,000 ppm $CO_2$ | ±75 ppm $CO_2$ |
| Humidity/temperature/$CO_2$ DataLogger | Testo 160 IAQ | 0–+50 °C | ±0.5 °C |
| | | 0–+100% HR | ±2% HR |
| | | 0–+5000 ppm $CO_2$ | ±50 ppm $CO_2$ |

**Table 1.** Accuracy of the instruments used for monitoring

During the study period, a total of 103,680 readings were taken for the above-mentioned parameters. An hourly analysis is carried out to understand the behaviour of the church, while in the more detailed studies, analyses were carried out every 15 minutes.

### 3.4. Preparation of climatic files

One of the most important activities in obtaining valid DT for designing strategies to ensure the conservation of heritage assets is the collection of quality data and, among them, the design of valid climate data files.

The calculation engine of the simulation tools uses climatic files to perform its calculations. In the case of the EnergyPlus 23.2 calculation engine used, the climate file, in .epw format, is generated with data obtained from the Spanish Meteorological Agency (AEMET – Valencia, Viveros) using the information collected by the meteorological station closest to the building during the study period.

 

### 3.5. Collecting data from the monitoring system and entering it into the digital twin

Given that the summer of 2023 has been the hottest since records have been kept, and given that temperature and RH inside the church have been very high, it was decided to use this calculation period to validate the DT. As can be seen in Figure 5, the temperature in the church rises steadily during the study period and does not reflect the variations generated outside. From the RH point of view, the RH varies but is not as pronounced as outside the building. The analysis of the results indicates that the thermal inertia of the building is very high, and the ventilation is totally insufficient.

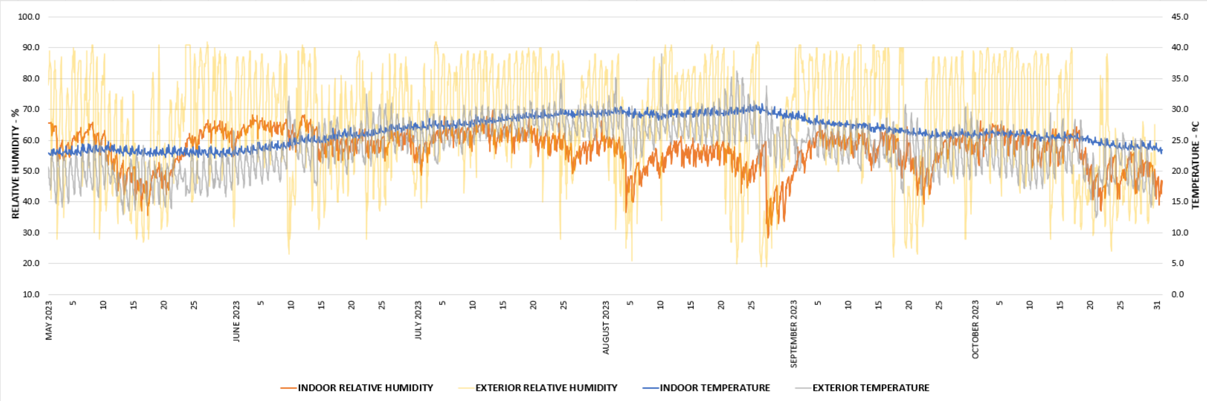


**Figure 5.** Monitoring of church behaviour and comparison with outdoor climatic conditions. Source: own preparation

From the point of view of $CO_2$ concentration, it can be stated that there is a direct relationship between church occupancy and the rises and falls of this monitored factor. As shown in Figure 6, the highest $CO_2$ concentrations occur during periods of high occupancy. In addition, it is also evident that the church has difficulty reducing concentration once it is empty of visitors.

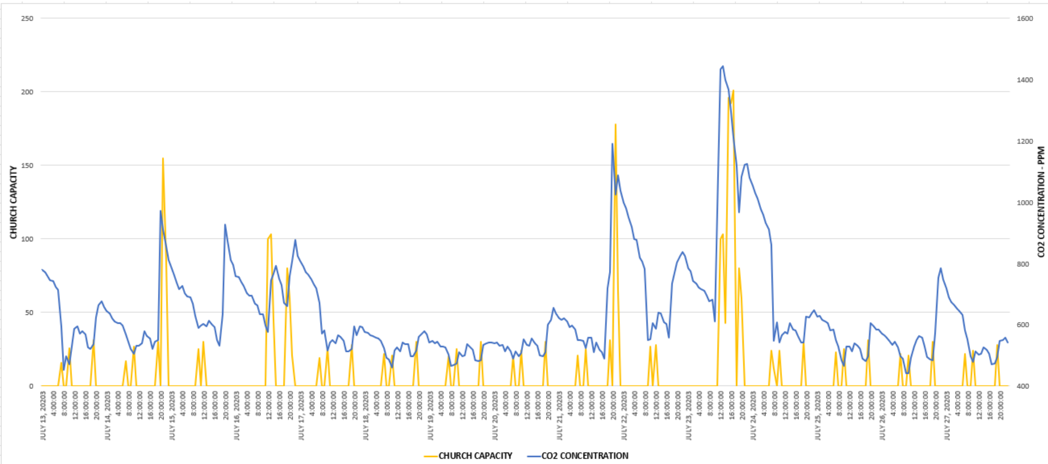


**Figure 6.** Comparison between gauging and $CO_2$ concentration. Source: own preparation

## 4. Results

The introduction of the climatic data corresponding to the study period and the readings taken from the monitoring system have allowed different simulations to be carried out in which the capacity and the lack of ventilation have been the most influential parameters in the validation process of the DT.

In this way, it has been possible to replicate the tendency of the church to stabilise the temperature variations that occur outside, and it exhibits an ascending pattern, with the maximum interior temperature reaching its maximum during the month of August. The temperature inside the church is above the maximum temperatures recorded outside from 1 May to 10 June, from 28 August to 26 September, and from 19 October to 30 October. During the study period, outdoor air temperatures in the city of Valencia ranged from 13 to 38 degrees Celsius, and temperatures inside the church ranged from 23 to 30 degrees Celsius. The internal temperature begins to drop at night, although this drop does not occur fast enough to guarantee a comfortable internal temperature at the beginning of the next day. At the beginning of the day, the energy released by the stone structure, the solar gain from the chancel windows, and the heat from visitors (to a lesser extent) cause the temperature to rise again, generally from an initial temperature higher than the previous day.

From the point of view of the $CO_2$ concentration inside the church, it is necessary to make a comparison with the number of visitors, as there is a direct relationship between the $CO_2$ concentration in the church and the number of visitors. As seen in Figure 6, the attendance of people for sightseeing tours or religious services generates an immediate increase in $CO_2$ concentration, with the church needing up to 20 h to recover to pre-activity levels in the highest cases. Comparing temperature and humidity with visitor capacity, the influx of people has a minimal effect on temperature, while RH increases slightly.

With these simulations, the validation of the DT is carried out in accordance with ASHRAE Guideline 14 for the calibration of building performance simulation models using monitoring data (ASHRAE Guideline 14-2014. Measurement of Energy, Demand, and Water Savings, 2014). This regulation was designed, among other things, to validate RH and temperature data, but in this new research, it was also used to calibrate $CO_2$ concentration.

In accordance with this standard, the normalised mean bias error (NMBE) and the coefficient of variation of the mean square error (CV(RMSE)) have been calculated hourly for each of the monitored parameters, all of them being below the limits set by the standard (Table 2). The limit for the normalised mean square error (NMBE) is 10%, and the coefficient of variation of the mean square error (CV(RMSE)) is 30% if simulated on an hourly basis.

| | **Limit** | **$CO_2$, ppm** | **Temperature, °C** | **RH, %** |
|---|---|---|---|---|
| Normalised Mean Bias Error (NMBE), % | ±10 | 9.32 | 8.58 | −8.76 |
| Coefficient of Variation of the Root Mean Square Error (CV(RMSE)), % | 30 | 15.30 | 9.89 | 25.87 |

**Table 2.** Summary of NMBE and RMSE according to ASHRAE 14**.**

In this way, 4320 hourly data taken in situ for each of the parameters under monitoring could be compared with their equivalent in the DT, exhibiting the deviations defined, e.g., in Figure 7 for dry bulb temperatures and RH and Figure 8 for ppm of $CO_2$.

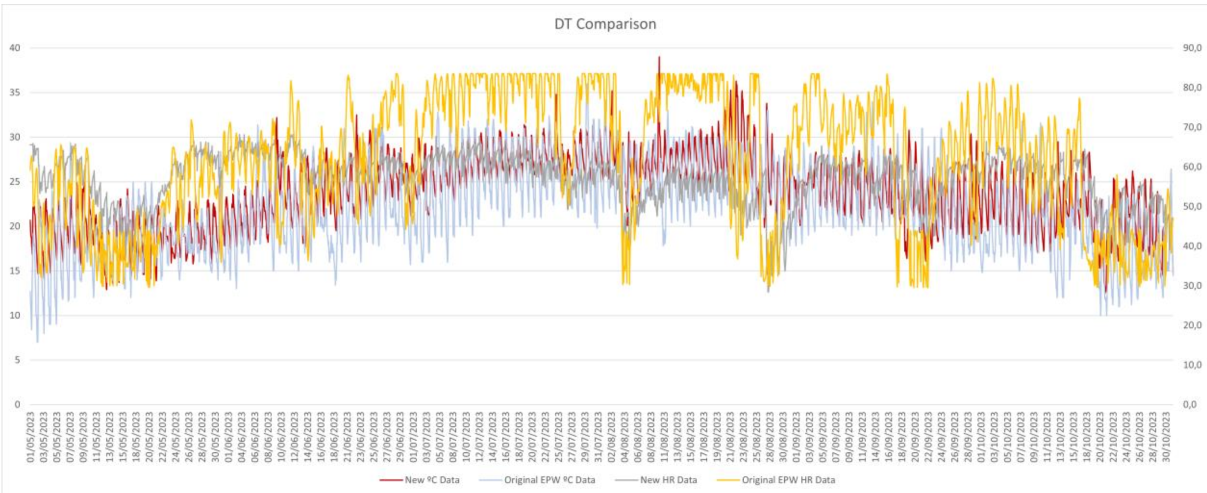


**Figure 7.** Deviation of the DT dry bulb temperature and HR results from real values. Source: own preparation

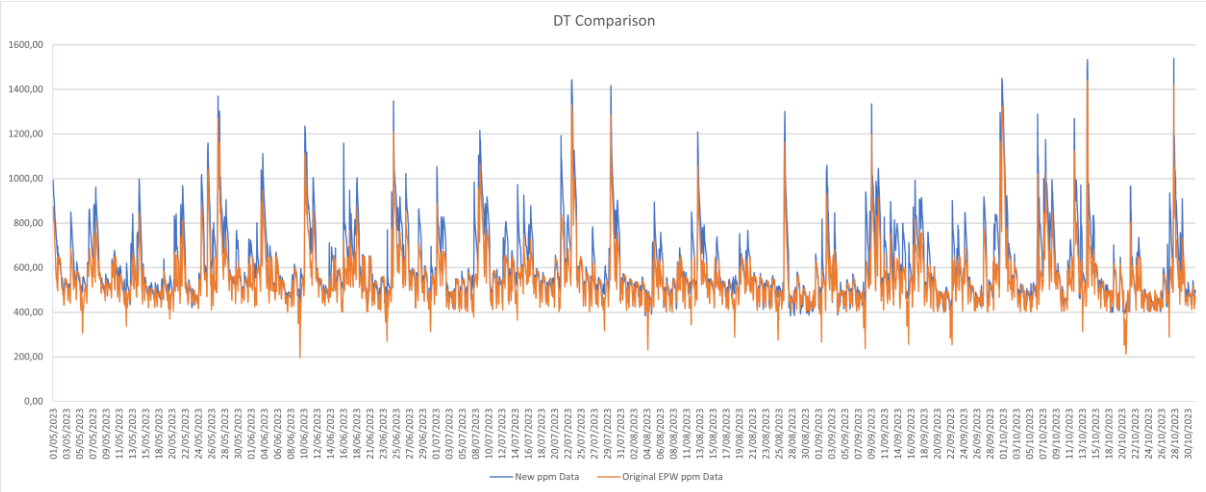


**Figure 8.** Deviation of the DT ppm of $CO_2$ results from real values. Source: own preparation

## 5. Discussion of Results

Although the DT successfully simulates within the minimum parameters set by ASHRAE 14 for hourly simulations, there is a larger deviation to be studied in the case of RH. This is due to the very low ventilation values available to the church. Performing ventilation simulations with such low hourly ventilation values for the church makes it difficult to adjust, indicating the need for more accurate testing of the amount of air infiltrating the building.

Similarly, the very high $CO_2$ accumulations are also a direct consequence of the low ventilation. Crowded events produce increases in ppm levels that do not have time to dissipate until the next event.

From the point of view of temperature, the results confirm the importance of thermal inertia and the need for ventilation in a climate such as that of the city of Valencia. The temperature builds up as outside temperatures rise and cannot be reduced during the night period when temperatures are lower.

## 6. Conclusions

This research confirms the feasibility of exchanging information between different platforms to achieve validated DT. Starting from point clouds, it is possible to generate geometries with BIM programs that are later exported to simulation programs to perform simulations that support the decision-making process in building maintenance. Simulation tools make it possible to detect problems in the operation of buildings and to define strategies to ensure their conservation.

The introduction of reliable data from weather stations and installed sensors has made it possible to replicate the behaviour of the real building with, in some cases, minimal deviation percentages.

In the case of the San Juan del Hospital church, it has been possible to replicate the operation of the building in terms of temperature, humidity, and $CO_2$ concentration, detecting that the lack of ventilation is the key factor in the generation of the indoor conditions detected during the monitoring. In the case of high temperatures, the lack of ventilation has made it impossible to reduce the temperature during the night period. At the same time, the serious problem generated by the high $CO_2$ concentrations originates in the visitors and the lack of ventilation necessary to renew the indoor environment.

To conclude, it can be stated that new technologies can play a very important role in the process of defining heritage conservation strategies and verifying their viability.

## 7. Acknowledgements

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# Complex Spaces in HBIM Models: Volumetric Visualization for a Data Insertion

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***Abstract***

*In recent years, digital technologies are increasingly being used to document and monitor heritage buildings, acting as decision support tools for technicians and managers working in these buildings. Among the most widely used tools, HBIM (Heritage Building Information Modeling) as a methodology for virtual documentation of information on heritage buildings and their life cycle, and sensors as tools for recording environmental data of extreme relevance for preventive conservation, maintenance and visitor management in heritage buildings stand out. This paper presents a 3D modelling process using BIM software, where the model allows a more accurate measurement of the volume of interior spaces in rooms bounded by complex ceilings. This process also makes it possible to visualise the spatial volume in 3D as well as to attribute informative parameters to it. For this purpose, the vaults of the church of the Real Colegio-Seminario del Patriarca in Valencia, Spain, have been used as a case study.*

***Keywords:*** *HBIM, 3D Model, Revit, Spatial Volume, Environmental Sensors, Dynamo, Preventive Conservation, Maintenance, Cultural Heritage Management.*

## 1. Introduction

The development of different methodologies for the integration between the monitoring data of heritage buildings collected by sensors and HBIM models is growing, as can be seen in Rolim et al. (2024). As important as this integration is the definition of how they will be visualised, i.e. how the collected information will be visualised within the HBIM software itself where the 3D modelling of the building was done, or how these data will be visualised in another external platform when exported. Studies by Banfi et al. (2017); O'Shea & Murphy (2020); Nagy & Ashraf (2021); Ni et al. (2021); Hou et al. (2022); Meoni et al. (2022); Mitro et al. (2022); Machete et al. (2023); Moyano et al. (2023) show some of the different possibilities of visualisation of sensor data integrated into HBIM models.

The definition of the level of semantic and geometric information that the 3D model will have is highly relevant, as is the consideration of its final objective and its preparation for possible exportation to other platforms that can facilitate its visualisation and analysis of the integrated data, such as scenario simulation, GIS (Geographic Information System) software and DesignBuilder® simulation software. These integrated tools can assist technicians and managers in the decision-making process related to preventive conservation, maintenance, and management of public use. They can also be applied to an isolated building or a group of them.

Regarding the levels of semantic and geometric information that the 3D model must have, Escudero (2021) discusses the different strategies that can be taken when developing the geometric model and the election of its Level of Development - LOD, which is formed by a set of different sub-levels. Some relevant concepts on this subject are: the Level of Detail – LoD (Biljecki et al., 2016; Historic England, 2017; Freitas et al., 2023); the Level of Information – LoI (Garcia-Gago et al., 2022); the Grade of Generation – GoG (Banfi, 2017); the Indoor/Outdoor Level of Detail – ILoD/OLoD (Tang et al., 2018); the Level of Geometry – LOG (Brumana et al., 2018, 2022); the Level of Knowledge – LOK (Castellano-Román & Pinto-Puerto, 2019); and the Level of Development – LOD (Talaverano et al., 2021).

In this context, this work has been devoted to developing a 3D modelling process where it is possible to visualise and generate more accurate data about the internal volumes of the environments of heritage buildings with complex roof shapes. From this process, it is possible to add informative parameters to this volume that can be extrapolated to GIS software.

### 2. Aims and Objective

The integration between environmental sensor data and the HBIM methodology to monitor the state of conservation of heritage buildings, in addition to considering the building's constructive structure and internal elements, whether or not they are integrated into its structure, such as frescoes and paintings, must also consider its public use and spatial elements such as rooms. With that, it is necessary to identify the environmental conditions of these rooms and analyse data on temperature, humidity, air quality and load-bearing capacity. The analysis of these data is essential for monitoring the preventive conservation conditions of the building and the safety and comfort of its users. In order for the analysis and management of environmental data to be more efficient and accurate, it is necessary that the environmental data be directly associated with its corresponding inner space and not with its built elements.

The Autodesk® Revit 2024 software presents data on the areas and volumes of rooms linked to a family of spatial elements. These data are calculated semi-automatically, requiring the insertion of the height limit to report the volume data. The vertical limits can be realised by the roof, floor or ceiling tools. Already, the horizontal room boundaries are detected automatically, being delimited by walls and, when necessary, by the room separation tool.

Dealing specifically with vertical delineation, Autodesk® Revit 2024 software performs well when dealing with relatively simple geometric shapes, such as pitched roofs, domes and simple vaults. But when it is bounded by more complex geometric shapes, such as groined vaults, there is where the problems start.

The 'room' tool does not obey the vertical delimitation of some complex shapes, generating errors in the measurement of volume data and in its 2D visualisation. Furthermore, these errors prevent the volumes of the environments from being recognised in Autodesk® Dynamo, making it impossible to visualise and assign parameters to the volume generated by the plugin.

Considering this, the aim of this work is to identify a 3D modelling process where the room tool of the Autodesk® Revit software recognises the vertical delimitations in environments with complex ceilings and thus can generate more accurate data on the spatial volume of the room and allows its linkage to the Autodesk® Dynamo plugin to attribute the necessary parameters for the analysis and management of its environmental data. For this purpose, the vaults of the Church of the Royal College-Seminary of Corpus Christi in the city of Valencia, Spain, have been used as a case study.

The Real Colegio-Seminario de Corpus Christi de Valencia, commonly known as the Colegio del Patriarca, occupies an entire block in the heart of the district of Ciutat Vella, the old quarter of the city of Valencia, Spain (Figure 1). It was built between 1586 and 1615, during the Counter-Reformation period, with the aim of training priests according to the guidelines emanating from the Council of Trent. The building stands out in the Spanish panorama for being one of the few religious buildings that have preserved in its entirety both its fabric and its belongings. The church, which stands out for its bell tower (Figure 2a), occupies the southwest corner of the college complex, which has its rooms distributed around a central cloister. The internal spaces of the church are vertically limited by groin vaults reinforced by ribs in each section, which in turn are supported by the walls that separate these spaces (Figures 2b and 2c).

This work is part of the HBIM-SIG-Tourism research project of the Universitat Politècnica de València, where the whole of the Colegio del Patriarca is being modelled, and sensors for environmental monitoring have been installed in some of its rooms in order to carry out the environmental analysis and integrate them into the HBIM model and subsequently extrapolate it to a GIS platform.

**Figure 1.** Location of the Real Colegio-Seminario de Corpus Christi in the historic centre of Valencia. Source: Own elaboration from images generated in Google Earth (2024).

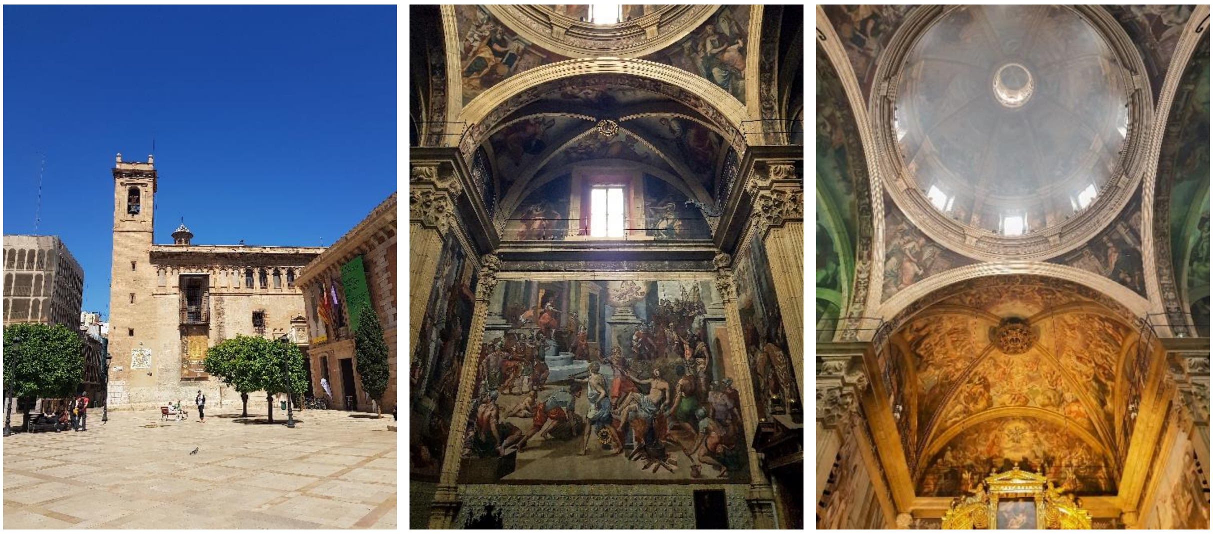

**Figure 2.** a. View of *Colegio del Patriarca* from the Plaza del Colegio del Patriarca (2024); b. Vault of the transept nave-gospel side (2023); Vault of the Altar-Mor (2024). Source: Author.

## 3. Methods and procedure

The point cloud of the *Colegio del Patriarca* taken by PhD. Junshan Liu, which was made available by the researchers involved in the HBIM-SIG-Tourism project, was used for this study. From the point cloud, the development of a 3D model of the *Colegio del Patriarca* was started using Autodesk® Revit 2024 (Figure 3).

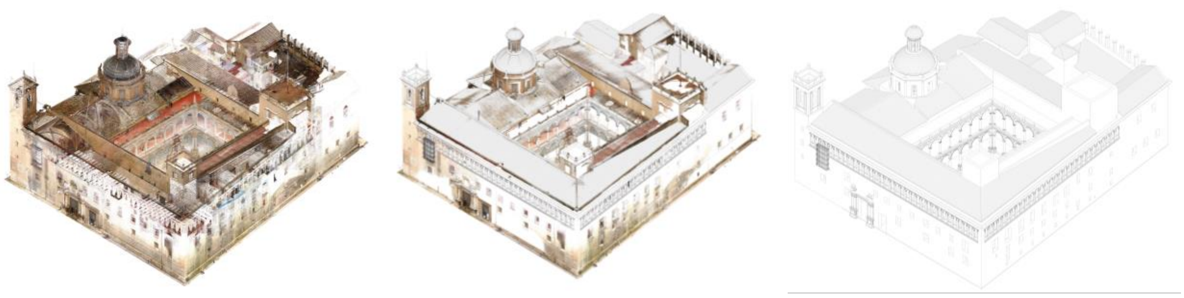

**Figure 3.** Point cloud of Colegio del Patriarca; Point cloud superimposed on the 3D model; 3D model of Colegio del Patriarca under development. Source: Own elaboration from the point cloud taken in 2023 by PhD Junshan Liu.

Considering that one of the objectives of the 3D model developed in the project is to enable the visual representation of the environmental data collected by the sensors installed in the building, an efficient way was sought to insert and visualise the information collected by the sensors directly in the software in which it was being modelled. To make the incorporation of parameters and the materialisation of the 3D volume in Autodesk® Revit 2024 feasible, the Autodesk® Dynamo plugin was used as an auxiliary tool.

### 3.1. Tests carried out

#### *3.1.1. First Modelling Test*

In order to model the ribbed vaulting infilling masonry, the mass tool was used due to its ease of modelling and its plasticity, which allows it to get very close to the original representation of the point cloud. At the moment of generating a thickness for the masonry using the mass layer, errors occurred in the extrusion of its curvature, deforming the final volume of the masonry (Figure 4).

 

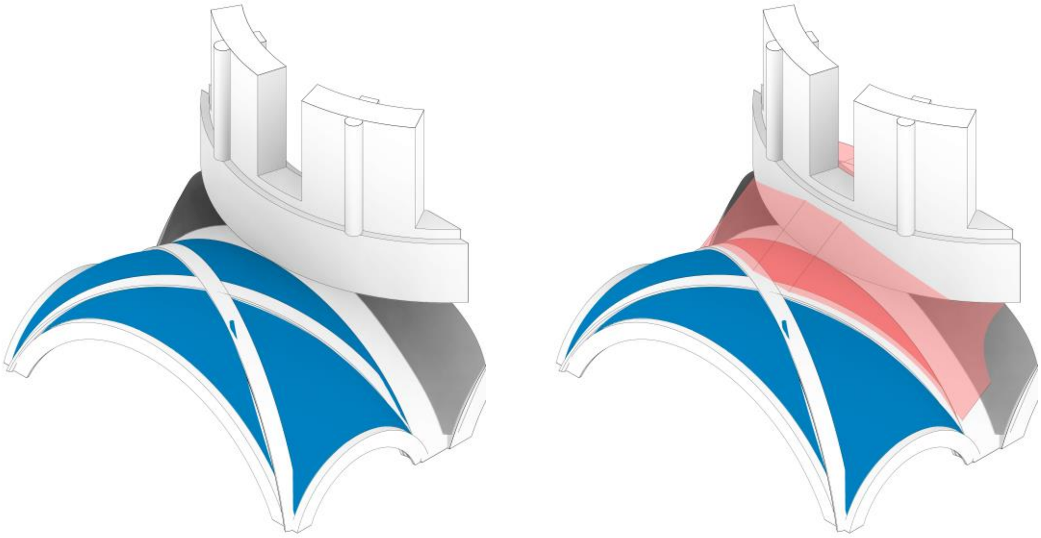

Figure 4. In blue - Modelling of the plementeries with the dough tool; In red - Error in the extrusion of the modelled plementeries. Source: Own elaboration (2024).

Another problem encountered was that the modelled infillings did not vertically limit the volume generated by the 'room' tool of the Autodesk® Revit 2024 software. The volume was only visible so far through the 2D sections of the model (Figure 5).

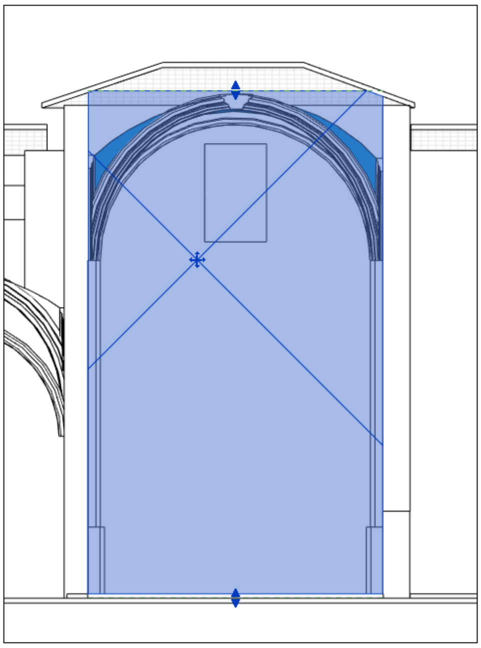

**Figure 5.** Volume of a room without vertical limitation visualised in a 2D section of Autodesk® Revit 2024. Source: Own elaboration (2024).

Subsequently, it has been identified that the vertical limitation for volumes would only be possible if the massing was modelled as curtain wall, roof, ceiling, roofing, or floor families. An attempt has been made to convert the modelled mass layer into one of these elements, where a third problem was identified: the impossibility of converting the mass layer into one of the above volume-limiting elements, with the exception of the curtain wall. By converting the modelled mass layer into a curtain wall, it was possible to limit the vertical volumes, but there were still errors in the connections between the infillings and the walls (Figure 6).

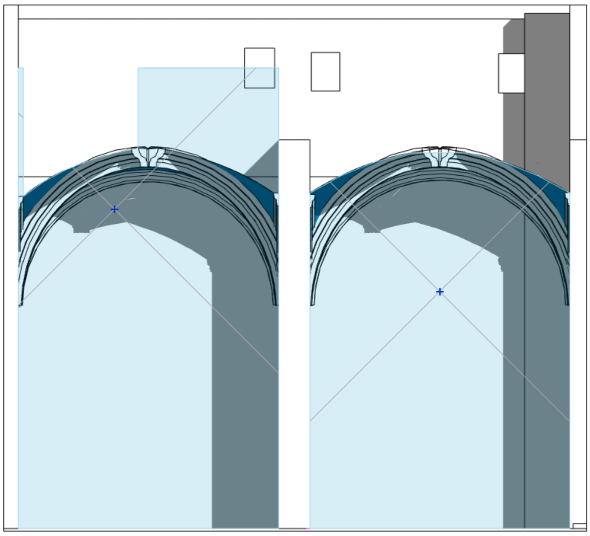

**Figure 6.** Volumes of two rooms constrained with the 'curtain wall' tool visualised in a 2D section of Autodesk® Revit 2024, (left) error in the vertical constraint, (right) vertical constraint corrected manually. Source: Own elaboration (2024).

In addition, the adoption of curtain walls as a solution was not satisfactory, as it required detailed manual adjustments to make it possible to avoid boundary errors, not meeting our expectations of a more automated solution.

*3.1.2. 3D volume visualisation*

The volume generated by the 'room' tool in the previous process was only visible in 2D sections of the model (Figures 5 and 6). Therefore, in parallel to the modelling of the vault infillings, tests were carried out to generate the 3D volume using a routine implemented in the Autodesk® Dynamo plugin. From the generated 3D volumes, it was possible to identify the modelling errors and correct them, but the volumes produced errors that did not allow the attribution of their materialisation for parameter attribution, only their visualisation (Figure 7).

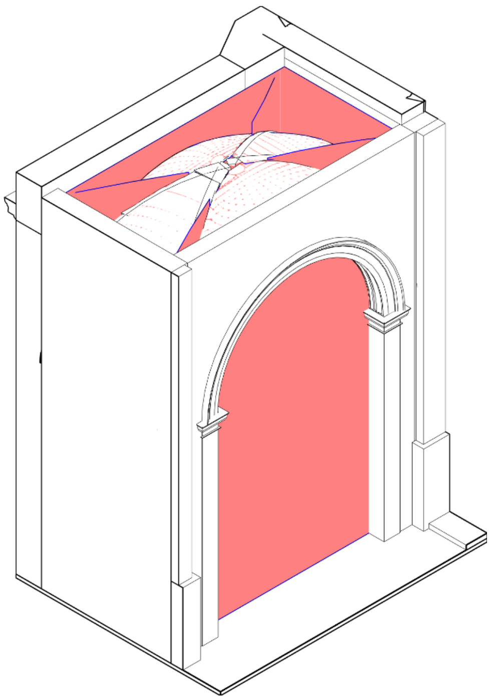

**Figure 7.** Visualisation of the volume generated by the 'room' tool using the Autodesk® Dynamo plugin. Source: Own elaboration (2024).

 

### *3.1.3. Second modelling test*

Considering that the first solution was not satisfactory, the modelling of the infillings was started using the ‘cover’ family of the software. This tool, despite limiting the volumes vertically, reduced the accuracy of the model, as it made it difficult to model the original deformations of the plementeries, visible in the point cloud.

The modelling of the infillings was started separately, using the tools for creating volumes by extrusion, sweeping, revolution and subtraction of voids. The resulting infillings continued to generate errors in the connections between the plements and with the walls, limiting the vertical volumes in parts, as was the case with the masses converted into curtain walls. An attempt was, therefore, made to model the whole of the plementeria as a single element. This attempt has led to a large error of divergence between the original infillings of the building, identified in the point cloud, and the ones generated in the model. In addition, it still did not limit the vertical volumes, giving worse results than the previous solution.

With the worsening of the result, it was possible to work again with the infillings separately, where it was identified that, by means of the union of only two infillings facing each other, it was possible to limit the volume. This way of modelling presented only small errors in the connections with the walls, which were not completely orthogonal, and in the central connection between the infillings, where the keystone of the vault is located. To solve the first problem, the infillings were extended to the central axis of the walls, and to solve the second, a small central circumference was placed so that the points that conceived the infillings did not touch each other, thus achieving a satisfactory result (Figure 8).

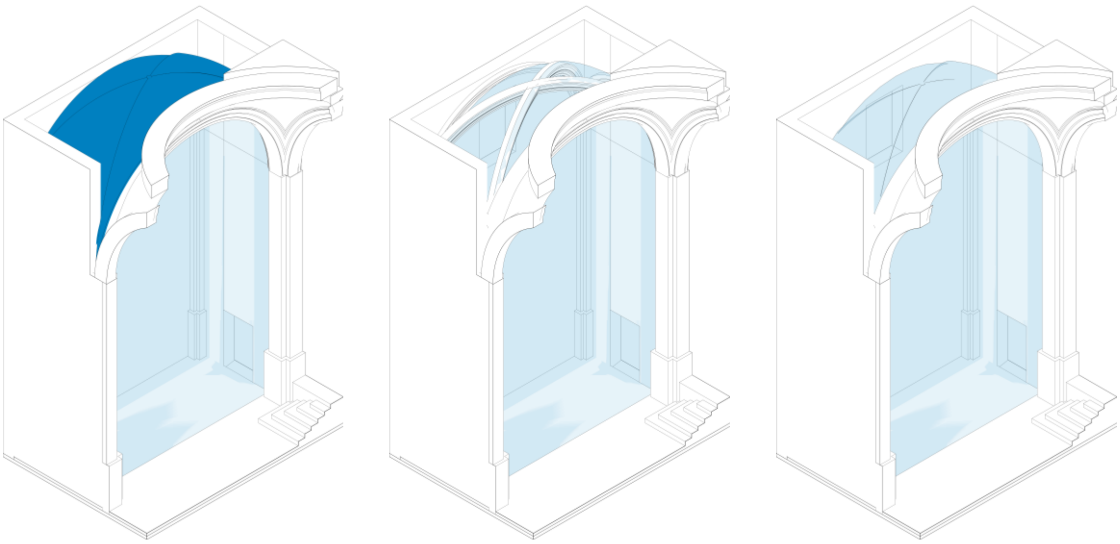

Figure 8. 3D volume vertically bounded by the de Autodesk® Revit 2024 "roof" tool visible by the Autodesk® plugin Dynamo. Source: Own elaboration (2024).

### *3.1.4. Attribution of parameters*

Through tests with the different geometric shapes, it was identified that when complex volumes were generated, they were not visible on the Autodesk® Dynamo plugin screen, only on the Autodesk® Revit software screen, and therefore it was not possible to attribute parameters to them. Therefore, we tried to change the ‘mass’ category in which the volumes were being generated, looking for another category of family where we could materialise it in 3D and attribute informative parameters to it. The successful category was that of ‘piece’.

## 4. Results

From the process presented, it was possible to generate spatial volumes in environments with complex ceilings that allow their visualisation and the attribution of informative parameters within the software in which the building has been modelled (Figure 9).

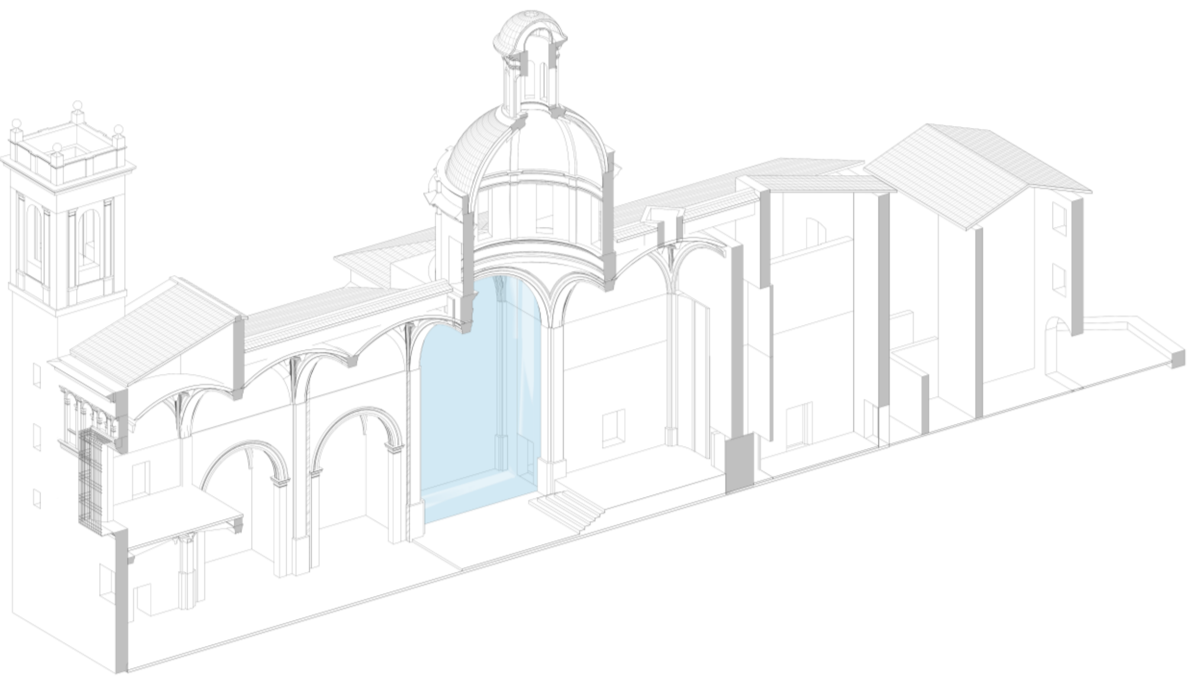

**Figure 9.** 3D volume visualised inside a 3D section of the Colegio del Patriarca church. Source: Own elaboration (2024).

The information incorporated in the volumes can be extrapolated to GIS platforms by means of the IFC format and is also recognised by other plugins compatible with Autodesk® Revit software, such as DiRoots®, allowing the use of filters and comparative analysis between parameters using colour ranges.

## 5. Conclusions

From the Autodesk® Revit 2024 software, using the 'room' tool, it is possible to accurately calculate its area, as well as to calculate its volume. But, unlike the area that is generated automatically, the volume needs manual adjustments. The demilitation of the height of room volumes works very well for simple shapes such as pitched roofs, domes or simple vaults, but when it comes to more complex shapes such as ribbed vaults, measurement errors occur.

The solution adopted allows more precise volumetric data to be generated, enabling a more accurate environmental analysis that is closer to the real one. The process also facilitates compatibility with plugins and export to GIS platforms of the integrated parameters and 3D volumes, allowing them to be visualised by colour range, generating different visualisation maps according to the parameter used, facilitating the visual analysis of all the building's environments, and also allowing analysis in conjunction with other buildings.

Taking as a reference the ILoD presented by Tang et al. (2018) and the current level of detail of the 3D model, an ILoD2 level would fit. But considering the final objective of this model, which is the environmental analysis closer to the real one and dedicated to the improvement of the preventive conservation and maintenance of heritage buildings and the comfort and safety of its users, it is possible that the level of detail increases up to ILoD4 level.

The result of the process implemented in this work may help future stakeholders in the integration of environmental sensor data with HBIM models, allowing a more accurate and closer analysis of the real environment, as well as facilitating the compatibility of the model with plugins and other external tools such as GIS or simulation software.

## 6. Acknowledgments

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# GIS and HBIM for tourism management: a multiscale challenge

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***Abstract***

*Historic cities present complex management challenges, requiring strategies that balance cultural preservation with planning and enhancement efforts, particularly in the context of tourism activities. Digital twins, which integrate various data sources to create spatial databases, offer a promising solution to this challenge, enabling comprehensive views of urban environments and historical structures. Among the key tools employed in this digital transformation are Historic Building Information Modelling (HBIM) and Geographic Information Systems (GIS). HBIM provides detailed representations of historical structures, while GIS offers spatial analysis tools for organizing and visualizing data at larger scales, crucial for tourist management. The integration of these tools facilitates informed decision-making processes and supports the development of smart tourist cities. However, to achieve this, it is first necessary to define the levels of information that will be addressed for both. In this document, various element levels are proposed considering different scales, along with the levels of geometric and semantic complexity they may have. Additionally, it also explores how these data can be represented within a GIS platform.*

***Keywords:*** *GIS, HBIM, Tourism, Scale, Digital Database.*

## 1. Introduction

Cities, and specifically historic ones, encompass multiple layers of information; because of that, they require complex management strategies mostly for the preservation of their cultural values, while also facilitating their planning and enhancement (Cecchini, 2019; Tamborrino & Rinaudo, 2015). In these areas, the management extends beyond buildings and urban elements to encompass specific urban dynamics, such as tourism activities. For this, it is necessary to find a balance between safeguarding the heritage and local community's well-being while ensuring optimal visitor experiences (Viñals et al., 2017).

One emerging solution to address this challenge is the concept of digital twins to generate spatial databases. These digital representations integrate various data sources, offering a comprehensive view of the urban environment and its components, and facilitating their analysis, management, and visualization (Garcia-Valldecabres et al., 2023; Lehner & Dorffner, 2020; Ródenas-López et al., 2023). One of the benefits about this dataset is the possibility to present reality and information at different scales, representing the entire urban landscape, and, at the same time, being able to detail elements such as historic buildings (Cecchini, 2019; Del Curto et al., 2019).

To achieve this digital transformation, Historic Building Information Modelling (HBIM) and Geographic Information Systems (GIS) are widely employed; the first one details historical structures representations providing information on materials, structure, and more relevant information; meanwhile the second offers spatial analysis tools to organize and visualize data in larger scales, considering more than one element and their connection with their surrounding area (Del Curto et al., 2019; Ramírez Eudave & Ferreira, 2021); these characteristics are important from a tourist management perspective.

The integration between these tools is becoming increasingly relevant to achieve more effective and informed decision-making processes in the management of historical urban areas (Álvarez et al., 2018; Cecchini, 2019; Garcia-Valldecabres et al., 2023; Zhu et al., 2019; Zhu & Wu, 2022). At the same time, it is an option to achieve smart tourist cities; however, there is still a gap between city-scale analysis and building-scale information in this area (Zubiaga et al., 2019), posing a challenge in effectively work with the distinct formats inherent to each digital environment (Cecchini, 2019).

In summary, managing historic cities involves complex strategies to preserve cultural values while accommodating planning and enhancement efforts. Digital twins offer a promising solution, enabling comprehensive spatial databases that provide insights into urban environments and multiple historical structures. Integrating GIS and HBIM facilitates informed decision-making processes and an efficient tourist management. However, bridging the gap between different scales of information and digital formats remains a challenge, hindering efforts towards achieving smart tourist cities.

Therefore, the central objective of this paper is to identify the data required from HBIM and GIS models, aiming to efficiently manage and visualize these buildings from a tourism management perspective.

To achieve this, the following steps were considered: identify the information required for inclusion in both HBIM and GIS, determine the most adequate level of detail and information for HBIM and GIS models, establish how the information will be represented and visualized, and, finally, exemplificate the process.

## 2. Procedure and results

As mentioned earlier, the first step is to identify the information required for inclusion in both BIM and GIS, taking into account the levels of detail or information needed for the analysis to be performed. This information will be part of the geodatabase, which comprises two types of data: geometric, geographic or spatial data, and non-geometric, alphanumeric or attribute data.

In the case of GIS, the information required for tourism analysis typically includes traditional data layers such as roads, buildings, vegetation, land cover, terrain, among others, along with thematic layers like hotels, restaurants, monuments, viewpoints, event areas, and more (Jovanović & Njeguš, 2008; Pühretmair & Wöß, 2001; Sabou, 2015). In both cases, these data comprise geometric information, such as lines, points, polygons, or raster images, which contain non-geometric attributes and geographic information, characteristic of GIS environments.

In the case of HBIM, the geometric components comprised of 3D models, commonly parametric, which contain non-geometric information, can be similarly considered. This information may refer to data related to geometry, such as area or volume; construction details, such as the construction date or number of restorations; its use, such as the type of equipment or number of spaces; structure and construction method, such as the type of material or its structural load; and performance, such as temperature or lighting, among many others. Additionally, in HBIM models, it is possible to consider extra layers, such as the sources of information that allowed the model to be created, whether point clouds or plans, as well as linked documents, such as technical specifications, dossiers, or the management layers generated based on the model (Khan et al., 2022).

Although the information that can be included in an HBIM model is extensive, for using the model for tourism management, the public use of the building must be considered. Therefore, in addition to the normally considered components, attention must be paid to spatial elements, such as rooms. Rooms should be seen as key elements to include relevant information that allows for proper management of people. For example, if temperature or load capacity data for a room is available, it is crucial that this information is directly associated with this space and not with its walls or floors, thus ensuring more efficient and accurate space management. On the other hand, it is also necessary to consider the visualization component concerning the model, especially when various buildings are to be handled in the GIS environment. Under this premise, the building envelopes or sectioned floors should also be considered as elements to be visualized, including relevant data regarding tourism management. Finally, it is also important to consider commonly smaller-scale elements, that is, heritage assets such as paintings, relics, architectural elements, or others, which are often the elements of interest for tourists.

This contrast between exterior and interior elements, at macro or micro scales, which must be visualized at different levels, leads to considering the levels of detail, development, information, or knowledge that the elements can adopt, especially when they must respond to two different environments, such as HBIM and GIS. This degree of information -whether geometric or non-geometric- included in an element has been widely analyzed by various authors (Biljecki, 2017), as well as the complexity involved in harmonizing not only the levels of detail but also the digital formats of both environments (Sani et al., 2019; Zhu et al., 2019; Zhu & Wu, 2022).

Although determining a compatible level of detail between HBIM and GIS is beyond the scope of this research, it is possible to mention the different levels of detail according to each environment that may be useful for tourism management. For this, the levels of detail proposed by Tang et al. (2018) differentiating the exterior (OLOD) and interior (ILOD); and those studied by Biljecki (2017) and Biljecki et al. (2015) considering the CityGML standards for GIS environments; as well as the levels of development (LoD) proposed by BIMForum (2023) for HBIM elements in IFC format will be considered.

Regarding the information to be included in each element, the information proposed by Viñals et al. (2017) in their sheets for sustainable heritage tourism management will be considered for buildings and heritage elements. This includes information such as the typology of the element, year of construction/creation, state of conservation, intrinsic values, recognition, among many others. Considering the work of Salvador García et al. (2020), the itineraries between valuable elements inside the buildings, observation points to consider, among others, can also be taken into account. Likewise, the load capacity can be considered as information to be incorporated into the room elements. In rooms, qualitative data such as the name of the space, the degree of enclosure, accessibility regarding the degree of visitability, among others, can also be considered; quantitative data such as volume, interior temperature, CO2 levels, among others, can also be considered, with the latter usually obtained through sensors.

At the urban context level, information about the roads or public spaces surrounding the buildings can be included. This information can help determine the number of people circulating in the vicinity, the physical characteristics of the streets (Orozco Carpio et al., 2024), the most walkable areas (Bassiri Abyaneh et al., 2021), places suitable for hosting tourist groups (Orozco Carpio et al., 2023), as well as proposed tourist routes according to the presence of landmarks, street length, historical value, among others (Vicente-Gilabert et al., 2022). At the urban level but on a pedestrian scale, the focus can also be on urban furniture or other urban elements, considering their importance, attractiveness, comfort, protection, among others (Gehl, 2013).

These data, organized according to their scale of visualization, along with their levels of detail and contained information, can be found in Table 1.

**Table 1.** Potential data to be included in GIS for tourism management

| **Element** | **Origin** | **Level of detail** | **Quantitative data** | **Qualitative data** | **External data** |
|---|---|---|---|---|---|
| Heritage element (furniture, carved facades, paintings, others) | HBIM | LOD1-LOD5, LoD100, LoD500 | Dimensions, volume … | Age, state of conservation, threats, intrinsic value, material, social recognition … | Pictures, bibliography, records … |
| Rooms | HBIM | ILOD1 LoD100, LoD500 | Usable area, volume, carrying capacity, comfort and safety data (temperature, noise levels, levels of CO2, humidity, air quality, others … | Name, type of lighting, level of enclosure (enclosed, open, semi-open), level of access (visitable, non-visitable, private) … | Pictures, records, plans, historic plans, bibliography … |
| Building | HBIM | OLOD3, LoD100, LoD200, LoD500 | Surface area, height, total carrying capacity … | Typology, age, conservation status, threats, intrinsic value, social recognition, ownership … | Pictures, records, plans, historic plans, bibliography … |
| Urban element (urban furniture, vegetation, street art, others) | GIS/ HBIM | LOD1-LOD5, LoD100, LoD500 | Dimensions … | Presence, level of comfort, degree of protection provided (shade, coverage), delight … | Pictures … |
| Streets | GIS | LOD0, LOD1 | Length, ratio and weight (by street), betweenness, closeness … | Walkability, age, streetscape characteristics, historical value, security perception, type of circulation … | Tour routes, meet points, urban plans, pictures, records, events … |
| Urban buildings context | GIS | OLOD1 | Height, number of floors, others | Age, ground floor use, active facade, type of commerce, conservation status … | Cartographic bases, topography, protected environments, borders … |

Once the required information has been determined, it is possible to define the type of representation according to the need and level of detail desired for visualization. Both the chosen format and the type of model will greatly influence the fluency and comprehension of the GIS. In this case, HBIM models of buildings generated in Revit were used and introduced into ArcGIS Pro in IFC format (Figure 1); this format, compared to others such as OBJ, allows for accurate georeferencing based on the coordinates entered in Revit. Additionally, the data schema and entity division in the format enable parts of the buildings, such as rooms or heritage elements, to be observed and analysed individually (Figures 2 and 3). It is important to mention that GIS platforms easily allow for the visualization of semantic data and external data, such as photographs, through pop-ups.

While the IFC format is commonly studied for integrating HBIM elements into GIS, other formats and methods are not ruled out, such as RVT formats or introducing 3D elements such as mesh models or even point clouds, and linking data directly to them.

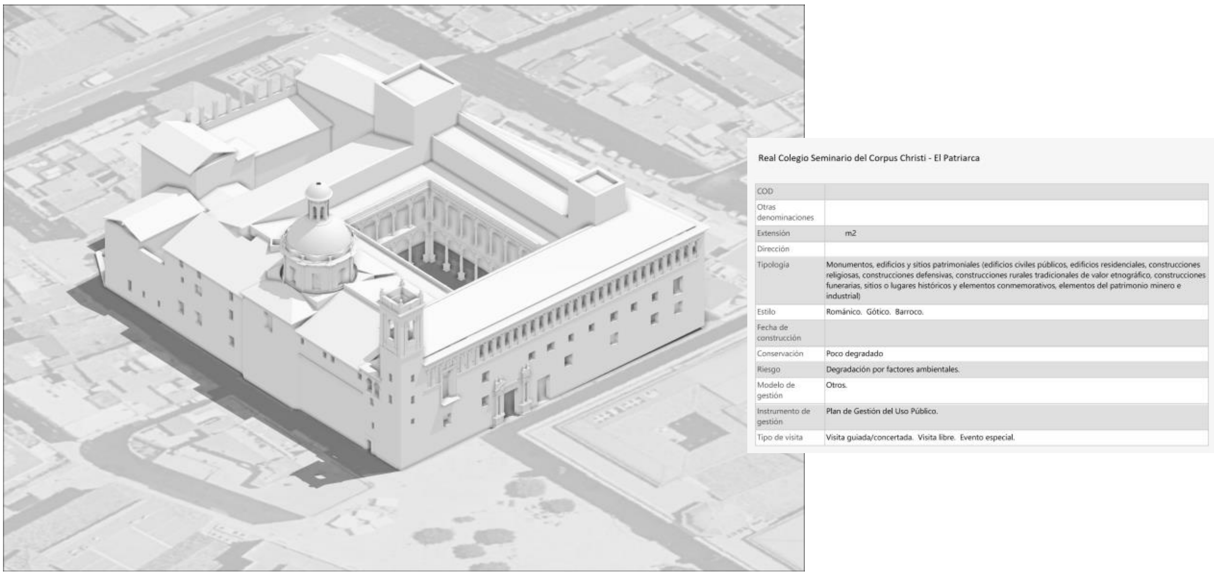


**Figure 1.** Example of an HBIM model of a building along with its data sheet in ArcGIS. OLOD3, LoD500.
Source: Own elaboration.


**Figure 2.** Example of an HBIM model highlighting a room along with its data sheet in ArcGIS. ILOD1, LoD500.
Source: Own elaboration.


**Figure 3.** Example of an HBIM model highlighting a dome as a heritage element along with its data sheet in ArcGIS. LOD3, LoD500. Source: Own elaboration.

When discussing the visualization of elements for urban scales generated in GIS, various methods can be mentioned to include this information regarding the immediate context, such as elements in CityGML, LAZ, KML formats, among others; still, one of the most commonly used ways to achieve an OLOD1 environment is through elements in SHP format, typically obtained from cadastral databases, plus height data that allows for extrusion in three dimensions. In addition to visualizing their height, it is also possible to graphically display much of the data mentioned above, either by introducing information to these volumes or by including more external data in the form of points, lines, or polygons that can be visualized in three dimensions (Figures 4 and 5). All of this, together with orthophotos and Digital Elevation Models (DEM) for topography, allows for a degree of visualization that adjusts to reality and provides diverse graphical information to the user.

**Figure 4.** Example of OLOD1 building context in ArcGIS highlighting the protection areas of two heritage buildings. Source: Own elaboration.

 

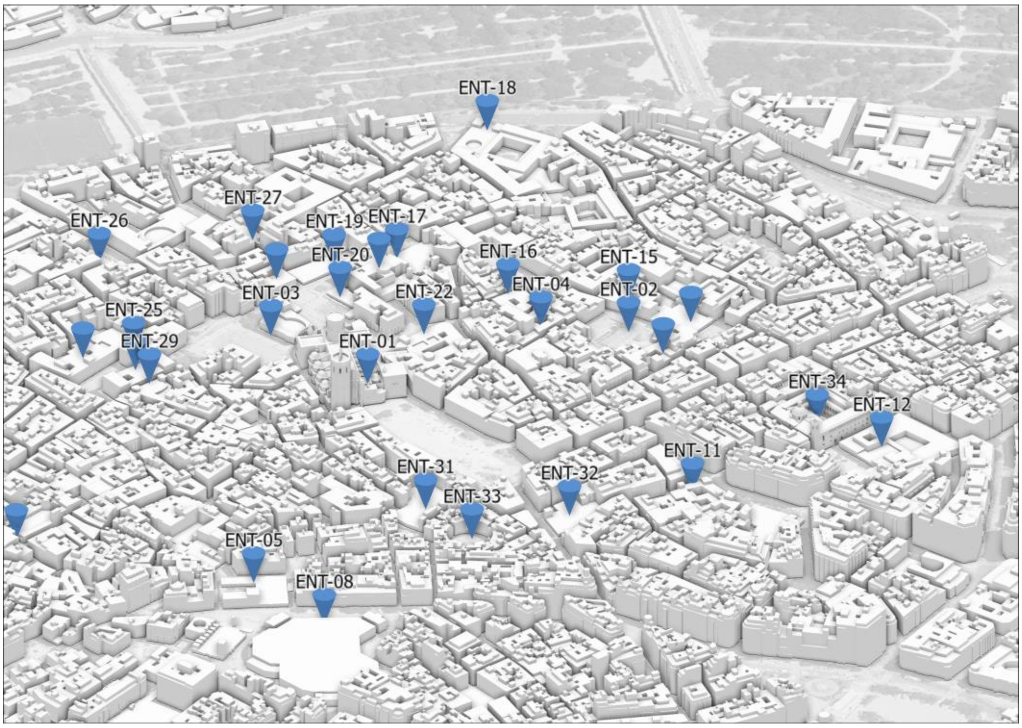


**Figure 5.** Example of OLOD1 building context in ArcGIS where points elements with information about points of interest were added. Source: Own elaboration.

## 3. Conclusions

Based on the information provided, integrating HBIM models into GIS environments proves to be a powerful tool for tourism management, allowing for detailed visualization in various scales of both heritage and urban elements. The choice of level of detail, information required, format and model type, significantly influences GIS fluency and comprehension, making it more informative, aiding in effective decision-making processes for tourism planning and development.

But in this scenario, establishing a common level of detail for each element is a challenging task; therefore, it is often preferable to work with the proposed levels of detail for each element separately. This approach allows for a more tailored and flexible representation of the data, accommodating the specific characteristics and requirements of individual elements. By adopting this strategy, it is possible to capture the complexity and diversity of urban and heritage features in a better way.

Future lines of research could focus on determining the methodology, from a technical standpoint, to more efficiently integrate tourist information from HBIM to GIS. Additionally, conducting hierarchical studies among professionals to determine which information is prioritized from a tourism perspective could offer valuable insights. By understanding the specific needs and preferences of tourism professionals, future research endeavours could tailor GIS integration efforts to better meet the demands of the tourism industry, ultimately leading to more informed decision-making and improved tourism management practices.

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# Smart technologies in the museum environment. AR experiments on physical models at the Museum of Oriental Art in Turin

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***Abstract***

*The concept of Smart Tourism has developed rapidly within the Smart Cities paradigm, which emerged at the beginning of the new millennium in various scientific fields. Museums, traditionally centres of cultural and technological dissemination and display, are becoming places to experiment with smart technologies (digital survey, AR, VR, digital fabrication, and AI) for analytical purposes and to enhance the visitor experience. This technological revolution affects the way museum visitors interact with cultural heritage. This process is part of the Fourth Industrial Revolution and is based on multiple technologies that blend physical and virtual environments. These tools have shown benefits for accessing, comparing, and understanding space-related information about artefacts and advantages in developing compelling forms of storytelling aimed at visitors.*

*Trying to give an overview of the technologies used, which have some relevance to the disciplinary field of representation, one can talk about digital acquisition techniques, Augmented Reality, Virtual Reality, digital fabrication, and artificial intelligence.*

*The models obtained with different digital acquisition techniques allow new ways of content fruition. Both virtual and physical outputs aim to increase the inclusiveness of collections, meeting the various needs of users related to age, physical, sensory, cognitive, cultural, and experiential factors.*

*The paper presents the outcomes of some experiments conducted in Museo d'Arte Orientale of Turin aimed to explore the continuum between real and virtual in the museum field through intelligent technologies. The experiments illustrate how to integrate AR technologies into the enjoyment of content, inside and outside the museum, with the support of real models.*

***Keywords:*** *Museum, Accessibility, Multisensory exhibition, Digital fabrication, AR.*

## 1. Introduction

The concept of Smart Tourism has rapidly evolved within the Smart Cities framework, which emerged in various scientific fields at the turn of the new millennium. Anything designated as "Smart" is characterised by the utilisation of Information and Communication Technologies (ICT) aimed at enhancing user experiences and providing analytical tools for institutions (Battino & Lampreu, 2019; S. Shen et al., 2020) identify numerous innovative technologies applied in tourism, including the Internet of Things, Cloud computing, Artificial Intelligence, mobile communication technologies, mobile devices and apps, Big Data, Virtual Reality, Augmented Reality, intelligent chat robots, wearable devices, and beacon networking. This network thrives on continuous interaction between the physical and digital realms.

Museums, traditionally hubs for cultural and technological dissemination, are now experimental grounds for smart technologies, improving analytical capabilities and enriching visitor experiences (Wang, 2021). A 2020 study by Mateusz Naramski on their use in Polish museums offers an international overview of these applications (2020). Examples include Near Field Communication (NFC), utilising intelligent object monitoring and preservation technologies, integrating audio guides with Augmented Reality, and analysing visitor profiles to address their needs and expectations.

The COVID-19 pandemic has accelerated the adoption of intelligent technology in tourism (Fong et al., 2020), marking a transition from traditional to smart tourism (Hassannia et al., 2019).

This technological revolution is reshaping how museum visitors interact with cultural heritage.

Universities and museums worldwide are digitising collections through techniques like 3D scanning, Computer Aided Design (CAD), and Virtual Reality (VR) (Comes, 2016). Notably, interactive and immersive experiences, mainly AR, VR, and other technologies, have been extensively studied in the Cultural Heritage domain over the past two decades (Bekele et al., 2018; Luigini, 2019), enhancing visitors' access to artefacts and storytelling.

Key technologies relevant to representation disciplines include digital acquisition techniques, Augmented Reality, Virtual Reality, digital fabrication, and artificial intelligence, all contributing to new ways of experiencing content. Virtual and physical outputs aim to increase collection inclusivity, addressing diverse user needs based on age, physical abilities, sensory perception, cognitive factors, cultural backgrounds, and experiential preferences.

VR technologies offer lifelike experiences and additional contextual content, albeit with associated costs and equipment requirements (Charr, 2024). Augmented Reality, often part of gamification processes (Rocha, 2020), provides intuitive spatial information by overlaying digital content onto the real world (Amin & Govilkar, 2015), transforming in-situ visits.

AR, like direct tactile experiences, fosters new interaction possibilities, including for individuals with sensory or cognitive disabilities, offering auditory, haptic, and olfactory experiences (Sheehy et al., 2019).

Modern museums emphasise physical or virtual object manipulation and multisensory experiences, engaging all senses. Examples include the Louvre Abu Dhabi or the Touch Gallery at the Louvre Paris, which showcases comprehensive exhibitions featuring digitally fabricated replicas and tactile stations.

Digital fabrication complements this by creating tactile replicas or models that deepen object understanding and engagement, embracing a "Design for All" perspective (Ronco, 2021).

Museums increasingly employ artificial intelligence to develop tools like robots, chatbots, and websites for data analysis related to visitors and collections (Styx, 2023). Object recognition operations, central to representation research, are employed by numerous museums based on colour, form, line direction, or spatial and light characteristics (e.g., Cooper Hewitt Smithsonian Design Museum, Dallas Art Museum, Barnes Foundation).

The combined use of AI, AR, VR, and digital fabrication represents a vital area of investigation, catering to a broad audience inclusively.

## 2. Aims and objectives

By examining surveying and digital fabrication technologies, along with research on multisensory pathways in museums and perceptual modalities beyond sight, this study seeks to achieve two main objectives:

- Develop a workflow encompassing digital acquisition by creating a digitally fabricated tactile model coupled with an augmented reality (AR) experience.
- Establish guidelines for an inclusive, multisensory, modular, and adaptable exhibition pathway that includes architectural and exhibition spaces and a curated selection of artworks.

The work proposes an inclusive approach to knowledge, catering to a broad audience, including non-experts. The 3D models serve as interactive spaces, encouraging the exploration of diverse scenes using user-friendly, affordable systems. Combining AR with direct haptic experiences opens up novel interaction possibilities, enhancing sensory engagement and knowledge dissemination (Sheehy et al., 2019).

Tactile media can be rendered interactive through Text-to-Speech synthesis (TTS) that enriches object augmentation, eliminating the need for physical transit between objects and associated captions. Audio feedback facilitates interactive tactile graphics, leveraging TTS to describe content and events (Thevin & Brock, 2018).

The presented case study is Museo d'Arte Orientale in Turin (MAO), a prominent and dynamic institution within the Italian landscape dedicated to presenting, appreciating, and disseminating Asian arts and cultures. Housed within Palazzo Mazzonis, a baroque building dating back to 1639 that underwent significant alterations in the 18th century, the museum is structured around a central core flanked by two wings enclosing an inner courtyard accessible from the street via a grand collonaded atrium. This atrium leads via a double staircase to the distinguished hall of honour on the first floor. These spaces have primarily retained their original structure, albeit with some modifications to their decorative elements.

In terms of its collections, the MAO currently boasts a repertoire of 2,500 artworks originating from diverse Asian countries spanning various historical periods, categorised into five main areas—South Asia, Southeast Asia, China, Japan, and the Himalayan Region—based on historical and geographical contexts (Bruno & Ricca, 2010).

MAO has consistently demonstrated an interest in leveraging digital technologies for heritage communication, mainly through online platforms (website, social media pages, YouTube channel, and Google Arts and Culture). However, physical visits to the museum's permanent collections currently incorporate limited multimedia elements, primarily audio guides, and need additional supports to ensure inclusive access, such as tactile models, dedicated audio descriptions, or LIS (Italian Sign Language) format.

## 3. Methods and procedure

This project targets various types of outcomes. The structured process is segmented into three stages, traversing the spectrum between reality and virtuality. The virtual phase involves digital survey, redrawing, digital modelling, and maquette development; the real one encompasses tactile reproduction, and the AR experience exemplifies the virtual-real one. As a result, this initiative operates across multiple perceptual visual, hyper-visual (AR), and haptic (Ronco, 2023).

The suggested workflow suits the container (exhibition spaces) and the museum's content (artworks). The initiative encompasses the architectural spaces and ten artworks (two for each geographic collection area) chosen based on specific criteria: ease of handling and inspection, ability to be illuminated, surface texture, clarity of details, opacity, and colour richness.

Photogrammetry was utilised for the artworks, while two metric surveys were done for the spaces. One was carried out by Professor Concepción López González (Universitat Politècnica de València) with a terrestrial laser scanner (TLS), and the other by Fabrizio Natta (Politecnico di Torino) with Structure from Motion technique.

The outputs of the digital surveys have been used for the virtual 3D modelling through Rhinoceros® software at the base of real models, conceived from the perspective of tactile fruition and experience, easy to handle, and perceivable at the same time.

Finally, in this experimentation, we opted to evaluate marker-less anchor AR due to its capability for direct interaction with real-world models. Unlike MR and VR, AR generally offers a lower level of interaction.

In particular, this paper focuses on the atrium of Palazzo Mazzonis and artwork from the Chinese collection.

### 3.1. From digital survey to digitally fabricated models

#### *3.1.1. Architectural spaces: the container*

The spaces digitally surveyed by the research group led by Prof. R. Spallone and M. Vitali belong to the ceremonial route and include the atrium (Figure 1), the staircase, and the hall of honour on the first floor of Palazzo Mazzonis, home of the MAO.

The modelling process of the space, based on the point cloud acquired through the TLS technique, starts with identifying the distinctive horizontal and vertical sections. The model has been done with Rhinoceros®, drawing on point cloud sections and obtaining closed solid poly-surfaces (Figure 2). This ensures an optimal result in the digital fabrication phase.

The maquette of a portion of the atrium, designed at a scale of 1:50, is constituted of four parts: the base, made with a laser-cut printer (Trotec speedy 400) on MDF panel; the wall; the entablature and the column 3D printed with Fused Deposition Modelling (FDM) technique in PLA (Ultimaker S5). MODLab Arch of the Department of Architecture and Design supplies both machines.

The printed parts are linked with magnets to facilitate the assembly from an inclusive perspective (Figure 3).

**Figure 1.** Palazzo Mazzonis' Atrium. Source: Google Arts and Culture.

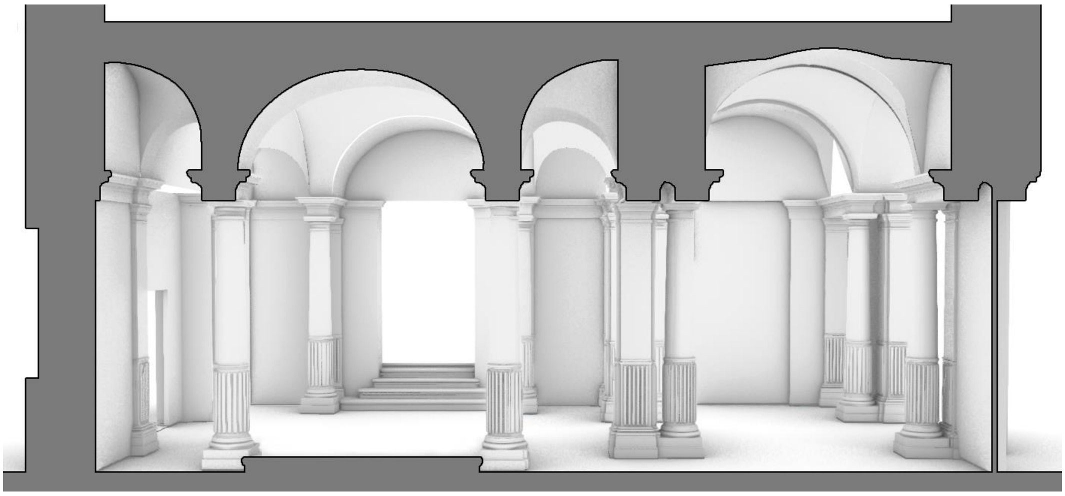

**Figure 2.** Palazzo Mazzonis' Atrium 3D model's longitudinal section. Modelling: Awada, A.

**Figure 3.** Maquette of a portion of Palazzo Mazzonis' Atrium. Model engineering: Ronco, F.

### *3.1.2. Artworks: the content*

Conversely, the work on artworks starts from a photogrammetric digital survey. Here, the author presents a Chinese tomb statue of an actor (Shaanxi area, VII century AD) belonging to a group of four travelling foreign actors (Figure 4). The selected one, the shortest of the four, addresses a hypothetical spectator directly, spreading his arms wide in a theatrical gesture that the other three follow in a mimetic fashion. The tunics with billowing sleeves constituted the typical attire of the show, and the vast, bipartite headdresses belted with ribbons (futou). According to some reconstructions, these figures belong to the people of the Sogdians, an ancient kingdom in Central Asia of which most information has been lost.

The replica in PLA has been realised at a scale of 1:1 with the FDM technique (Figure 5), following principles to allow the reader/user an easy vision/perception of the whole figure based on the simultaneous use of two hands (Levi & Rolli, 1994). The 3D printer (Bambu PS1) of the MODLab Arch laboratory of the Department of Architecture and Design has been used.

**Figure 4.** Museo d'Arte Orientale, Chinese collection: travelling foreign actors (Shaanxi, VII century AD). Photogrammetric survey and processing: Ronco, F.

**Figure 5.** Foreign actor 3D printed replica. Print: Ronco, F.

### 3.2. The AR Experience Design

AR experiences have been developed on the presented real models with Unity® and Vuforia SDK.

Vuforia™ Engine, leveraging Model Target technology, enables recognition and tracking of real-world objects using standard mobile devices. Initially, the virtual models must be transformed into recognisable features for the software. Vuforia™ offers the Model Target Generator tool, which converts the objects' polygonal mesh into a three-dimensional model suitable for integration into Unity® as a target.

In both cases (atrium and actor), the Advanced Model Target allows a 360° recognition of the model. The Model Target Generator software requires you to confirm the orientation of the .obj file since the system of Cartesian axes used in Rhinoceros® is different from that used in Vuforia™ and Unity® and to express the unit of measurements. Finally, an advanced Guide View has been created, as the developer wants it to frame the object at 360° on a plane. In the end, the Model Target is trained and exported to a .unitypackage file to be imported into the project on Unity®.

After the object recognition, all assets regarding the 3D model (different architectural parts and the textured model of the actor) and the Canvas (children of the Model Target) appear.

 

Inside Canvas are all the user interface elements, such as lettering and buttons. There is also an Event System associated with the Canvas, which does not appear in the scene but is responsible for managing the interactions of the Canvas and its elements.

In the “container” application, five UI buttons trigger the various architectural parts of the maquette to teach the user their correct nomenclature. On the other side, the application on the actor includes only one button that activates written and audio descriptions (Figure 6).

The layout of the controls on the right of the screen provides for using the screen in a vertical position. For each button action associated with it, the OnClick window indicates which Game-Object to act on; for all buttons, the Set Active command allows the actuation or deactivation of the referenced object (Figure 7).

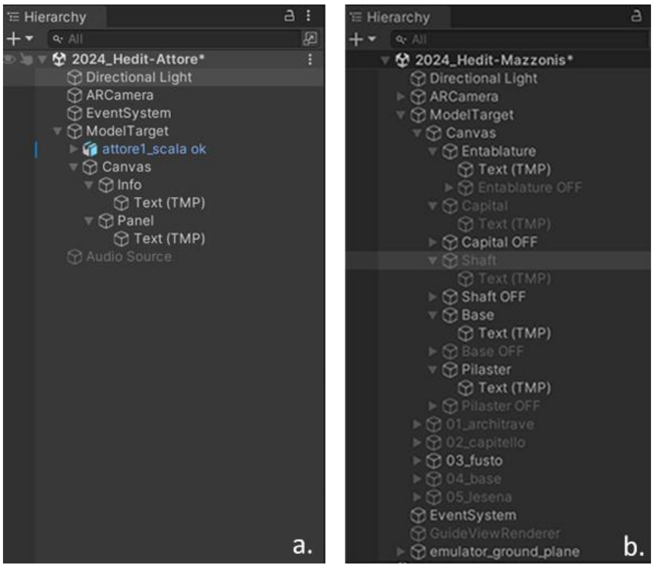


**Figure 6.** Unity® *project hierarchy: a) Actor’s app; b) Atrium app.*


**Figure 7.** Palazzo Mazzonis Atrim app: a screenshot of the AR experience.

In the actor app, the audio content was created using MURF.AI Studio, a text-to-speech software featuring a diverse selection of over 120 natural-sounding male and female AI voices across 20 languages. This range of options enables easy implementation and customisation of the application based on specific requirements.

Subsequently, the TMP content and audio were integrated into the model target to display after framing the model and clicking the *info* button. The descriptive texts and audio relating to the statue enhance the haptic experience, improving the accessibility of the content (Figure 8).


**Figure 8.** Actor's app: a screenshot of the AR experience**.**

## 4. Results

These activities are part of broader research conducted within the scientific collaboration agreement between Politecnico di Torino and Fondazione Torino Musei. Specifically, they involve the Department of Architecture and Design and the MODLab Arch and MODLab Design Research and Teaching Laboratories at Politecnico di Torino under the supervision of MAO's team.

In this framework, the presented research endeavours to develop a workflow model for managing the digitisation of artworks and exhibition spaces, culminating in creating tactile replicas and AR applications. A notable research gap exists in workflows and methodologies, leaving critical questions unanswered regarding scale, material selection, and public presentation methods (Wilson et al., 2017).

From social and economic standpoints, tactile exploration of artefacts and AR experiences undoubtedly enriches visitor understanding and engagement. Furthermore, integrating tactile experiences with audio descriptions adds significant value, enhancing the museum experience from an educational and inclusive "Design for All" perspective.

The most important result of the broader research is the funding (European Union under National Recovery and Resilience Plan - PNRR M1C3-3) of a project to eliminate physical and cognitive barriers in museums and public cultural places. The project written with the MAO's team seeks to enhance knowledge accessibility through the continuum between real and virtual, or in other terms, physical and digital realms.

This encourages us to pursue the goal of creating a model, establishing a shared language to minimise errors in museum institutions' accessibility assessments, and streamlining users' multisensory experiences, making them more intuitive and less reliant on introductions and explanations.

 

For this reason, a multidisciplinary team has been assembled for the overall project implementation, incorporating expertise in multisensory museum communication, tactile experiences, digital art, and multimedia, combining curatorial knowledge with that of heritage representation (Ronco, 2022; Spallone et al., 2022; 2023).

## 5. Conclusions

Emerging technologies facilitate the preservation and enrichment of cultural heritage and provide new avenues for interpretation and more impactful communication. In particular, the partnership with MAO provides opportunities to explore diverse representation languages to enhance museum heritage accessibility from a *Design for All* perspective.

In particular, digital fabrication and AR straddle the boundary between the real and virtual realms, amplifying the levels of understanding and interpretation of museum content or its container. The physical model itself results from a reworking of previously gathered data, representing the culmination of a project. Augmenting it enhances effectiveness, promotes increased interactivity, and adds a playful dimension. This engagement leads users to deeper involvement, improved recollection of the experience, and enhanced learning.

Employing VR, AR, tactile models, and other cross-media techniques deepens the connection between the museum and its visitors. Leveraging the continuum between real and virtual, physical and digital realms, it offers a workflow adaptable for diverse operators and accessible to various audiences. This formula holds promise for scalability across different museum contexts.

## 6. Acknowledgements

I would like to thank Dr Davide Quadrio, Director of MAO; Dr Mia Landi, member of the museum's education department; and Mrs Patrizia Bosio, from the Technical and Security Office, for favouring the current research.

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# From Research to Application of HBIM for Conservation Management Plan: The Experience of the School of Mathematics by Gio Ponti in Rome

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***Abstract***
*Between 2019 and 2021, a multidisciplinary group, scientifically coordinated by Prof. Simona Salvo, conducted research on the Gio Ponti School of Mathematics - a work from 1935 located within the city of Rome - funded by The Getty Foundation under the "Keeping it Modern" project. After studying the building in all its aspects, the ultimate goal of this multidisciplinary experience was to develop a plan for scheduled conservation. Once the work was completed, all the data was collected in a technical report. Still, there was a spontaneous inquiry into which digital tool could be suitable for conveying its findings. It was decided to experiment and investigate the potential of the H-Bim model, which was, however, introduced ex-post compared to the research process. In conclusion, this contribution aims to address the result of this experience, highlighting the merits, potential, and limitations of HBIM modelling.*

***Keywords:*** *Rationalism in Italy, Conserving Contemporary Architecture, Conservation Management Plan, H-BIM.*

## 1. Introduction

In its critical-conservative sense, restoration is a "cultural act" (G. Carbonara) philologically founded and characterised by the dual purpose of preserving and revealing historical and formal values. Today, the object of restoration is an increasingly widespread heritage consisting of both material and immaterial assets. The values to be revealed and the instances to be considered seem to multiply. Numerous research contributions investigate modelling that can accommodate all these instances and serve the restoration project and its subsequent management and maintenance. Since the 1980s, there has been a need to develop modelling proposals aimed at providing useful information for the execution of the restoration intervention through the so-called "semantic graphing," meaning a model that contains within it information related to the state of conservation, as well as the proposed interventions (Lo Turco et al., 2017).

In this line of research, the concept of "formal modelling" developed by Fiorani and Acierno deserves attention, as it "aims to go beyond the simple establishment of a database on historical buildings, intending to offer a coherent support system for investigative activities and the design itself, excluding the reductionist and misleading objective of the expert system" (Fiorani, 2017).

The experimentation of computer tools capable of accommodating the needs of the disciplinary field of conservation that are queryable, interoperable and implementable proceeds in parallel with digital innovation and seems to find a valid response today in the H-BIM model.

Starting from these considerations, the present contribution does not intend to focus purely on modelling, which was carried out collaboratively and with the assistance of the BIM-Specialist Arch. Federica D'Orazio emphasises the need to experiment with and identify a structuring of the model itself that is as multidisciplinary as possible to achieve a level of completeness and exhaustiveness necessary to respond to the numerous instances of proper conservation.

## 2. Multidisciplinary Research on the School of Mathematics

Between 2019 and 2021, a multidisciplinary group scientifically coordinated by Prof. Simona Salvo (Professor of Architectural Restoration at the Department of History, Design, and Restoration of Sapienza University of Rome) conducted research on Gio Ponti's School of Mathematics, a 1935 work located within the university city of Rome. The Getty Foundation funded the research as part of the "Keeping it Modern" project.

The School of Mathematics, thanks to its unique volumetry, the attention to the choice of covering materials, furnishings, and decorative apparatus - although the latter is now lacking due to the loss of the monumental polychrome stained glass window, designed by Gio Ponti, that characterised the main facade, lost following the bombing of San Lorenzo on July 19, 1943 - represents a unique entity within the university city of Rome. Gio Ponti conceived the building in three pure volumes, characterised by formal, aesthetic, and functional autonomy: a prismatic representation volume, the *front body*, with a grand character, designed to house the monumental Mathematics Library and a series of rooms intended for the professors' life; two *curved wings* developed on two levels, illuminated by large ribbon windows that run along the curved walls and which once had opal thermal glass, the so-called "Termolux" consisting of two sheets of transparent drawn glass with an internal insertion of "Vetroflex" spun glass felt. The sheets were completely sealed at the edges by a special hermetic sealing putty. Its composition allowed for strong insulating capabilities and the filtering of incident rays, making the light optimal for the rooms intended for the drawing of descriptive geometry models in the School of Mathematics; finally, the last block is the *classroom tower*, a fan-shaped body with a daring structure - designed by Eng. G. Zadra - with portal concrete walls, hosting on three levels the stepped classrooms for the first two years of Engineering and Mathematics and, in the basement, the caretaker's house. These three blocks sit on a residual space, a horseshoe-shaped courtyard with irregular pavement and grass crevices (Figure 1).

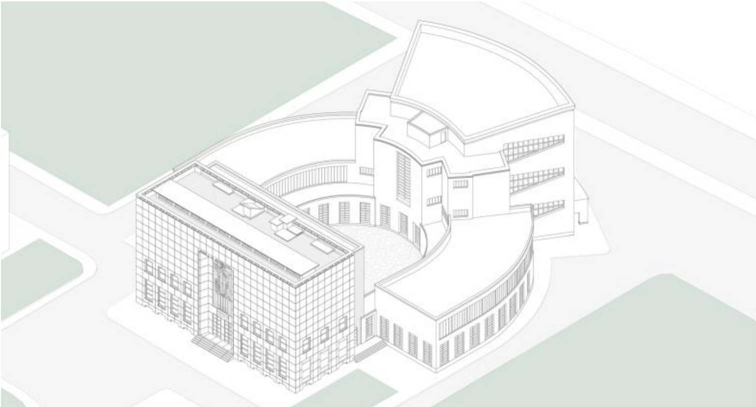

**Figure 1.** The School of The School of Mathematics in its original State (1935). The HBIM model was developed using Autodesk Revit 2021 ©: Cortesi, M. (2022)

However, as early as 1939, just six years after its inauguration, the building underwent a series of alterations that, in some ways, would become paradigmatic and would later be repeated in various parts of the building. Functional needs initially led to a transformation and internal subdivision of the spaces and later resulted in real expansions and extensions of the building's bodies. The safety regulation adjustments in the second half of the 1980s, with the insertion of fire escape stairs within the horseshoe-shaped courtyard, also obliterated the original conception of the building. Ponti's idea of pure volumes as finished crystals, not susceptible to additions or modifications, was undermined. The strengths of Ponti's project, such as the spatial crossings, both longitudinal, transversal, and vertical, and the junctions between building bodies differing in material and function, are those that, as we will see, suffered the greatest losses in value and meaning due to alterations, additions, and visual interruptions.
This multidisciplinary research experience allowed for the study of the building in all its aspects—its dimensional data, construction and transformation history, structures, systems, constituent materials, and furnishings—recognising its spatial, historical, and aesthetic values.
Based on this broad recognition, a technical report was prepared, including all the collected data and a conservation management plan. The interventions provided by the plan, conceived according to various categories of urgency, aim, on the one hand, to maintain the status quo, paying attention to the more fragile elements, such as coverings and finishes, and on the other hand, it also provides more strictly design-related guidelines that could partly lead to a reinterpretation of the building's obliterated values.

## 3. From research to the application of H-BIM

Upon concluding this process, it became natural to question which digital tool could be suitable for channelling its outcomes, for holding together data and results that are profoundly different from each other, such as cataloguing tables of archival documents, as well as geotechnical surveys, structural psychometric tests, chemical analyses, and polished sections of materials. Although all these aspects are highly specific, it was decided to experiment with and investigate the potential of H-BIM modelling to verify how such complex content and the synoptic conservation plan could be collected and made queryable in a computerised three-dimensional model.
It should be noted that the model was integrated ex-post concerning the research process. This resulted in rapid modelling of the construction elements. However, the level of detail and information collected for the building was not uniform, which led to a general inconsistency and the choice to maintain a less specific but uniform level of detail for the entire building.
Initially, it was decided to replicate the structuring of the research into multidisciplinary tasks in the organisation of the H-BIM model browser (Figure 2).

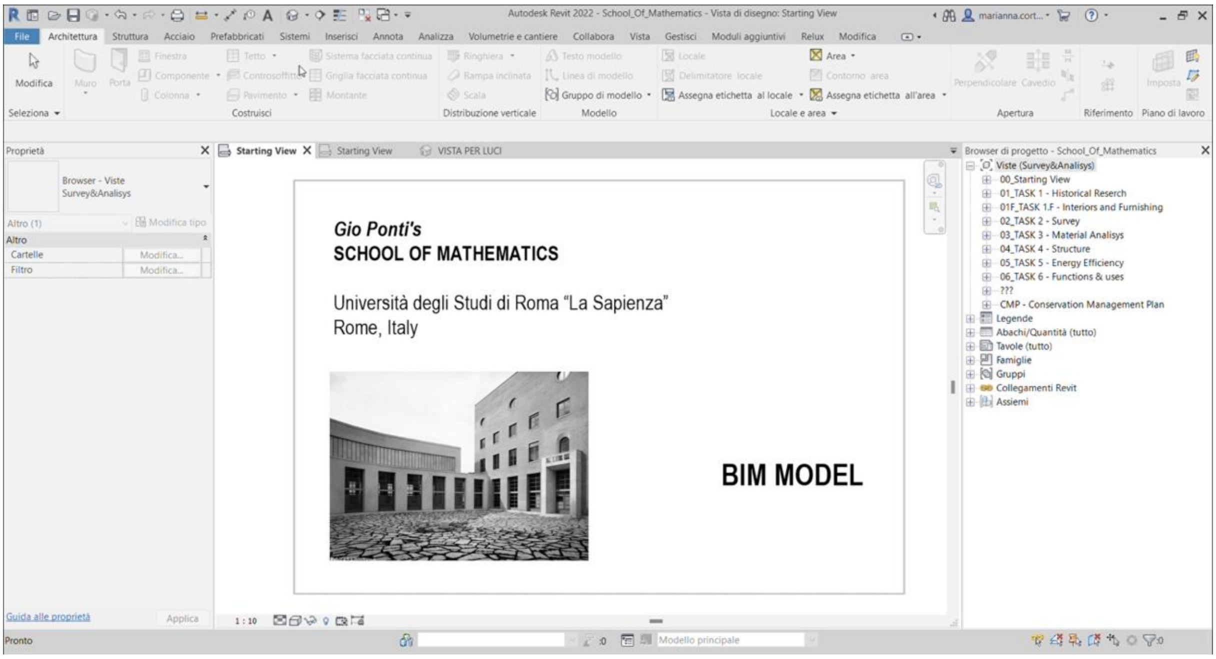


**Figure 2.** On the right is the organisation of the browser into multidisciplinary tasks. The HBIM model was developed using Autodesk Revit 2021 ©: Cortesi, M. (2022)

Once tasks defined the browser, the actual modelling began. The survey carried out with a 3D Laser Scanner by the Department of History, Design, and Restoration at Sapienza (see Attenni, Rossi 2022) had already highlighted a certain irregularity and uniqueness of the elements constituting the building. For instance, consider the pseudo-square slabs that cover the main facade, which increase and decrease in size according to the rhythmic axes that structure the entire facade, as well as the diverse constituent materials typical of the "autarchic" production of 1930s Italy.

The modelling of such a unique pre-existence in dimensions and construction characteristics required working not with standardised elements present in BIM software libraries but with parametric objects, the so-called "families." Thus, a methodology was devised to apply to complex forms through a "customised" modelling process for decomposable and parametric elements, with which data and parameters from the research were associated.

The model was developed for the entire building, while detailed aspects focused exclusively on the front body, as it was more extensively investigated during the research phase. This block is particularly interesting because it encapsulates those spatial crossings, expressed in the triple height of the library, and a conception of a total work of art that is reflected throughout the building and finds its greatest fulfilment here in terms of design solution and realisation. The front body, in addition to being of considerable architectural value, is also important for its contents: specifically, the library on the second-floor houses custom-designed integrated furniture and a noteworthy book collection, the so-called "Antique and Rare Book Fund" - approximately 2500 works published between 1482 and 1830, including Euclid's "Elements" from 1482 and Regiomontanus's "Almagestum Ptolomei" from 1496 - which requires particular microclimatic precautions also from a maintenance perspective in the scheduled conservation plan.

First, based on the survey of the current state, it was necessary to decompose the building into its constituent elements: the construction elements were parameterised and codified, and the different temporal phases of belonging were assigned to allow reading through a filter the original state of 1935 and the current state. In the browser section related to "interiors and furniture," the furnishings and all the doors were modelled as parametric objects, and schedules were developed and extractable in tables containing information about dimensions, materials, manufacturers, and conservation status. Similarly, in the browser section related to structures, the reinforced concrete columns and beams were modelled as decomposed elements, coded, and information from psychometric tests was inserted.

In the "Material Analysis" section, a particular focus was given to the reinforced concrete element crowning the flat roof of the front body. This element, a sort of *leitmotif* in Gio Ponti's architecture, comprised of voids, solids, and corner solutions, was decomposed according to its components and assigned archival information and data on its conservation status (chemical analyses and polished sections).

To graphically show the level of degradation of this particular element, a visual programming application – Dynamo – was used, allowing the automation of processes. By examining the script of this application in detail, there is an initial group where all the families of the reinforced concrete components are selected; each is assigned a degradation value according to tabulated values defined by the task responsible for analysing the construction elements and technical material investigations carried out at Sapienza's "AstreLabMat" material analysis laboratory. In the immediately following node, the quantified parameter is converted into colour. The degradation value is thus associated with a colour shade, allowing the visualisation of what was previously only quantitative data (Figures 3 and 4).

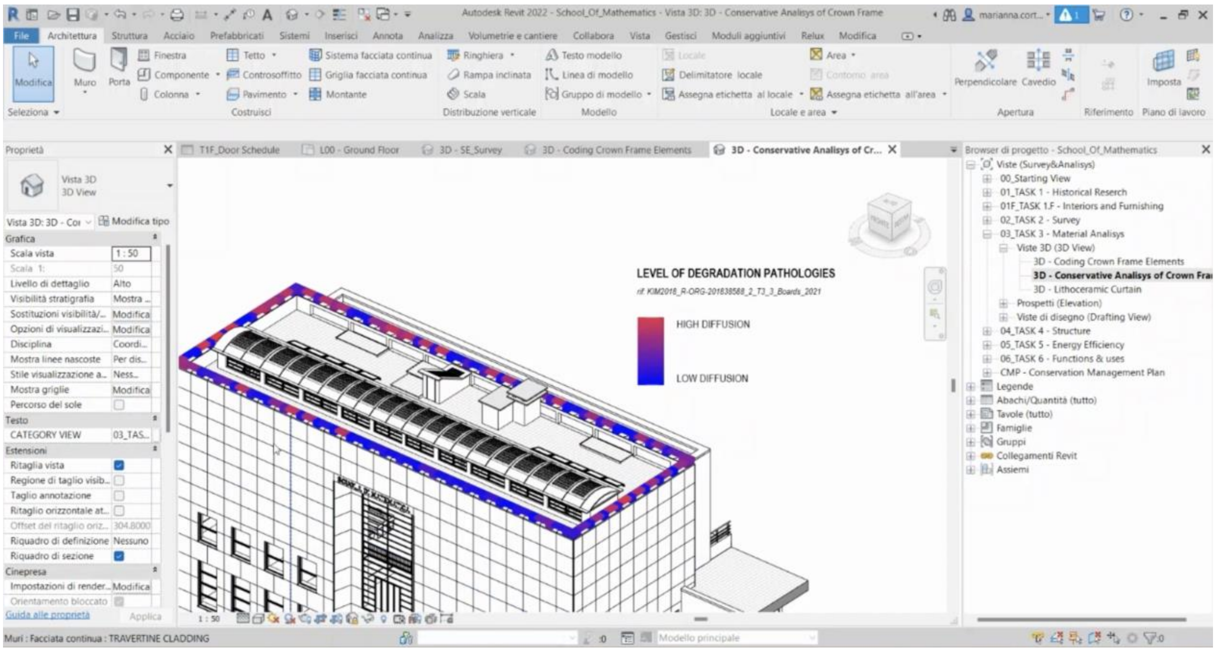


**Figure 3.** Deterioration of the concrete crown of the roof covering the front body at the current state: Cortesi, M. (2022)

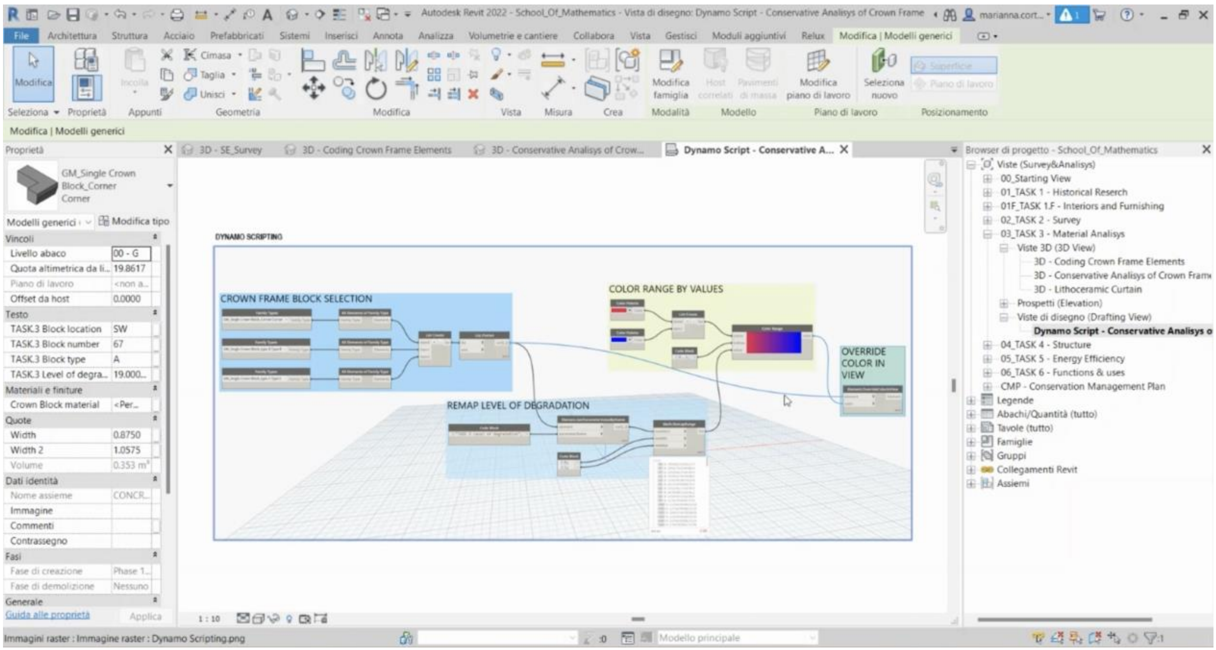


**Figure 4.** Dynamo script to visualise the level of degradation: Cortesi, M. (2022)

In a subsequent phase, to ensure that the model could also include the prescriptions of the conservation plan, each construction element was equipped with information regarding the interventions to be carried out according to different urgency categories defined in advance in the conservation management plan. Each category was associated with a colour, and it is possible to isolate one category over another through filters. The model thus becomes queryable, allowing the specific operation to be performed on each component to be read and updated once the intervention is completed (Figure 5).

Finally, in the browser section related to historical research, a virtual archive was created to contain all the links that refer to the numerous tables cataloguing documents and iconographic sources resulting from meticulous and extensive archival research.

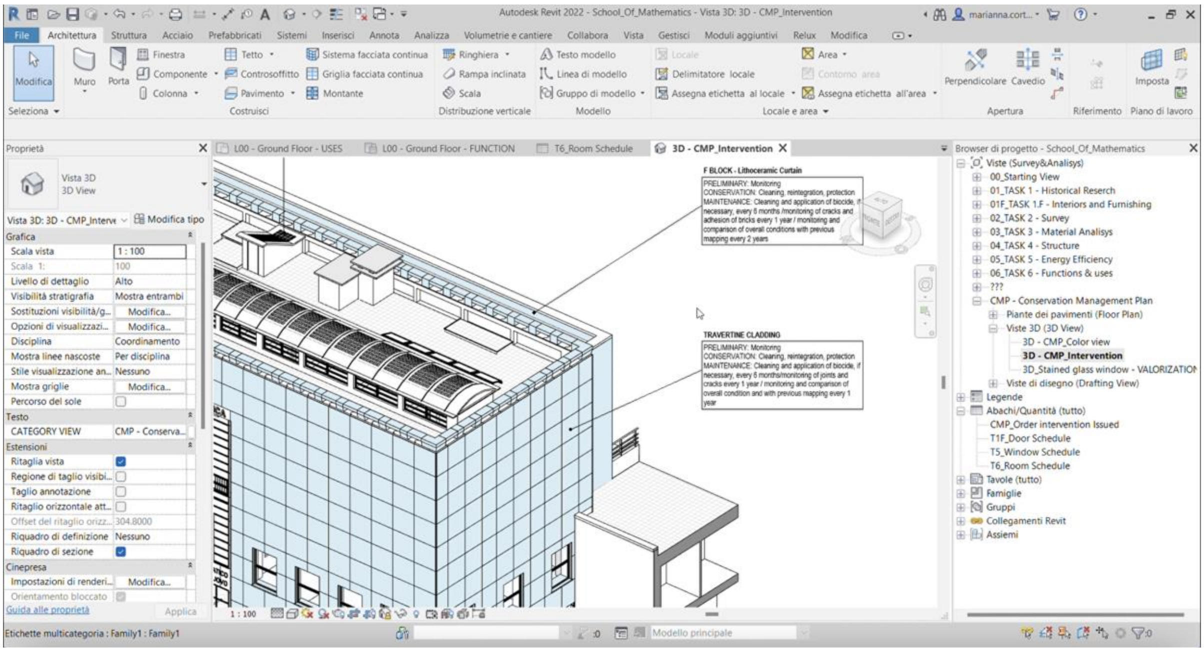


**Figure 5.** Conservation Management Plan. The HBIM model was developed using Autodesk Revit 2021 software ©: Cortesi, M. (2022)

## 4. Conclusion

In conclusion, this experience, which I recall as an early stage of reasoning without claims of completeness, highlights the merits, potential, and limitations of HBIM modelling. Among the qualities are the degree of synthesis, the detailed reading of continuously implementable information, interdisciplinary interpolation, and potential interoperability with other software. On the downside, a limitation in data interpretation emerges: the need to consult the model and the prescriptions of the conservation management plan presupposes a broad heterogeneous audience not always experienced in using H-BIM models. Therefore, it is necessary to experiment with the currently existing viewers, seeking an interface that is immediate, accessible to everyone, and capable of correctly displaying the complexity of the inserted data. In this sense, it is necessary to keep track and outline almost a *vademecum* that specifies first the method of structuring and organising the browser. Secondly, the properties of the elements, or the types of parameters assigned, bearing in mind that the reference standard UNI 11337 of 2017 defines the LOD for restoration but does not provide any indication on the definition of the parameters themselves, thus constituting a limitation in the design of H-BIM models.

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# Virtual tour with multimedia information of the Chapel of Los Dolores (Icod de los Vinos) for tourist and cultural dissemination

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## *Abstract*

*Virtual tours using 360-degree photos offer a quick, simple, and accessible way to share immersive experiences of real places. For this experience, a virtual tour has been created with 360-degree photos of the Chapel of Nuestra Señora de los Dolores, also known as Capilla de la Huerta, located in the municipality of Icod de los Vinos, on the island of Tenerife. It currently belongs to the Bishopric, and although the temple is still open for worship, access is limited to specific days and festivities. It has been designated as an Asset of Cultural Interest in the Monument category since 2013. To create the virtual tour, a 360 camera, model Insta 360 X3, was used. A total of 27 photographs were taken of both the exterior and the visitable interior. In addition, areas that are not ordinarily accessible to the general public due to their poor state of conservation were also photographed. Subsequently, the virtual tour was generated with the CloudPano program. A simple tour was created without multimedia information that can be viewed using virtual reality glasses such as Cardboard, allowing for a completely immersive experience. At the same time, another version was created, enriched with data that can be viewed in a non-immersive way on a computer screen or Smartphoneand enriched with data that can be viewed non-immersively on a computer screen or smartphone. This chapel has been selected for a virtual tour with 360 photos due to its originality and historical-artistic interest, which justifies its dissemination. In addition, we have taken into account its good general state of preservation and the amount of existing documentation, thanks to the studies and interventions carried out. In short, this project aims to enhance the value of the Chapel of Dolores, making known, in addition, rooms and spaces that are not currently accessible to the public.*

***Keywords:*** *Virtual tour, Added information, Chapel of Dolores, Tourist interest, Cultural heritage.*

## 1. Introduction

For this project, a virtual tour enriched with data about the Chapel of Nuestra Señora de los Dolores, also called Capilla de la Huerta, located in the municipality of Icod de los Vinos on the island of Tenerife, has been carried out. This construction is part of the Antiguo Convento Franciscano del Espíritu Santo facilities, an extension of the convent complex catalogued as an Asset of Cultural Interest in the category of Monument since 2013 (BOC, 2013). The chapel's construction at the end of the 18th century was promoted by the Hurtado de Mendoza family, following the wish of Captain Hurtado de Mendoza, who wanted to dedicate it to the Virgen de los Dolores. The chapel was considered finished in 1770, although it underwent modifications until 1774 (Martínez de la Peña, 1998).

Occupying the front of the chapel is the main altarpiece (Figure 1), which belongs to the second half of the 18th century and is catalogued as a Rococo-Chinesque altarpiece (Trujillo Rodríguez, 1977). It can be considered that this altarpiece is registrable, which means that it can be accessed through several accesses that were created at the time for functional reasons, and this has made it possible to identify and analyse its construction system, of the architectural box or sheet metal, which is hidden behind the façade of the altarpiece (Díaz & Tudela, 2021).

The interest aroused by this altarpiece has led to different technical studies and interventions on it (Díaz et al., 2023). The last of these works took place in 2021, within the framework of the Final Degree Project in Conservation and Restoration of Cultural Property, where the study and conservation-restoration of the central niche of the main altarpiece was carried out (Chinea Peña et al., 2021).

**Figure 1.** Interior of a single nave. In the background, the main altarpiece presiding over the chapel.

This chapel has been selected for a virtual tour with 360º photos, on the one hand, to visualise in a virtual reality headset and, on the other hand, with multimedia information, given its originality and historical-artistic interest. This dissemination is supported by its excellent state of preservation and the abundant documentation available thanks to previous studies and interventions. It also has the possibility of making the tour of the altarpiece registrable. It is exciting to have this virtual tour because the chapel is only open on specific days.

In essence, this project seeks to highlight the value of the Chapel of Dolores, offering access to rooms and spaces that are currently not accessible to the public. The additional information in the tour enriches the visitor's knowledge and promotes the dissemination of books, texts, and information about restoration work carried out in the chapel.

## 2. Background

A virtual tour is a recreation of an entirely virtual environment where you can move freely and interact using a digital device. Virtual tours can be a copy of a reality or a fictitious space and even a mixture of both (Sanchez Riera et al., 2022), where the user can walk through or examine the place. To create these tours, there are a variety of programs and applications: on the one hand, advanced, expensive technologies that require specialised knowledge to operate, and on the other hand, simple and accessible technology available to anyone who works through a cell phone (Nieva García et al., 2022).

3D modelling technology, facilitated by CAD (computer-aided design) tools, makes it possible to create realistic virtual tours (Janovský et al., 2022). These programs enable modelling, texturing, lighting, and animation of scenes and elements. Video game engines such as Unity or Unreal Engine are used to convert these models into virtual tours (Meier et al., 2021). The creation of virtual tours that are exact replicas of reality can be done by 3D technologies using techniques such as photogrammetry or point cloud creation by 3D scanning (Rüther, 2020). These digital twin tours represent the real environment in great detail in a virtual model (Lucchi, 2023). On the other hand, 360 cameras provide a fast and affordable option for creating realistic virtual tours (Nieva Garcia et al., 2022), although they limit the user's movement to the captured viewpoints.

In all technologies, it is feasible to integrate digital elements that do not physically exist in the real world, thus allowing virtual experiences to be enriched, which considerably expands the application possibilities. In most programs, it is possible to incorporate visual information such as text, images, videos, and audio. In addition, links to external sites can be included, which opens up various options, from linking books or online documents to providing geolocation, contact data, weather forecasts, and even three-dimensional models (Fernández García & Herrera Arenas, 2022).

The way to visualise a virtual tour can vary, from downloadable programs for computers, tablets, or mobiles to online versions. Tours created with CAD programs and video game engines require high processing and are usually limited to computers or consoles. Point clouds generated by scanners also require powerful devices for viewing, usually by download or installation on a computer. In contrast, 360 videos are easily accessible, and virtual tours with 360 photos can be viewed via links. In terms of immersion, virtual tours are classified into three levels: low, semi, and high immersion. Tours on screens controlled by a mouse or touch screen are low immersive while viewing with added information in a full dome or with smart glasses is considered semi-immersive. Finally, virtual reality goggles offer a fully immersive experience (Di Natale et al., 2020).

A 360 camera, specifically the Insta 360 X3 model, was used to capture images for this virtual tour, and the Cloudpano online program was utilised to create the virtual tour from these images. One tour has been designed without added information for viewing in a virtual reality headset, and another has multimedia information to be viewed on other devices.

## 3. Materials and Methods

A total of 27 spheric photographs were taken with the Insta 360 X3 camera (approximately the price of the camera is 500€). Images were taken of both the exterior, i.e., the entrance door, and the interior, which people can visit with access, as well as parts not generally due to their poor condition and the walkable part of the altarpiece. This process took about two hours. The photographs were then entered into the online program Cloudpano to generate the virtual tour. Organising the images and creating the link points for a simple virtual tour took approximately three to five hours. The process takes longer to insert the added information, such as data, images, links, 3D models, etc., depending on the amount of material available (Figure 2).


**Figure 2.** Virtual tour created in Cloudpano with multimedia information buttons

Additional information that has been added to the virtual tour is as follows:

- Informative text;
- Informative text in image format for better visualisation;
- Images of details such as damage or Map of alterations;
- Videos with detailed explanations (Figure 3a);
- Links to other sites;
- Multimedia resources in HTML5 format;
- 3D models embedded in the tour (Figure 3b);
- Access to the documents on the web about the work and restoration carried out in the chapel and the altarpiece.

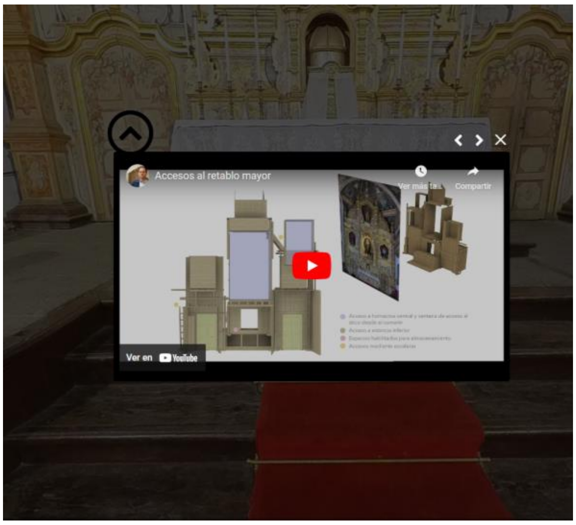


**Figure 3a.** Example of added information (video)

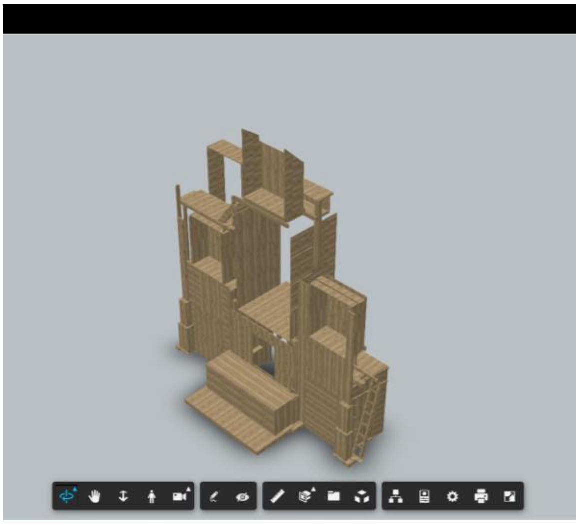

**Figure 3b.** Example of multimedia information (3D model in interactive viewer)

 

## 4. Results

A functional virtual tour has been created (https://capilladoloresvr.cultimerse.com) that can be experienced with virtual reality glasses in an immersive way (Figure 4a). In addition, a new version has been created (https://capilladolores.cultimerse.com) with multimedia information that can be viewed on mobile devices or computers (Figure 4b).

**Figure 4a.** Virtual tour for immersive devices

**Figure 4b.** Virtual tour with multimedia information

In the virtual tour enriched with data, most of the possibilities presented by the Cloudpano program have been implemented, including a great variety of multimedia resources (Figure 5). This virtual tour can become a container for all the information of interest associated with the Chapel of Dolores. The information can also be incorporated wherever needed, combining a visual tour with the restored details added live.

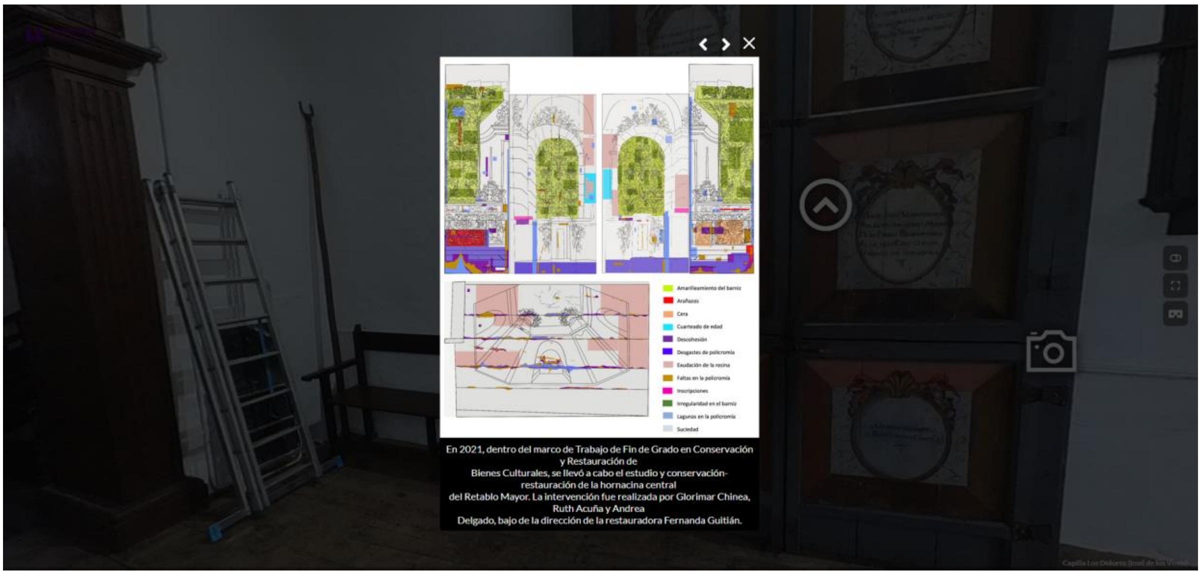


**Figure 5.** Example of added information (Map of alterations of the central niche). Source: Chinea Peña et al. (2021).

Information has been added in text format (Figure 6) to describe the painted ceiling, the chapel roof, the semicircular arch, and the altarpiece (year, typology, description, etc.). This information is described in more detail in the introduction to this text and can be consulted in Martínez de la Peña (1998).

We have also added details in image format (Figure 7) of the interior of the Altarpiece, the rear view of the tabernacle, a map of alterations (Figure 5), and a timeline elaborated in a previous research work (Chinea et al., 2021).

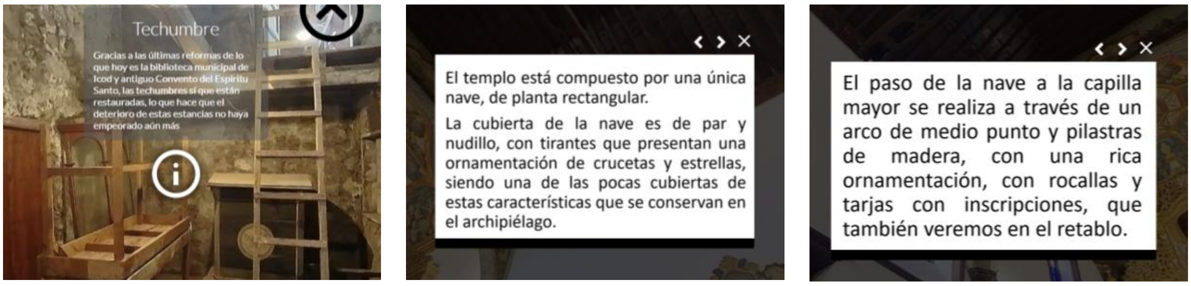


**Figure 6.** Information in text format with details on the ceiling, the nave and the semicircular arch.


**Figure 7**. Details in image format of the interior of the altarpiece, the rear view of the tabernacle and a timeline of the construction of the chapel.

Information points have also been inserted to highlight details such as information on the restoration of the ceiling, details of the pulpit, the division of the chapel, the current use of the processional staircases, etc. On the other hand, two videos have been integrated (Figure 8), one with a detailed description of the altarpiece and its components and the other of a procession of the Virgen de los Dolores in the chapel. Both videos can be found on YouTube, but they have been embedded in the virtual tour in HTML5 format to avoid having to leave the virtual tour.

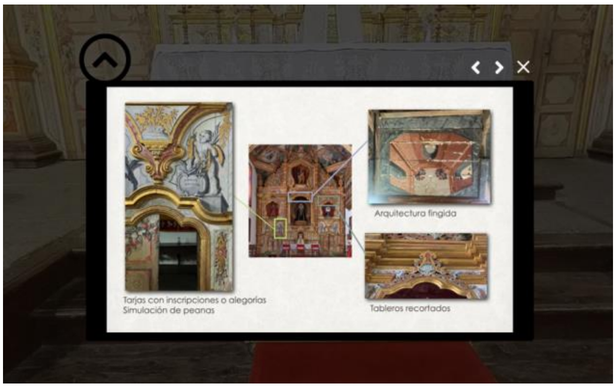


**Figure 8a.** Video with a detailed description of the altarpiece (Saorín, 2024a).

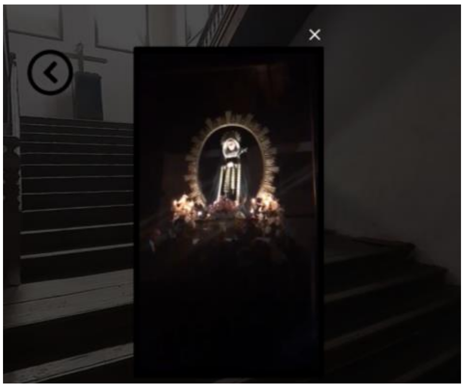

**Figure 8b.** Video of a procession of the Virgen de los Dolores (Saorín, 2024b).

## 5. Conclusions

Virtual tours using 360-degree photos offer a quick, easy, and accessible way to share immersive experiences of real places. Compared to the financial investment of a scanner or the time needed to 3D model a chapel, 360 photos are a low-cost, easy-to-create option that does not require advanced knowledge to create a virtual copy of a place.

By being able to incorporate as much information as possible into the tour, it becomes a complete informative material. On the one hand, tourists can obtain more information about the building and visit it virtually when it is not open to the public. On the other hand, it can be a very interesting resource for teachers to work on the Chapel because a direct visit is not always feasible; you can use the virtual tour and work directly on the information associated with the different rooms.

We propose the installation of a plaque with a QR code on the exterior of the Chapel of Dolores to offer direct access with mobile devices to tourists and other people interested in heritage. It is especially interesting to have this virtual tour accessible with a QR code because the chapel is only open on specific days. The additional information included in the tour enriches the visitor's knowledge and promotes the dissemination of books, texts, and restoration work carried out in the chapel.

On the other hand, as future work, it is proposed to measure the user experience of the tour with multimedia information viewed on mobile devices. It is also suggested that the user experience be assessed when navigating the tour in an immersive manner using virtual reality headsets.

## 6. Acknowledgements

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# Conservation and dissemination of painted architecture: Technological challenges in the city of Malaga (Spain)

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***Abstract***

*The painted architectures constitute an urban landscape that has been altered over time and the successive accumulation of planning and management instruments that have addressed them, be they General Urban Planning Plans or Special Protection Plans, which, although they have made possible the guarantee for prolong their existence, they have not always the capacity to make this valuable heritage known. The research we present lies in the inclusion of New Technologies inin the baroque-painted architecture of Malaga to publicise the cultural heritage in an applied way, qualify urban environments, and promote recognition of the cultural value of the city.*

*The conservation of the mural paintings, their influence on colour plans, and the didactics and new technologies incorporated into the discourse of cultural tourism are the elements that constitute the axes on which our work is based. We propose to create a transversal discourse encompassing the cultural legacy of baroque-painted architecture in a highly modified urban landscape subject to the demands that mark contemporary dynamics. On the other hand, it is evident that the planning of a quality cultural tourism development model must keep in mind the principles of quality and sustainability, contributing to the maintenance and conservation of cultural heritage, avoiding the deterioration of cultural assets, and respecting conditions of habitability.*

*Our case study and project apply to the painted architecture of Malaga. They are the result of the project awarded to the HUM1050 research group of the University of Seville in collaboration with the architecture studio 360BIM in 2022.*

***Keywords:*** *Heritage, Painted architecture, BIM, Technology, Urban landscape.*

## 1. Introduction

When researching the influence of tourism on the recovery of historical centres, it must be borne in mind that this process is currently being analysed from a wide range of disciplines and points of view. The birth of the historic core of cities by heritage precedes concepts such as, for example, sustainability. It can be affirmed that, in an official context, the first time that such problems, as the care of the historic landscape of cities, are mentioned is in the Venice Charter of 1964, while the Norms of Quito of 1967 states that the need to reconcile the demands of urban progress with the safeguarding of environmental values is already today an inviolable rule in the formulation of regulatory plans on a local and national level. In this sense, and within the framework of its management, any development plan must be carried out in such a way as to integrate the urban development of historic centres or complexes of environmental interest (UNESCO, 1967). The concept of environment in urban planning had already been introduced by Giovannoni in 1931. Thus, in 1978, UNESCO declared Quito's historic centre the first on the World Heritage List. Several decades after that context, sustainability continues to be a guiding thread in a process that can be linked to the Nature Charter (1982), the Bruntland Report (1987), or various meetings such as the Rio Summit and the Earth Charter (2000).

The profusion of documents and research that have subsequently been carried out on them may be due, among other things, to the fact that it is in historical centres where the problems typical of any urban agglomeration are exacerbated: the concentration of tertiary activities in some areas, as opposed to the lack of them in others or the ageing of the population, can be cited as examples. In this path of work, the rapid advances in technology and communication, as well as certain effects caused by the massification, interrelation, and homogenisation of current cultures (Camacho, 2010), have led to the loss of the identity character that was previously evident in certain urban spaces. However, despite the blurring of distinctive features within today's essentially Western-based culture, there are still pockets with certain peculiarities and characteristics that remain and evolve (Llopis et al., 2015).

## 2. On the principles of cultural tourism and sustainability: Historic centres

The historic city centres correspond to these urban redoubts that maintain their singular character, remaining as remains of the living memory of the identity of the cities, since "in the city, the historic centre is configured as a paradigm of our background of all kinds, our past, the heritage, and the long journey until today," one of its most interesting values being the "fidelity to its belonging: its belonging to a geography, to a landscape, to coordinates within the great territories," which is reflected, among other things, in a determined use of colour and matter.

The delicate relationship between cultural tourism and sustainability speaks of the correct planning and management of our historical, cultural heritage linked to tourism, and it has become a key to action on heritage. The planning of a model for the development of cultural tourism in a historic city must bear in mind that tourist activity must be an economic activity, governed by the principles of quality and sustainability, capable of contributing to the maintenance and conservation of cultural heritage, avoiding the deterioration of cultural assets and respecting conditions of habitability. Innovative cultural strategies and quality tourism promotion are representative factors for Cultural Tourism in historic cities (Royo, 2019).

During these years, tourism was integrated as a relevant issue in the urban agenda; an express tourist policy was formed, and the rest of the urban policies assumed the tourist discourse as their own. Along the same lines, the World Tourism Organisation (WTO) defines cultural tourism as "any movement of people motivated by the need to satisfy the human need for diversity, giving rise to an elevation of the individual's cultural level and encouraging new knowledge, experiences, and encounters." In a positive sense of the definition, it has been considered that cultural tourism should facilitate knowledge of one's own culture as a means of enrichment. Still, it does not leave behind the tensions caused by the sector's industry associated with consumption, as on occasions, tourism becomes a source of problems due to poor or lack of management that can cause populations or historical areas to become products of mass. Consumption and loss of their authenticity and identity value is the extreme commodification of heritage, especially of its traditions and customs, which can go so far as to strip them of their true meaning and provoke a process of deculturation (Figure 1).


**Figure 1.** Tourists in the historical centre of Málaga. Source: Royo, L. (2023)

This is both the upside and the downside of the phenomenon of cultural tourism, which has a large academic bibliography, very interesting manuals, and recent experiences in tourism planning and management, which have been included in the plans for historical centres.

With the emergence of the new heritage category of cultural routes and itineraries in the city, we are offered the possibility of creating a new form of tourism management that goes beyond the traditional route or itinerary, encompassing new concepts applied to historical-cultural heritage and introducing new technologies. To pursue this objective, all those tangible or intangible assets that are linked to the different cultural landscapes must be taken into account; in this specific case, we refer to the painted architectures, where the context becomes an essential element to explain, give meaning and understand a story: ways of life, artistic heritage and cultural baggage of a town or city (Pinto, 2018).

## 3. Protection and recovery of historic centres. Malaga under debate

The recovery of historical centres, specifically Malaga's, has become a key to reviving tourism and the economic development that results from it for the municipality's benefit. Thanks to the demand for activities to do, places to visit, and places to rest, eat, stay overnight, and invest, Malaga is positioning itself as a city for new uses and its recognition in an urban space that is being transformed to meet new cultural and tourist objectives associated with the values of the historic city. However, we must go back a little in time to find out the reasons for this recovery and, above all, for the marked physical, functional, and symbolic degradation into which the historic centre of Malaga has fallen at a certain point in its history. In its most critical and, at the same time, a most important period in terms of economic development (1955-1975), the city of Malaga was subjected to rapid and uncontrolled urban growth, accompanied by an inoperative instrumentation that began with a PGOU approved in 1950 by the Central Commission for Local Health but which was never applied. The reasons for this were economic interests and speculative processes, which, in favour of development, led to the inoperability of restrictive urban planning measures (Olano, 1972).

We would have to wait until 1971 for the new PGOU of Málaga to be approved. At that time, the main objective was to guide and control the new growth inherited, leaving out of this regulation any mention of the state of conservation, rehabilitation, or recovery of the historic centre. These issues would worsen over time and would be taken up in the following PGOU of 1983 when it stated the need for the "recovery and conservation of the urban structure and its building typology through rehabilitation processes; control of tertiary activities, maintenance of the population, etc...". For these purposes, specific regulations were drawn up for the city centre, which included the historic centre as a sub-zone. Two years after the approval of the PGOU, on 18 July 1985, the Directorate General of Fine Arts initiated the official processing of the file for the declaration of the Historic-Artistic Ensemble of the Centre of Malaga as an Asset of Cultural Interest (BIC), which was published in the BOJA on 2 August of the same year. A file that was born under the figure of the Central Nucleus of the Property of Cultural Interest "Historic-Artistic Ensemble of Malaga" and that would end definitively 27 years later by Decree 88/2012, of 17 April, by which the delimited sector of the city of Malaga was inscribed in the General Catalogue of Andalusian Historical Heritage as a Property of Cultural Interest, with the typology of Historic Ensemble.

The fact of initiating the declaration process in 1985 would entail, as stated in Article 20 of the Heritage Law, the obligation to draw up a Special Protection Plan for the area in question and, to this end, a Special Protection Plan (PEP) was approved in 1988, to which a Plan for Internal Reform (PEPRI) was incorporated in the same document, approved for all legal and urban planning purposes in 1990. As a consequence of all the above, the historic centre of Malaga was plunged into a long period characterised by abandonment, degradation, and the substantial loss of an urban and architectural heritage to which it would not be possible to return. This situation is where different cultural, tourist, and strategic policies have recently approached in an effort and interest in its recovery, perhaps too late.

## 4. Colour schemes and their management: the cataloguing of baroque wall paintings

With regard to the role of colour in the process of heritage recovery in historical centres, the cultural legacy of painted façades is represented in a wide area of central, northern, and southern Europe. In an approach to the different territorial areas of Italy, Spain, and Central Europe, one can "notice the importance that the integration of these painted architectures has had, making them participants in the historical construction of their urban image" (Royo, 2022). However, with few exceptions, urban rehabilitation plans do not show much interest in this cultural heritage (Figure 2).

**Figure 2.** Tourists in the historical centre next to the Church of El Sagrario in Malaga, with mural paintings on its exterior. Source: Royo, L. (2023)

The recovery and conservation of these spaces should have led to the understanding and preservation of the principles underlying the very image of the city. This fact is what imposes the need to establish a scientific methodology for systematic studies of architectural and urban colour that will make it possible to endorse the most suitable conservation and treatment criteria for each case in order to maintain the unique characteristics of the urban environment, especially in areas of historical interest such as historic city centres. These methodologies of colour studies for their integration into protection plans have only been applied in a few Spanish cities, such as Barcelona, Malaga, and Valencia, among others. (Collado y Medina, 2002).

In the field of the conservation of exterior painted architecture and its inclusion in colour plans, Barcelona was a pioneer with its slogan “Posa’t guapa,” transforming a very different reality, thanks to Joan Casadevall and his team, which would later be incorporated in Andalusia (Casadevall, 2005). This was followed by Granada, and especially Malaga, whose PGOU has granted specific protection to painted architecture.

In general, except for specific restoration or rehabilitation interventions linked to nationally relevant research work, there is no interest in internationalising this cultural legacy, which, due to its peculiarity, makes it a unique opportunity to resize the cultural tourism image of Spanish cities. Perhaps with the help of new technologies, we can achieve this purpose.

## 5. Cataloguing wall paintings in Malaga. A project based on sustainability

There are many examples of how Malaga was a painted, colourful, and very baroque city. On this occasion, we are moving forward from what is currently in force and what users demand, that we interpret and make known this cultural legacy with new technology applied to virtual reality, augmented reality, and 360º videos with the development of texts that allow us to create experiences that captivate the public to such an extent that they want

It is the Town Council of Malaga that has its competencies in its municipal area regarding "Protection and management of Historical Heritage" (Law 7/1985, art. 25.2.a) and, at the same time, must conserve, protect, and guard, in particular, those of its property (Law 16/1985, art. 36.1). To guarantee the conservation, protection, and custody of its assets most effectively and efficiently, it is necessary to coordinate the management of all the aspects that affect it, in coordination with the rest of the City Council and the context of the rest of the city's historical heritage. Motivated by the need to establish effective protection measures for the mural paintings, it was established from that time onwards that, when applying for a building permit, a prior report was requested from the Archaeology Section, which established a condition in building renovation projects to document, protect and recover the pictorial repertoire and original treatment of façades. This procedure completed the work carried out since 1995 by the Municipal Housing Institute through the Office for the Rehabilitation of the Historic Centre. (Royo y Prado, 2023).

In the development of the Renovation of Historic Centres project, carried out in 2003, various studies, analyses, diagnoses, and recommendations were drawn up to assess the state of conservation and observe the management dynamics in the PEPRI area. Among others, it was proposed to enhance the value of the Painted Architecture of the Modern period, mainly corresponding to the last stage of the Malaga Baroque period in the 18th century. In this work, the Planning Department took on this initiative, drawing up a proposal in 2005 specifying the need to carry out parietal studies before granting a license in those buildings where remains of mural paintings were located. The year 2011 saw the incorporation of historical-artistic heritage protection into municipal regulations and management with the General Urban Development Plan (PGOU), Title X, Section 6, which initially allowed 192 walls to be protected. In 2012, Decree 88/2012 of 17 April established a further step forward in protection, with the inscription in the General Catalogue of Andalusian Historical Heritage of the Historic Ensemble of Malaga as a BIC, also pointing out the new criteria for the valuation and protection of cities and highlighting in the justification of the delimitation, the recovery of numerous buildings with mural paintings as one of "the most interesting images of the city." In 2013, the Provincial Historical Heritage Commission approved the documentation submitted by the City Council regarding the "Structural Modification 7" of the Urban Development Regulations of the PGOU in force, and the protection of mural painting was included in the architectural regulations of Title XII, being also regulated in art.12.4.12 of chapter four, updating the list of buildings with mural paintings. The current PGOU of Malaga includes Title XII, Mural Paintings: "as an instrument to regulate the defence and protection of the group of buildings with mural paintings and/or ornamental repertoires on façades belonging to the Baroque period in Malaga, incorporating a list of properties in which their presence has been confirmed or which are likely to contain them" (Figures 3 and 4).

**Figure 3.** Street Arco de la Cabeza two on the corner of Plaza Virgen de las Penas 5. Source: Royo, L. (2023)

**Figure 4.** Santísimo Cristo de la Sangre, plaza 2, Museo del Vidrio. Source: Royo, L. (2023)

 

## 6. Methods and procedure

Applying new technologies to the protection of Historical Heritage has, in the formative stages of heritage studies, a guarantee of involvement in future generations of professionals. Many institutions and companies in the public and private sectors and university research groups have already opted for these instruments to complement comprehensive rehabilitation, restoration, customisation, and knowledge projects of our cultural legacy. When approaching the application of new technologies in the field of Historical Heritage, we must bear in mind that this is nothing more than the object of study or action of protection, so it is this that scientifically defines the heritage action. Hence, its methodology, objectives, and foundations should determine the characteristics of the application of new technologies (Gómez & Quirosa, 2009).

In this part of the journey, where the use of Information and Communication Technologies (ICT) plays a leading role, tools with which to work on the heritage project and in the construction of measures with which to design and improve the conditions of accessibility and dissemination in the interests of sustainable tourism. (Peral y Royo, 2018). This is a process of no return to which different administrations are committed, with greater or lesser success, to increase profits by reducing the depletion of the resources of the Cultural Heritage immersed in the tourist circuits of the 21st century.

Linked to the first phases of heritage work, cataloguing and its subsequent protection, it is important to identify those technologies that allow them to be applied with greater versatility to the knowledge and identification of cultural assets. It comes as no surprise that recently, and with increasing prominence, we have seen examples and research that demonstrate the scope of knowledge in interventions on cultural assets of different magnitudes and that attempt in a certain way to discover information through technology that was hitherto unknown or unavailable to us. In this way, we consider it a priority to refer above all to the elaboration, monitoring, and access to all that information and/or research relating to the knowledge of the assets, which in some way constitute the main body of the general catalogues and inventories of Historical Heritage, both national and those drawn up by each Autonomous Community (Royo, 2014)

ICTs are currently a vital tool for the dissemination of cultural heritage as they have undergone a strong process of diversification in recent years and, along with traditional web channels, a multitude of tools and other aspects, such as augmented reality, have been developed that are vital for its dissemination (Caro et al., 2015). The application of instruments and new technologies, in this case, digitising documents or creating tools that facilitate their direct consultation or virtually recreating pieces, constitute an instrument that directly relates new technologies and the conservation of these assets, making it possible with their development to have an agile tool that is easy to update and accessible for consultation in documentation centres, museums, and cultural institutions (Ortiz, 2007).

In recent decades, BIM (Building Information Modelling) technology has become the most widely used collaborative work methodology in the architecture, engineering, and construction industries to create and manage digital representations of the physical and functional characteristics of buildings and other structures with a very direct application to the field of heritage (Baraibar et al., 2022). Its direct use in the heritage field also allows collaborative tools and 3D modelling to optimise asset design, construction, and maintenance, such as buildings in our field (Valdespino Tamayo, 2016).

BIM methodology is at the heart of the digital transformation of the construction sector, and Public Administrations across Europe are taking proactive steps to promote its use. The use of BIM in the management of Cultural Heritage projects allows us to achieve the following objectives (Martín, 2018):

- Adequacy and organisation of the information system according to the specific characteristics of the cultural assets and the fields of knowledge involved in their analysis, guardianship, and dissemination;
- Adequacy of graphic documentation and modelling of cultural assets according to their formal and constructive characteristics.

Within the life cycle of cultural heritage assets, the optimisation of the digital use of information facilitates the management control of the execution of actions that are carried out (Ruiz Torres, 2013) The recently developed Building Information Modelling (BIM) technique combines 3D modelling and information management. One of its modern applications is heritage documentation, which has generated a new concept of historical/heritage building information modelling (HBIM).

In the practical case of Malaga and the digitised façades, the methodology used has opted to work with the Leica-RTC360-3D Reality Capture Solution laser, capable of allowing scanning at 2,000,000 points per second and advanced HDR imaging system, in the creation of 3D point clouds in colour, allowing completion in less than 2 minutes, a range of up to 130m and an accuracy of 1mm at 10m. with 3 HDR 360 cameras that generate a combined image of 345MPx. (Ruiz Torres, 2017).

For the captures, at least three positionings were made for the building to achieve an accuracy of 1mm. The point cloud created by laser scanning allowed a BIM model of the current state to be created (a process known as Scan to BIM). This model has been used to establish the current state and the main dimensions of the paintings and elements to be analysed, which would be difficult to obtain by other means. Some significant examples can be seen in the images rescued as point cloud models obtained (Figures 5 and 6).

**Figure 5.** Arco de la Cabeza, cl. 2 –Virgen de las Penas, Plaza. 5. Source: 360 BIM.

**Figure 6**. Constitución, plza. 13-14. Source: 360 BIM.

 

Concerning the number of positions used to obtain the images scanned in BIM, it is important to point out that the same number of points has not always been required in the works delivered to Malaga City Council. For example, we can point out the scanning of the mural paintings of c/Arcos de la Cabeza (Figures 7 and 8), which presented the complexity of needing more positions than usual until now.

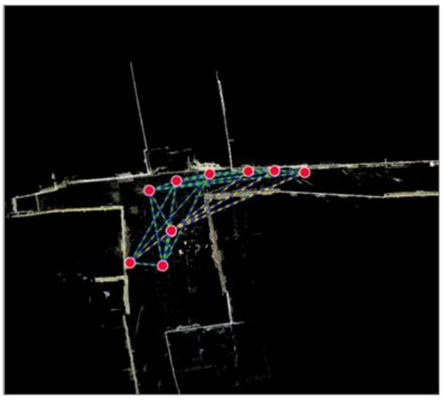

**Figure 7**. Taking of scanning points Arco de la Cabeza, cl. 2 –Virgen de las Penas, Plza. 5. Source: 360 BIM.

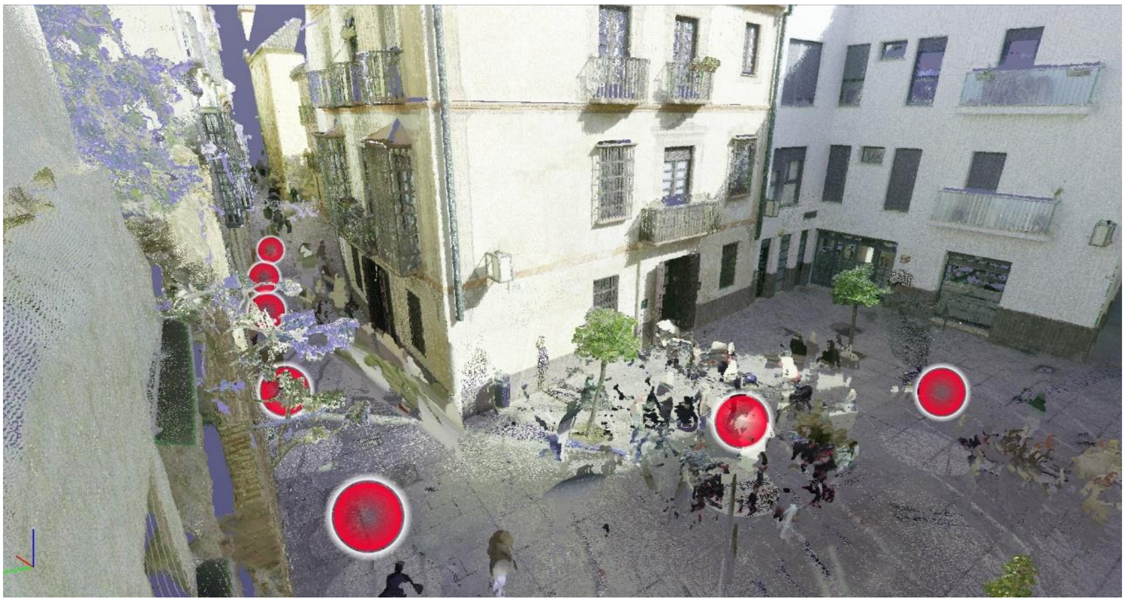

**Figure 8**. Taking of scanning points Arco de la Cabeza, cl. 2 –Virgen de las Penas, Plaza. 5. Source: 360 BIM.

As can be seen in the image, in this case, nine reference points were taken due to the urban position of the support building on a corner and very close to a wall, which made it more difficult to obtain a quality result with a smaller number of positions.

Although, indeed, the scanning of façades usually includes a percentage of shadows, as a consequence of the different architectural projections or elements that can be found, such as corbels, entablatures, closures, or balconies, their use acquires greater information in the final result than that obtained from a high-quality photographic image.

The scanner used, even without being calibrated, obtains, together with the BIM, an HDR photograph (high dynamic range images) whose quality is not at all questionable. Thus, when the laser scanning is carried out, we obtain an acceptable quality in the resolution of the possible changes, with an overall error of 1 mm (Figures 9 and 10). This margin of error allows us to control slumps or remains of pathologies in the future while allowing us to repeat the exercise soon and check the possible changes that the strata may have undergone, which would not be possible with another tool.

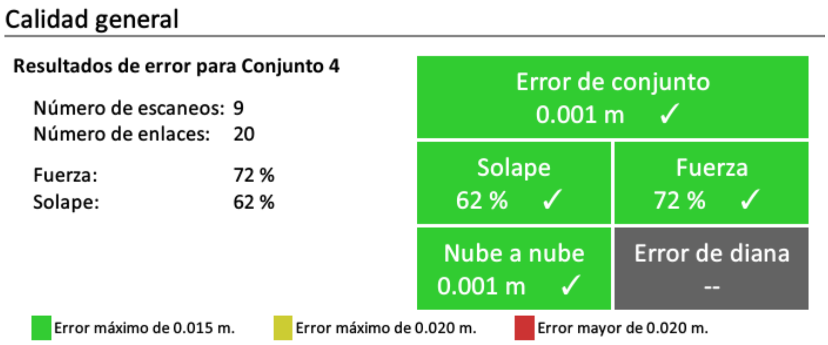


**Figure 9**. Calidad de los puntos en escaneo Arco de la Cabeza, cl. 2 –Virgen de las Penas, Plza. 5. Source: 360 BIM.

**Figure 10**. Scanning data collection details Arco de la Cabeza, cl. 2 . Source: 360 BIM.

## 7. Conclusions

The recovery of architectural and urban heritage in historic centres has become a priority, acquiring great value as a cultural product for cities as it supports local identities and is an important asset for growth (Armenta & Royo, 2017). This being so, the recovery of historical centres and their conversion into tourist destinations positions cities for new uses as urban spaces that must be transformed to meet cultural and tourism objectives associated with the values of the historic city. However, the thin and delicate line that separates tourist enjoyment and, therefore, those positive effects received also generates a series of dark and negative issues associated this time with phenomena such as the touristisation of heritage and the historic city (Grevtsova y Sibina, 2018).

The conservation of mural paintings, their effect on colour plans, and didactics and new technologies incorporated into the discourse of cultural tourism, are the elements that constitute the axes on which our research is based. We propose to create a transversal discourse encompassing the cultural legacy of painted architecture in a highly modified urban landscape subjected to the demands of contemporary dynamics. The vulnerability of this heritage is so great that it is doomed to disappear if joint action is not taken, and this type of research and knowledge initiative is a manifestation of the implementation of strategies that demonstrate its high heritage potential. The planning of a development model for quality cultural tourism must bear in mind that tourism activity must be an economic activity governed by the principles of quality and sustainability, capable of contributing to the maintenance and conservation of cultural heritage, avoiding the deterioration of cultural assets and respecting conditions of habitability (Caro et al., 2015).

About the intervention work, the incorporation of new technologies plays an increasingly relevant role, being an essential reference in all methodological processes of knowledge, treatment, and enhancement of cultural property, given the high degree of technification acquired by conservation and restoration in recent years, both at the level of scientific instrumentation and the increasingly precise and sophisticated analyses (Bellido, 2018).

 

As a complementary working tool in disseminating and interpreting heritage, ICTs facilitate general access to knowledge for society and, therefore, protect and conserve our heritage. This aspect of guardianship is not only related to the consultation of databases or digital documentation but also to access to all types of information, which, in turn, heritage research allows us not only to visit or consult, thanks to the digitalisation of documents or databases, but also to the use as a support for dissemination and reconstructions and virtual recreations in 3D of the assets which have become one of the most important tools for research, conservation, and dissemination of cultural heritage, allowing us to understand graphically part of our history in the different spaces provided: museums, documentaries or information sheets. (Quesada, 2019). Although the field of cultural heritage is full of intentions related to digital approaches and community participation, there is still a lot of work to be done, especially when trying to include both aspects of heritage conservation in the same experience.

Finally, and in relation to the level of innovation in the work presented, it is important to point out that never before had studies like the one we present been carried out in the specific case of the previous studies carried out on mural painting in the city of Malaga. Until now, data had always been collected to obtain information related either to illustrate the type or as part of the studies before a future intervention related to the state of conservation of the outer layer, ignoring the actual building supporting the mural painting and focusing on obtaining details that would provide more information for future intervention or consolidation. It should be noted that, at least in the city of Malaga, this type of analysis had never been carried out before, nor had this type of result been obtained, where the internal layers and/or the pathologies obtained could be collected and identified to complete the current state of conservation of the entire property.

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# The architecture of the early 20th century in the cities of Harbin (China) and Castelló (Spain)

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***Abstract***

*This research focuses on the historical and architectural analysis of Harbin City, especially on the interpretation of this urban space through historical traces, taking Lao Ding Feng architecture as an example. Much of the history of the city focuses on the Russian and Japanese invasions, so such aspects as architectural styles and the construction of the railway are attributed to the occupation of these countries, more especially to the Russian occupation. The research presents a qualitative methodology and bibliographic review of the baroque-style buildings found in Harbin, which reveals that many buildings today have endured over time and become one of the historical monuments of the city.*

***Keywords:*** *Culture, China, Europe, Neo-baroque, Architecture, 3D models.*

## 1. Introduction

### 1.1. Harbin city, China

China has many ancient Eastern villages, landscapes, customs, and cultures. However, in the late 19th century, in the northernmost part of the country, specifically in the city of Harbin, traditions and styles from nearby Russia were imported. This change was driven by the rapid growth of the city with the arrival of Russian engineers who built the eastern section of the Trans-Siberian Railway (Liang, 2001). During this period, China was in a society that was half colonial and half feudal, with an imbalance between political, economic, and cultural development (Huang, 1994).


**Figure 1**. Map of China, Author (2020)

Harbin is the capital of Heilongjiang province, located in northern China at a longitude of 125° East and a latitude of 44° North (Figure 1). The Songhua River passes through Harbin and the Xiaoxing Anling mountain range is located. The city has a population of 5,071,932 inhabitants (Liu, 2021) and the municipal area has an area of 493.77 km². Situated between the Songhua River and the Xiaoxing'an Mountains, Harbin is often called "Eastern Moscow" or the "Little Paris of the Far East". In the early 20th century, it was once considered China's fashionable capital, which attracted Russian settlers seeking refuge from European wars (Feng, 2017).

The city boasts a unique and exotic architectural and urban style that draws visitors from around the world. Within Harbin, one can find century-old buildings with architectural elements representing both Eastern and Western influences, reflecting the social, economic, cultural, and artistic characteristics of the early 20th century.

Various Western architectural styles have influenced Harbin's architectural history. Each building bears witness to its own story (Li, 1987). Many of these century-old Russian-style buildings still stand in the city centres, such as hotels, restaurants, banks, bookstores, and entertainment venues, enriching local public life (Jin & Wang, 2006). There is a strong local initiative to preserve these European-style buildings due to their historical and social significance for the city.

While some buildings fell victim to wars and revolutionary movements in the first half of the 20th century, several have been reconstructed as part of recent urban regeneration efforts.

### 1.2 Castelló city, Spain

Spain is a transcontinental country in Europe and Africa. The Canary Islands and the Balearic Islands are both archipelagos and autonomous communities of Spain, respectively. There were many ethnic groups living in this land, so the buildings are also diverse.

 

Castelló de la Plana is a city located in eastern Spain and serves as the capital of the province of Castelló. It borders the Mediterranean Sea to the east. It is situated in the northernmost part of the Valencian Community.


**Figure 2**. Map of Spain, Author (2020)

The city's geography is mostly flat compared to the surrounding region's mountainous areas. It enjoys about ten kilometres of coastline along the Mediterranean. The main urban area sits about thirty meters above sea level and is approximately four kilometres from the coast. Within its municipal boundaries lies the confluence of the 40th parallel and the prime meridian, known as the Greenwich meridian (Figure 2).

According to data from the National Institute of Statistics, the population of Castelló is approximately 176,238 inhabitants (INE, 2023). Its metropolitan area, comprised of two urban centres (Castelló city and the maritime district of Grau) and various dispersed population groups within its 107,50 km² municipal area, is estimated to be around 300,000 inhabitants. These figures make Castelló de la Plana the fourth largest city in the Valencian Community by population.

The Puerta del Sol (Sun Gate) of Castelló de la Plana is the city's heart, connecting its main commercial and important avenues. Since the early 20th century, this square has been the economic and social centre of Castelló, linking key commercial avenues such as Trinidad, Enmedio, Gasset, Ruiz Zorilla, and Plaza Real.

Over time, the Puerta del Sol has been known by many names, including Plaza de Isaac Peral, Plaza de la Unión, Plaza de la Salina, Plaza de Castelar, and finally, Puerta del Sol.

## 2. Objectives

The main objective of this study is to analyse the buildings constructed in the late 19th and early 20th centuries in Harbin, China, and those built in Castelló de la Plana, Spain, to establish relationships and connections between their architectural styles.

Therefore, this research compares the buildings of Harbin and Castelló de la Plana to identify any relationships between them. It also seeks to analyse the characteristics and evolution of the architectural style of both cities.

## 3. Methodology

To carry out this research, different activities related to heritage study and architectural surveys have been conducted. First and foremost, extensive research was conducted to gather historical, graphic, social, cultural, and artistic information. Second, an extensive on-site data collection of the studied buildings was performed for subsequent graphic representation. Third, the obtained digital information was classified, and digital models were generated using software such as Autodesk AutoCAD, Sketchup, and 3DS Max, which objectively represent the buildings.

## 4. Research buildings

To understand the evolution of architectural structures during the study period, several buildings in both the city centre of Harbin and Castelló were investigated. Notably, the type of buildings studied is similar to those constructed in other parts of Europe during the same period.

In Harbin, the Song Pu building and the Lao Ding Feng building were selected for study (Table 1).

On the other hand, in the city of Castelló de la Plana, the buildings chosen for study were those located in the current Puerta del Sol and the building of the former Savings Bank of Castelló (Table 1).

**Table 1.** Research buildings

| Harbin | Castellón de la plana |
|---|---|
| Songpu Foreign Firm (松浦洋行) | Bank of Castellón |
| Harbin Laodingfeng (哈尔滨老鼎丰) | The commercial and industrial circle of Castellón |

### 4.1 The Songpu Foreign Firm (松浦洋行)

The Song Pu company building is located at 120 Zhong Yang Street in the Dao Li neighbourhood of Harbin, China. It faces Hongzhuan Street, which is completely symmetrical in terms of the bisector formed by both streets. Construction began in 1906 and was completed in 1909. The architect responsible for the project's design was the Russian A.A. Myakoko (Yang, 1993). The specific information is as follows Table 2.

**Table 2.** Information about the building Song Pu

| Name | Song Pu or Matsuura Hiroyuki |
|---|---|
| Chronology | 1906-1909 |
| Architect | A.A. Myakoko (Russia) (Wu & Zhao 2016) |
| Architectural Typology | Commercial building. Ground floor plus 4 floors |
| Architectural Elements | Neobaroque elements on its facade |
| Construction Typology | Brick facade. Mansard roof covered in copper. Spherical dome. |
| Materials | Brick, mortar plaster, cast iron railing, and metal roof (Xie & Tan 2019) |
| Colors | Gray and red |

The Song Pu building on Zhong Yang Avenue can be considered the classic architecture of Harbin, regardless of the time of its construction or the artistic style in which it is framed. Built between 1906 and 1909, the 'Song Pu' building is a representative work of neo-baroque architecture, characterised by its beautiful appearance, vivid modelling, complex decoration, and rich contours. The crimson attic, Bangsar-style roof, and semicircular dome resemble a beautiful horizon. The use of brick and concrete reflects Harbin's architectural art style "baroque." The entire building is designed to create a dynamic and ascending form, representing early Harbin architecture (Figure 3).

**Figure 3**. The building of Song Pu in 1909 (Plataforma 2019) and 2019 (Author).

The ground and first floors of the Song Pu building are simple. Specifically, the ground floor has lintel windows, and the first floor has depressed straight arches, except at the corner, where they are semi-circular. The openings are framed by rectilinear pilasters, except in the corner area, which is framed by two Tuscan order columns on the ground floor. On the first floor, these columns transform into a caryatid and an atlas emerging from volutes, framing the main entrance of the building. These sculptural figures, with great plasticity, have inclined heads resembling a praying position, which may be due to the religious origin of this architectural style, reflecting some myths. On the first floor, corbels or brackets emerge to support the columns of the upper levels, each featuring a sculpted lion's head, the most common zoomorphic pattern in Baroque buildings (Figure 4). What should be noted is that the lion in China signifies dignity and majesty. In ancient China, lion statues were placed in front of important places or homes to symbolise power and nobility. In this way, this incorporation indicates a connection between Western and Eastern cultures in this building.

**Figure 4**. Side façade. First floor and Corbel with lion and caryatid head design (Author, 2019)

### 4.2 The Lao Ding Feng Building

The Lao Ding Feng Food Company was founded by Wang Ada and Xu in Harbin, China. This neo-baroque-style building is known for its distinctive façade pattern and is situated in the Dao Wai neighbourhood at 392 JingYu Street, Harbin.

Lao Ding Feng became famous because Emperor Qianlong enjoyed desserts from this brand. It was constructed in 1911 and remains popular even after 110 years (Figure 5).

**Figure 5**. Exterior image of the Laodingfeng building in the year 2000 (Zhou, 2018) and 2019 (Author)

This building features two floors but is quite long, so there are two doors on the ground floor. The main entrance is located on the façade of the building and has a semicircular shape, a characteristic often repeated in many Baroque-style buildings. In addition, the side door is on the right side of the building, and the wall is straight overall. At the top of the building is a unique pattern and shape known as a "parapet wall," which features designs based on grapes and vines (Figure 6). The round grapes symbolise a full life and abundant offspring. This pattern also uses the most common symmetric technique in the Baroque style (Lan, 2018).

**Figure 6.** Pattern on the parapet wall and drawing pattern (Author, 2019)

On the façade of the building's wall, you can see a lot of plant patterns (Figure 6), typical of the Baroque style. Semicircular decorations will be on each second floor window, along with a small post dividing the window into two sections, reflecting the building's aesthetic. The ground-floor windows are different from those on the first floor; these full windows have lintels, and the pattern is composed of semicircles and symmetrical cloud shapes. In Chinese culture, cloud patterns like these symbolise luck (Figure 7). Below each window on the ground floor is a complete flower pattern, and four symmetrical columns adorn the ensemble. Overall, every detail of the Lao Ding Feng building's façade contributes to its ornate design.

**Figure 7.** The pattern on the corbel and drawing pattern (Author, 2019)

 

### 4.3. The bank of castellón building

The building of the Bank of Castellón, located on Trinidad Street, is a bank headquarters built in 1923 by the architect Francisco Tomás Traver (ACTC, 2023). It currently belongs to Caixabank. The original façade was flanked by two Corinthian order columns, which were unfortunately lost during a renovation. In addition to the columns, the work of the sculptor from Castellón, Juan Bautista Fola, included two classical sculptures. In 1960, the architect Mr. Vicente Traver Espresati would remodel the ground floor (Figure 8).

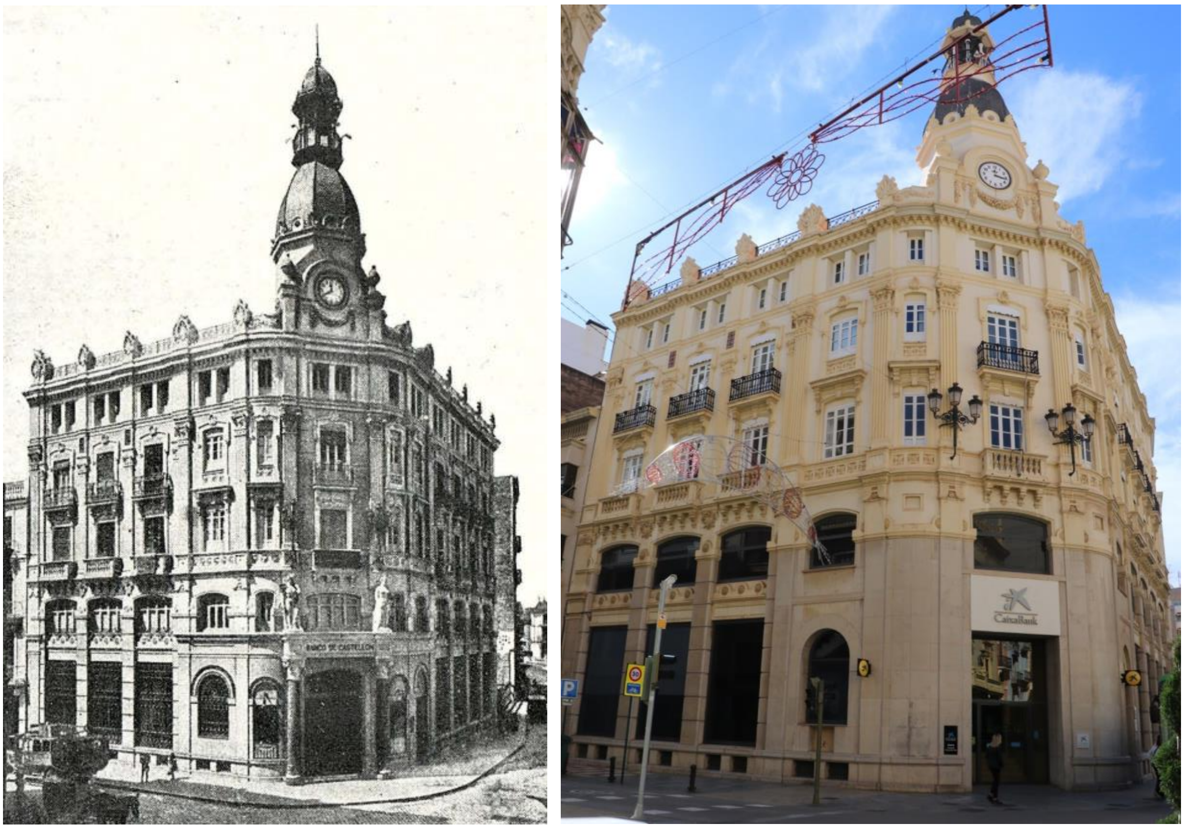


**Figure 8.** The Bank of Castellón building in the past (Pastor 1931) and now (Auhtor, 2020)

The building is distinguished by three levels: the first level consists of the ground floor and the mezzanine, with continuous decoration based on pilasters between each partition; the second level consists of the first, second, and third floors, which have fluted shafts. The capital connections between the pilasters and the openings; the third level corresponds to the upper level, which features cornice decorations, a balustrade, and an octagonal clock tower with lanterns on the corners. Most of the decorative elements reflect classicism and eclecticism, but modernist elements and botanical motifs were also incorporated into the design.

It is also worth mentioning the majestic wrought iron gate on the first floor of the bank, so delicate and incomprehensible. They were replaced by glass, which removed all the stately packaging that the bar gave to the side façades of Puerta del Sol and Trinidad Street.

### 4.4. The casino of the mercantile circle of Castelló

1897 the Circle of Artisans and the New Casino merged, with Miguel Armengot Rubio as its first president. Later, the Mercantile and Industrial Circle was located at 109 González Cherma Street (now Enmedio Street), and in 1909, they moved to Falco Street and Gasset Street in Puerta del Sol. The façade featured exterior terraces on both sides and two Solomonic columns on the corners, from the first to the second floor. Unfortunately, it was torn down in 1970 (Figure 9).

The Mercantile was once the headquarters of bands and music schools. From 1910 to 1924, it was home to the Band of the Firefighters Company, whose members then formed the Municipal Band in 1925. Also, in the 1930s, chess tests were held here in Castelló. By 1955, it became the Red Cross (Breve, 2019).


**Figure 9.** The Casino of the mercantile circle of Castelló in the past (Mon, 2018) and now (Author, 2020)

This building was primarily used as a major trade industry by the Republicans as a centre for leisure and entertainment during the Second World War. At the outbreak of the war, the Popular Front took over the building, installing offices and warehouses for their activities. In 1953, due to the presidency of Ricardo Gómez, the society was reorganised, and various buildings in Puerta del Sol in Castelló resumed operations (Mon, 2018).

## 5. Graphic documentation

Based on the graphic survey conducted, plans of the building façades have been developed using the Autodesk AutoCAD tool, which provides clear orthogonal views. These plans will allow for the subsequent analysis of the building from a metric and geometric perspective.

Then, starting from the building's floor plans and elevations, building modelling was carried out using Sketchup software and subsequently exported to 3D Max software for rendering. As shown in the following next Figures.

### 5.1 The Songpu Foreign Firm (松浦洋行)

According to the data provided by the building administrator and the measurements of the building, plans of the building's facades have been prepared using the AutoCAD tool and orthogonal views of them have been obtained. These plans allow an analysis of the building to be developed from a metric and geometric point of view (Figure 10).

 

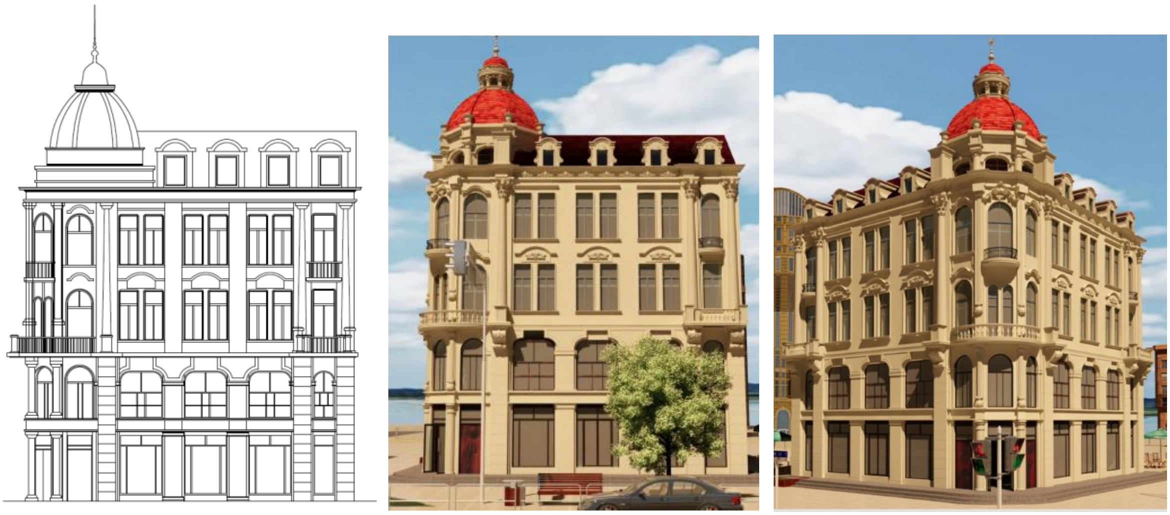

**Figure 10.** Façade plan and rendered. 3D view of the building (Own elaboration)

### 5.2 The Lao Ding Feng Building

From the graphic and measured survey carried out, plans of the building's facades have been prepared and the AutoCAD tool has been used to do so, through which orthogonal views of them have been obtained (Figure 11). These plans allow an analysis of the building to be developed from a metric and geometric point of view.

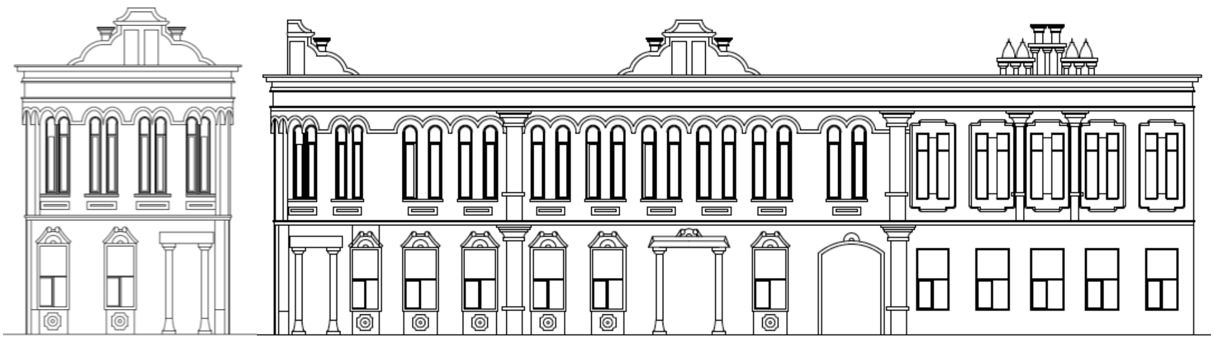

**Figure 11.** Façade plan of the building (Own elaboration)

**Figure 12.** Rendered. 3D view of the building (Own elaboration)

### 5.3. The bank of Castelló building

Documentation of the floor plans has been found in the UJI repository. The data have been organized to prepare a graphic survey of the Banco de Castelló building using AutoCAD and SketchUp software (Figure 13).

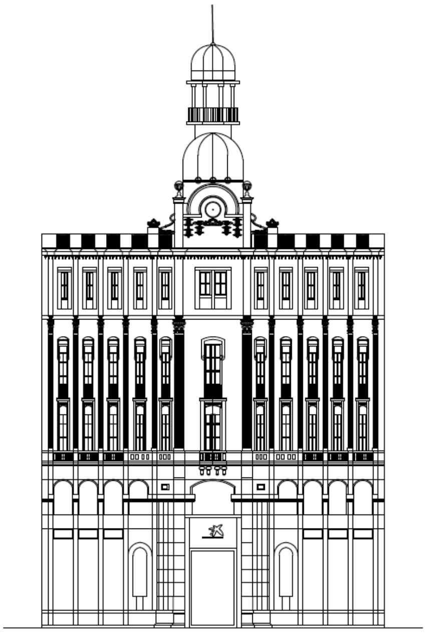


**Figure 13.** Façade plan and rendered. 3D view of the building (Own elaboration)

### 5.4. The Casino of the mercantile circle of Castelló

Although the building no longer exists, it will still be remembered for the Solomonic columns on the main façade. To create the virtual model of the building, AutoCAD and SketchUp software have been used to simulate and generate a virtual model of the building from the floor plan obtained from the cadastre cartography and by studying the historical images as can be seen in the Figure 14.

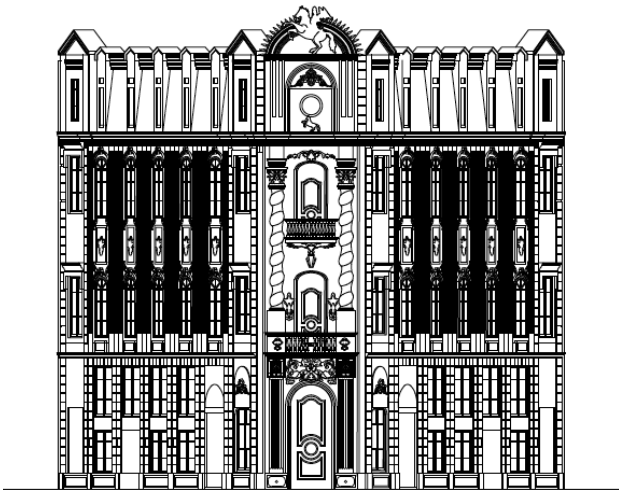


**Figure 14.** Façade plan and rendered. 3D view of the building (Own elaboration)

## 6. Conclusions

The architecture of the early 20th century in the cities of Harbin (China) and Castelló (Spain) comes with both similarities and differences. Both cities have European-style buildings, and Harbin's architecture is heavily influenced by Russian architecture. The historical buildings in Harbin uniquely blend Chinese and Western elements, while the architecture of Castelló focuses more on neoclassical and modernist styles. In addition, both cities have made efforts to preserve their historical buildings, although some have suffered damage from wars or neglect. Overall, the early 20th-century architecture in these cities represents a blend of cultures and architectural styles that reflect each region's history and cultural influences.

Harbin has undergone several events to become what it is today. In 1898, engineers and workers from the Qing Dynasty and Russia began building the Middle East Railway. Subsequently, a large number of Russian Jews fleeing domestic persecution, Russian nobles forced to leave due to the Russian Revolution, and White Russian troops seeking refuge after the defeat of the Civil War settled successively in Harbin.

The historical buildings in Harbin showcase strong Western influences, mostly designed by foreign architects of Russian nationality. The shapes are novel and romantic, solemn, fresh, elegant, or uniquely innovative. The façades and roofs of the buildings are unique to Baroque architecture. The contrast of stones, strong light, and shadow effects, as well as the colours of the buildings, are in Laodingfeng architecture, which is found in eclectic buildings. Besides, the architectural style combines Western Baroque, classicism, Renaissance, Art Nouveau, eclecticism, and Jewish style, where we also find Chinese architecture and modern Japanese architecture. Harbin has several mixes and important features of European cities and colonial cultural characteristics.

Most of the European-style public buildings have domes, especially churches designed in Russian and Byzantine styles. These buildings are characterised by towering domes, bell-shaped roofs, or tent roofs, forming a symbolic cityscape filled with domes. For example, Lao Daowai, known as a historic area, has more than 70 European-style buildings and imitation Baroque-style buildings. The four most influential architectural genres in the history of Western architecture are fully displayed, spanning almost 300 years of European cultural development.

Hundreds of neo-baroque buildings off the road are typical representations of the integration of Chinese and Western cultures for a century, reflecting deep Eastern cultural connotations and cultural characteristics of the combination of Chinese and Western cultures.

These buildings not only show the characteristics of the integration of Chinese and Western architectural cultures but also demonstrate a strong taste for "folklore." This is because most of the construction of these buildings is done by popular craftsmen. These people have been deeply influenced by the folklore and culture of both countries, especially traditional Chinese.

According to the research questions mentioned above we have found answers to both research questions. As for the first question about the condition of the buildings, it appears that some structures are well-maintained and in optimal condition. This is because the State Administration of Cultural Heritage has designated several buildings as a national unit for the protection of key cultural relics. However, during the wars, some buildings did not survive over the years.

Regarding the second research question regarding the use of the buildings, they are currently used by the local population. Some of these historic buildings are used as shops, restaurants, and hotels, among others. There are many shops on the street, and tourists are sitting in the outdoor cafe of the cafeteria, which was once a building built by the Russians for other purposes.

The architecture of Castelló, Spain, is diverse and rich in styles, ranging from Gothic and Renaissance to modernism and rationalism. Specifically, it is characterised by a greater influence of the Baroque and Neoclassical styles, with a less pronounced presence of foreign cultural influences. Castelló boasts numerous historical buildings and monuments, such as the Cathedral of Santa María, the Town Hall, and the Co-Cathedral of Santa María. In addition, modern and contemporary architecture has also developed in the city, with examples such as the Auditorium and Congress Palace or the Coastal Park. The city has managed to preserve its architectural heritage and adapt to society's changing needs and preferences. In this way, it has become an appealing destination for visitors and serves as a testament to Spain’s rich cultural and architectural diversity.

In addition, all the digital models used in this article are for better visual observation. In particular, some buildings have disappeared, and we use digital models to give forms to the buildings and prevent people from forgetting.

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# Architecture in Conservation Areas - Humboldt Hotel, Caracas, Venezuela

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***Abstract***

*The following study provides the latest environmental strategies to reduce the building's energy consumption and mitigate the environmental impact that the Humboldt Hotel will have during the life cycle of the building.*

*As a result, a compilation of historical data from official sources is provided, as well as a technical investigation through Revit Insight and Designbuilder programs to evaluate the energy performance of the building and provide a timely and assertive action plan.*

***Keywords:*** *Designbuilder, Hotel Humboldt, Radiation Analysis, Environmental Impact, BIM model, Energy Consumption Analysis.*

## 1. Introduction

The Humboldt Hotel, located in the city of Caracas, Venezuela, is an iconic work of Venezuelan architecture conceived by the renowned architect Tomás José Sanabria. (Brillembourg, Carlos. 2008). This work pays homage to the explorer Alexander von Humboldt (Sanabria, Tomás. 1957) with its name, the hotel was built in the 1950s and illustrates and accompanies the country's socio-political historical trajectory. (Gómez Rico, Verónica, and Andreina Méndez Antonetti. 2008). Since its conception, this hotel has experienced a tumultuous operational life marked by various closures, changes in its management concession, and prolonged periods of inactivity dating back to 1986. (Gonzalez Capitel, Antón. 1996) In pursuit of the reactivation of this emblematic work of the capital city (Sanz, Pedro. 1997) (Lameda, Hernán. 2017), restoration and remodeling of the hotel facilities is proposed, a project that began in 2000 and concluded in December 2020. However, in emblematic works like these, restoration is focused on conserving the essence and original work of its author, (Vertullo, Gregory. 2019) often overlooking or omitting the importance and innovation of its construction and/or environmental solutions. This paper presents the historical trajectory of the Humboldt Hotel and its surroundings, (León, María Gabriela. 2014) the technical analysis of its remodeling and restoration through bioclimatic tools to evaluate the relationship between major architectural projections and constructions, and their adaptation to new environmental criteria and requirements today.

## 2. Objective

### 1.1. General Objective:

Evaluate sustainability strategies applied to using the Humboldt Hotel to reduce energy consumption and mitigate environmental impact.

### 1.2. Aims:

Analyze the energy behaviour of the building and its environment;

Calculate the environmental impact of the Humboldt Hotel focused on energy consumption during the operational phase of the building;

Identify sustainable strategies to reduce energy consumption during the operational phase of the building;

Quantify the building's energy reduction and environmental impact based on the proposed sustainable strategies.

## 3. Methods and/or procedure

- Analyse the energy behaviour of the building and its environment;
- Calculate the environmental impact of the Humboldt Hotel focused on energy consumption during the operational phase of the building;
- Identify sustainable strategies to reduce energy consumption during the operational phase of the building;
- Quantify the building's energy reduction and environmental impact based on the proposed sustainable strategies.

## 4. Results

A historical record of the changes undergone by the hotel from its inception to the latest rehabilitation is made in BIM software, highlighting the collapsed and new elements (Figure 1).

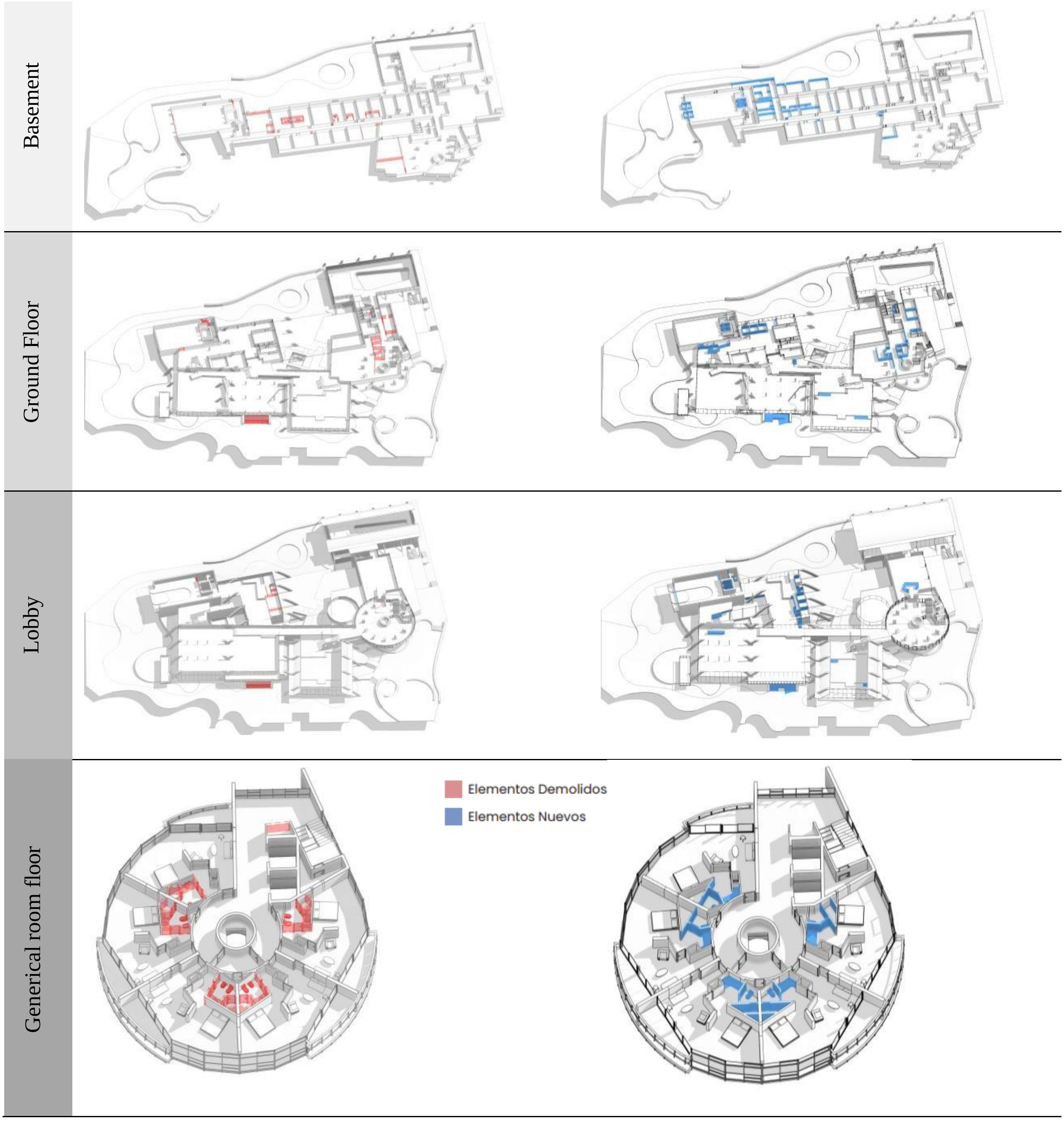


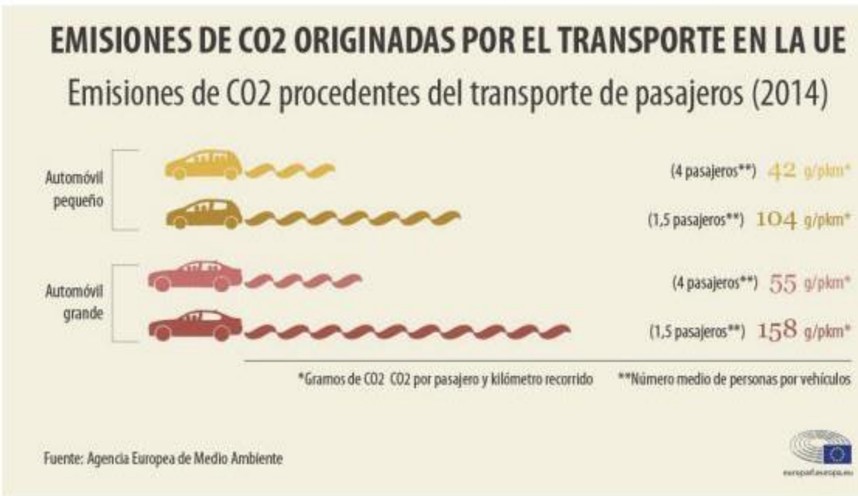

**Figure 1.** Demolished Elements. Own Source

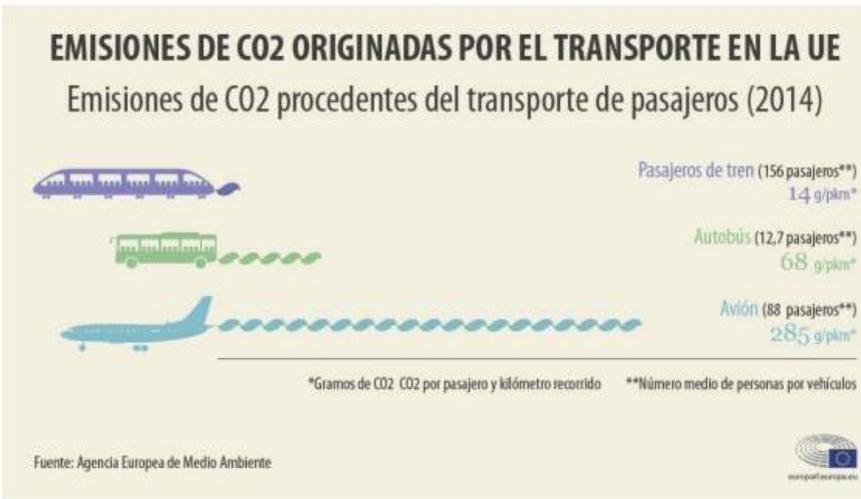
Environmental strategies related to mitigating the environmental impact of the Humboldt Hotel are the following:

### 1.1. Transport and Accessibility

The cable car transport system not only significantly contributes to the accessibility of the Humboldt Hotel but also reduces the carbon footprint and environmental impact on the park (Figure 2). (Biberos-Bendezú, Karen, and Ian Vázquez-Rowe. 2020). Based on the grams of CO² produced per person per kilometre in diverse types of transportation according to the European Environment Agency (2019), (Sandó Marval, Yovanna. 2011) a comparison was made between the cable car system of Ávila and a four-wheel-drive car, considering the following variables:

- Generating 1 GW/h of energy in Venezuela produces approximately 307.4 $TCO^2$/Gwh. (Osal & Pérez, 2019);
- The average energy consumption of the entire cable car system is 415 Kw/h. (Source: Doppelmayr) Considering that for one hour, six complete trips are made with 82 operational cabins, approximately 1.960 people can be transported per hour;
- The approximate energy consumption per person per kilometre of the cable car system is 4.39x10^-8 Gwh/p.km. Calculations are based on the total energy consumption e of the cable car system, the distance of travel, and the capacity of transportation;
- The Cable Car's inclined length (with slope) from the San Bernardino station to the Ávila station is 3,463.77 meters;
- A four-wheel-drive car emits 55 and 158g of CO2 per passenger per kilometre (European Environment Agency, 2019);
- The distance by SUV drive car from the San Bernardino cable car station to the Humboldt Hotel is 11.6 km, while the Cable car system is only 3.5 km. The results of the analysis between the two means of transportation used to travel to the Waraira Repano Park show that the cable car system has an approximate $CO^2$ emissions savings between 3.59% and 32% per kilometre travelled, considering the minimum and average demand of users in this transportation system. (Brida, Juan Gabriel, Manuela Deidda, and Manuela Pulina. 2014) It is noteworthy that the travel distance between both transportation systems is different due to the difficulty of accessibility in the area, further accentuating the advantages of using the cable car system.



**Cuadro 2.** Emisiones **de GEI** por la generación de energía eléctrica (t/GWh) para Venezuela en el periodo 2006 – 2017.

| Gas | Año | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| $CO_2$ | 196.76 | 181.58 | 252.59 | 270.64 | 261.73 | 233.60 | 263.54 | 251.54 | 251.40 | 316.19 | 298.26 | 307.40 |
| $CH_4$ | 0.0148 | 0.0138 | 0.0241 | 0.0252 | 0.0259 | 0.0228 | 0.0256 | 0.0251 | 0.0193 | 0.0249 | 0.0265 | 0.0273 |
| $N_2O$ | 0.9575 | 0.8865 | 1.4369 | 1.5208 | 1.5156 | 1.3385 | 1. 5164 | 1.4662 | 1.2382 | 1.5682 | 1.6087 | 1.6567 |

Fuente: Osal W, Pérez R.
Artículo de Investigación
Universidad Nacional Experimental Politécnica Antonio José de Sucre, Barquisimeto, Ven.


Análisis comparativo de Emisión de CO2 por sistema de teleférico
Fuente: Propia

**Figure 2.** Comparative analysis of $CO^2$ emissions in the transportation system. Own Source

### 1.2. Interior Space Quality:

The room tower of the Humboldt Hotel (the most relevant and prominent space of the entire complex) is selected to create thermal simulations using DesignBuilder software. These simulations are classified into three scenarios:

- Initial Situation (Inauguration);
- Current Situation (Current Rehabilitation);
- Proposal (Traditional panels are replaced by photovoltaic panels and the simple exterior glazing of 6mm thickness by double-glazed photovoltaic glass with an SHGC of 0.40). The choice of material is due to its innovative technology that allows capturing energy and reducing solar radiation. Additional,

A layer of 6cm of fibreglass thermal insulation is added to the intermediate floor. Initially, natural ventilation is considered to establish the possible differences in the behaviour of the chosen construction materials and their impact on the thermal comfort of the space.

All simulations consider construction, climatic, and human parameters, such as:

- Climatic factors of the sector (Orientation, altitude, winds, temperature, radiation, humidity, etc.) from an EPW bioclimatic file of Meteonorm software, which interpolates different sources of climate information from the sector to obtain more accurate environmental information. In this file, it can be observed that right in the immediate surroundings of the Humboldt Hotel, the climate presents the following characteristics:
- Construction materials with their respective thermal transmission properties. (Materials and their original dimensions as insulators are assumed; others are deduced through photographic collection during the building rehabilitation process);
- Shadow elements or any adjacent physical element that may interfere with energy results - Programming of use (Schedules and activities) and space capacity.

Regarding the comparative analysis of the energy gains of the three simulations, it is observed that the results of the proposed simulation are much lower compared to the previous simulations, reaching an annual solar radiation gain of 1,144.35 Kh/h. This figure represents only approximately 35% of gains from radiation compared to the original design and rehabilitation simulation of the Humboldt Hotel (Figure 3).

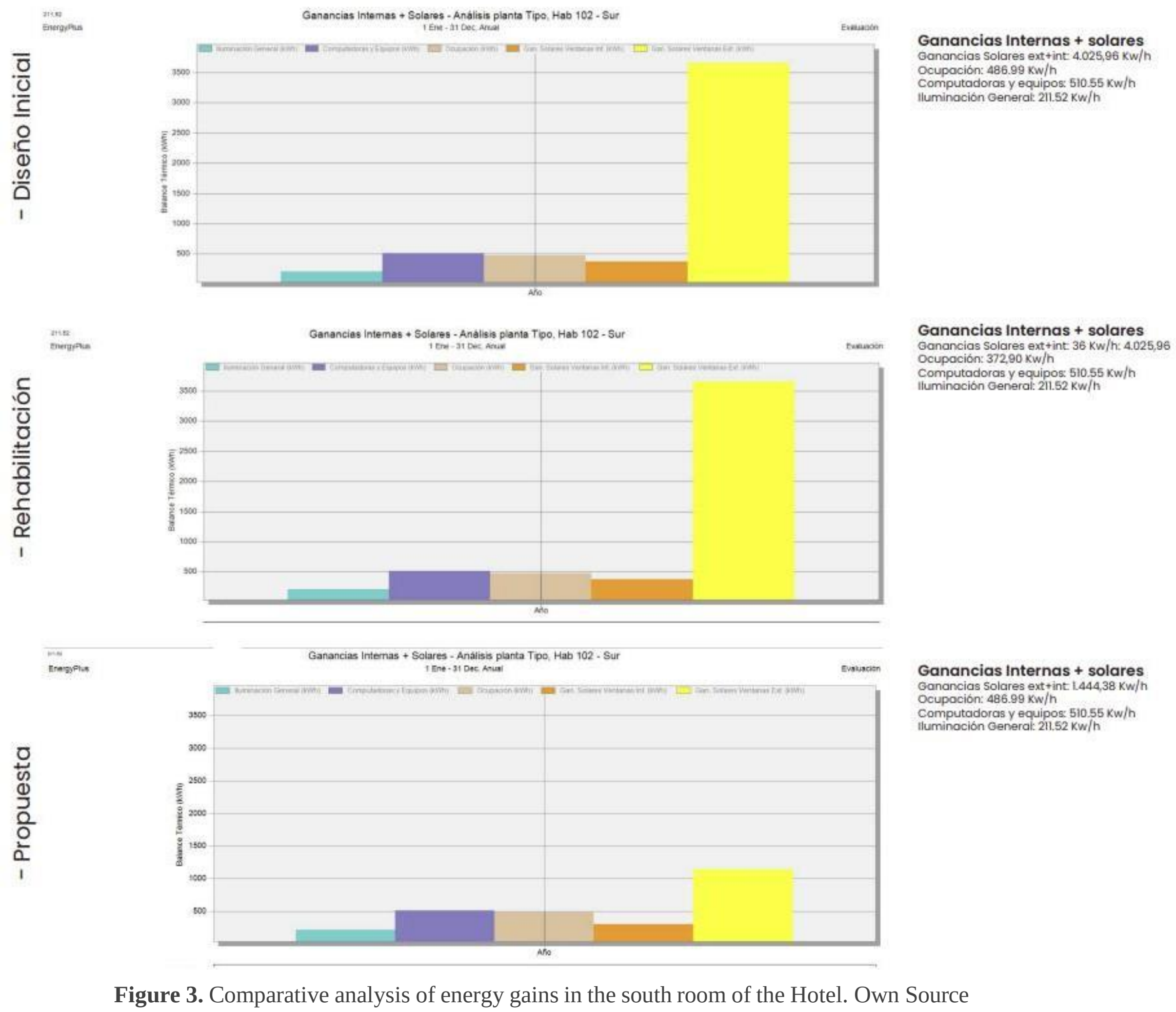



**Figure 3.** Comparative analysis of energy gains in the south room of the Hotel. Own Source

To objectively evaluate the three scenarios and determine a more efficient outcome regarding thermal comfort, the adaptive comfort standards established by ASHRAE 55 (2017) are used as a basis. Based on this comfort standard (Humphreys, M. 1994), a comparative analysis of the room with the highest temperature peaks is conducted across the three simulation scenarios presented (Original Design, Rehabilitation, and Proposal). The Adaptive Comfort Building Environmental (CBE) graph results indicate that thermal comfort is achieved in the "proposal" simulation, unlike the previous simulations. This highlights that the use of double photovoltaic glass with a low solar transmittance coefficient would significantly benefit the project by providing more hours of comfort to hotel users.

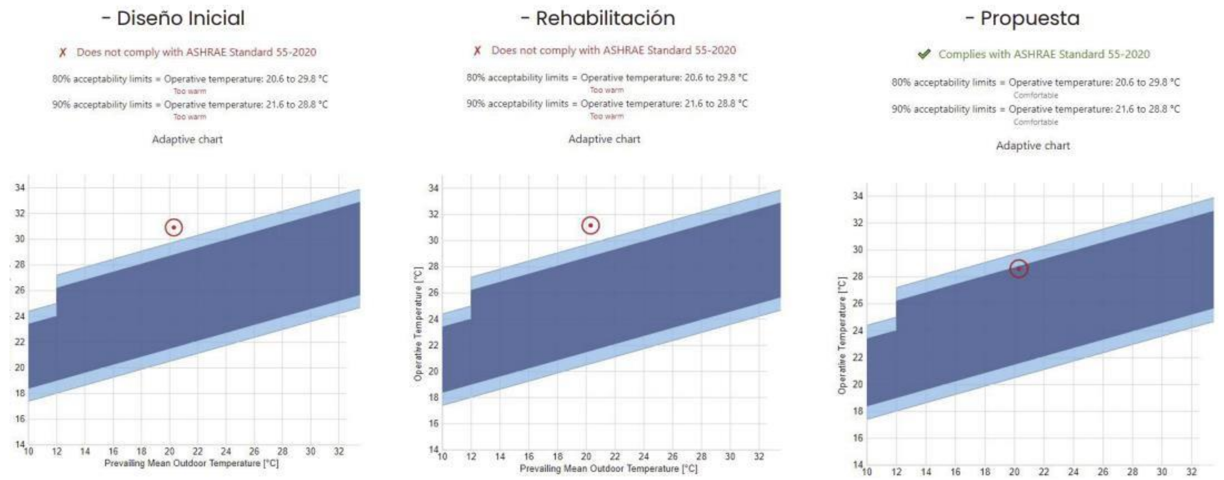



**Figure 4.** Comparison of Adaptive Comfort of the three scenarios. CBE thermal comfort tool. (confort.cbe.berkeley.edu/). Own Source

### 1.3. Energy Optimization.

Based on the simulations carried out in DesignBuilder for the three scenarios, we can estimate a hypothetical electrical consumption of the rooms in the tower of Hotel Humboldt regarding cooling/heating, hot water, equipment, and lighting. (Gössling, Stefan. 2012)

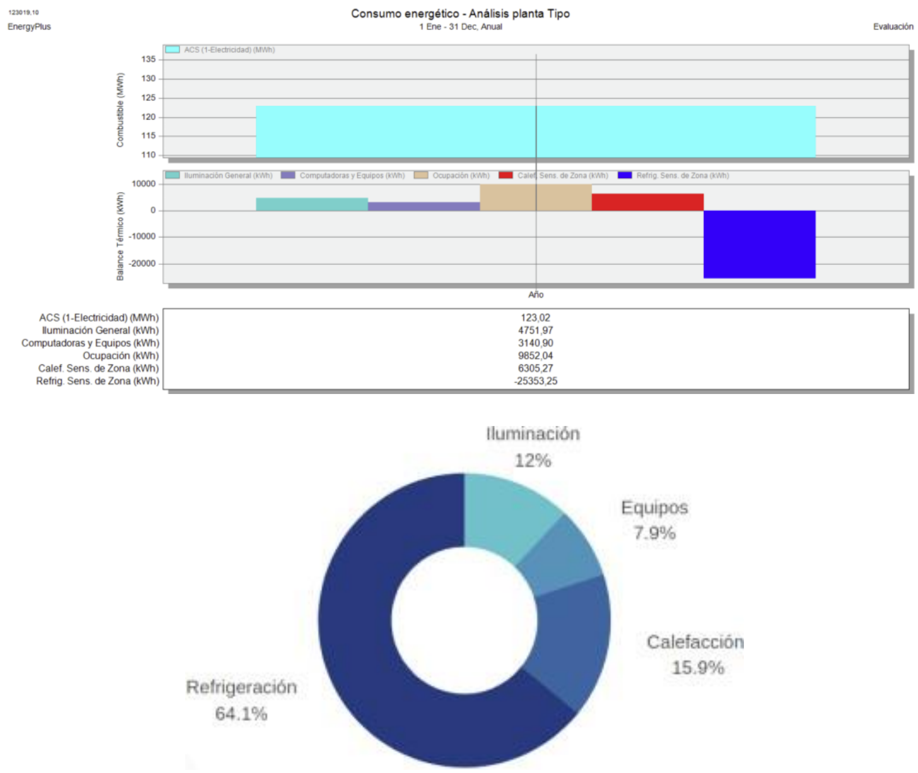



**Figure 5.** Approximate distribution of energy consumption of the Humboldt Hotel type plant. Own source

The results of the thermal comfort simulations show that solar radiation is one of the main sources of energy acquisition that can generate thermal discomfort in the afternoon due to overheating the operative temperature.

Therefore, it is quite important to harness this energy source to reduce the building's energy consumption and mitigate the environmental impact during the life cycle stage.

A radiation analysis is made on all elevations of the room tower and the vaulted roofs to determine the amount of radiation these surfaces receive. Critical days of the year (solstices and equinoxes) are analysed, as well as the cumulative radiation over a full year. The daily radiation analysis on roofs shows that solstices are the least favourable days for radiation, with a daily energy accumulation of up to 9,502 kWh with an average of 2.54 kWh/$m^2$ in winter and up to 7,290 kWh daily with an average of 1.95 kWh/m2 in summer. On the equinox, days show that the daily energy accumulation in spring can be up to 13,844 kWh with an average of 3.70 kWh/m2 of surface. In autumn, an energy accumulation of up to 12,948 kWh with an average of 3.46 kWh/$m^2$ of roof surface can be obtained. In the daily radiation analysis, the envelope shows that, like the roofs, the most favourable radiation days are the equinoxes, with daily accumulative radiation of up to 6,214 kWh with a distribution of 1.65 kWh/m2 in autumn and up to 5,973 kWh with a distribution of 1.59 kWh/$m^2$ in spring. In contrast, on the winter and summer solstices, the daily accumulative radiation is 5,899 kWh and 3,400 kWh, with a distribution of 1.57 kWh/$m^2$ and 0.90 kWh/$m^{2,}$ respectively (Figure 6).

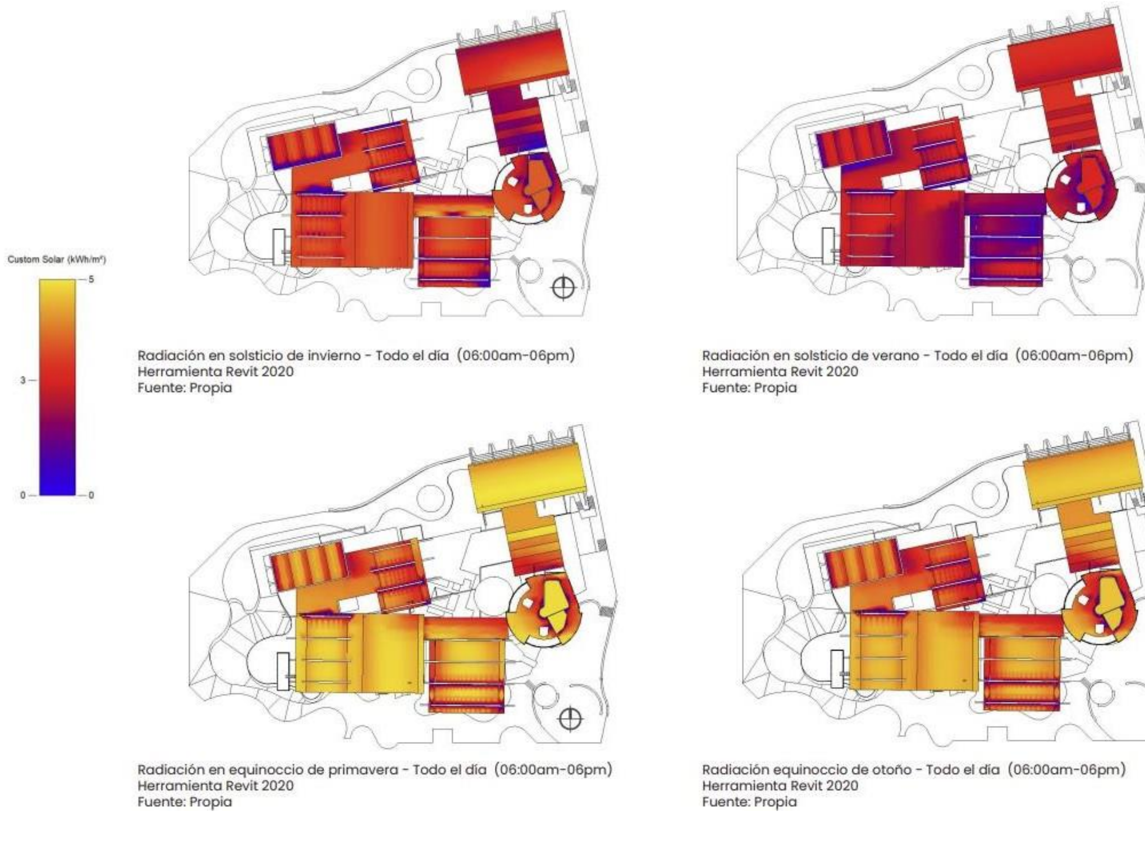



**Figure 6.** Radiation Analysis on Solstices and Equinoxes. Own source

The values obtained in the annual radiation analysis indicate that on the total surface of the Hotel Humboldt tower (3,993 $m^2$), it receives a direct solar radiation of 2,016,800 kWh accumulatively throughout the year with an average of 505 kWh per square meter of surface (kWh/$m^2$). In comparison, the roofs represent 3,506 $m^2$ and receive an annual radiation of 4,004,078 kWh with a distribution of 1071 kWh/$m^2$ (Figure 7).

Overlaying the shadow chart for the critical days of the year, we observe that only a minimal portion of the hotel complex achieves 100% efficiency. The most optimal areas for efficient energy caption are the roofs of the room tower and the vault of the pool, where very few days of the year are projected. Most roof surfaces have an approximate efficiency range of 35-50% (Figure 8).

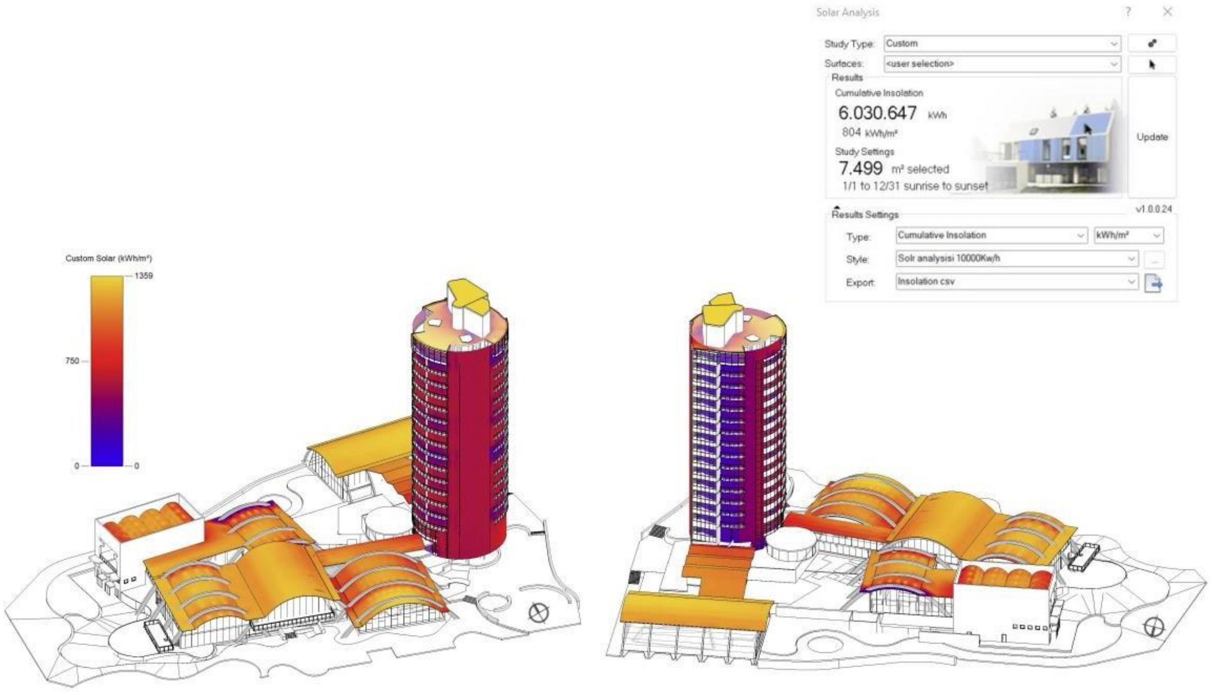



**Figure 7.** Annual Radiation Analysis. Own source

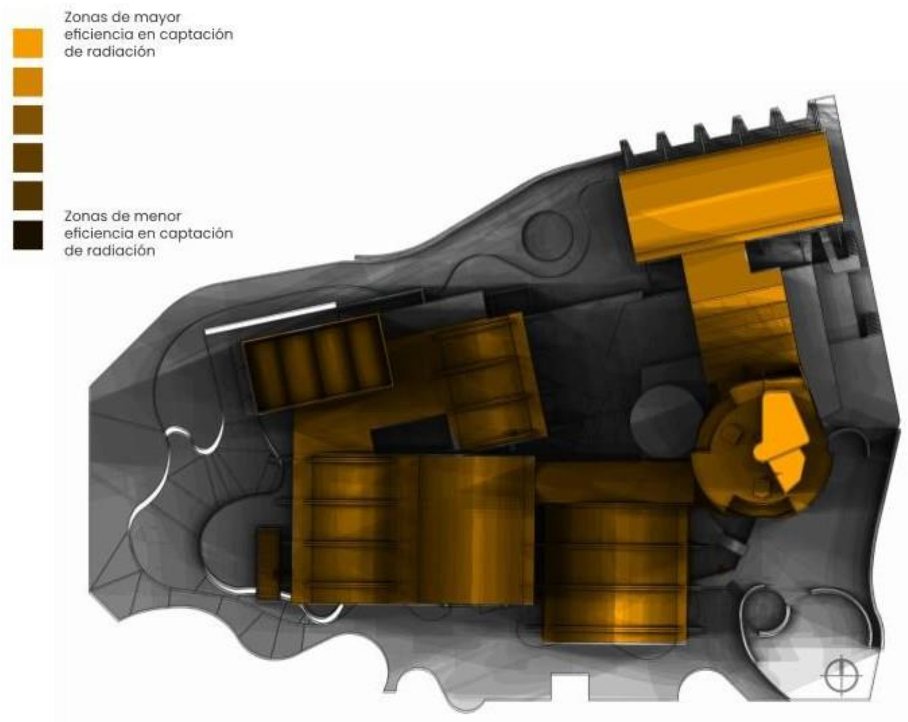



**Figure 8.** Efficiency analysis. Shadow Card. Own Source

Like the hotels in the Caribbean and those in Bogotá, as discussed in the research article by Jarba, M. and colleagues (2014), Hotel Humboldt shows higher consumption in the air conditioning category. With the total energy consumption of a typical floor, it is estimated that the approximate energy expenditure of the room tower of Hotel Humboldt is 553,713.46 kW/year. If photovoltaic materials are implemented throughout the hotel complex, enough energy would be generated to cover up to 80% of the tower's consumption (Figure 9).

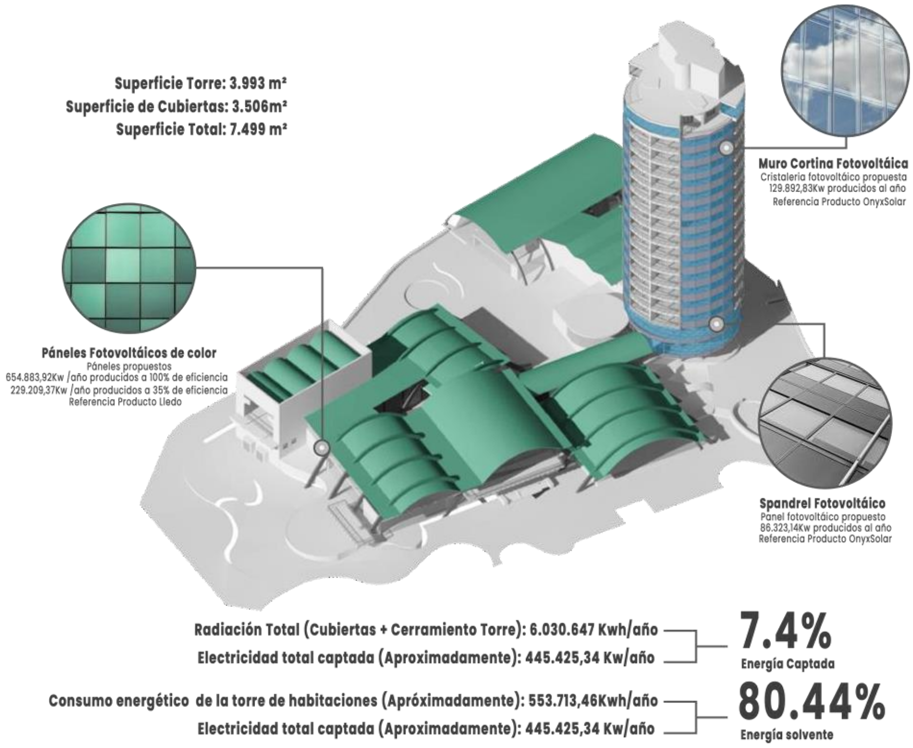



**Figure 9.** Photovoltaic materials implementation chart. Own source

### 1.4. Lighting Analysis

A comparative analysis of natural lighting is conducted between the original design scenario and the proposed design of the Hotel Humboldt Tower. In both cases, similar behaviour is observed regarding the distribution of natural lighting, with parameters ranging between 200 and 1000 lux in the rooms, with the perimeter area being the most benefited in terms of illumination, while the central core of the building has values below 100 lux. The proposed design has a clear reduction in perimeter natural lighting compared to the original design due to the material change in the envelope glazing. Based on Spanish regulation UNE12464.1, the table of areas of public access in hotels states that corridors must have minimum acceptable values above 100 lux. Therefore, implementing efficient artificial lighting is necessary to meet these requirements. No parameter or similar space is observed in regulation UNE 12464.1, indicating the minimum lux required in the rooms (Figure 10).

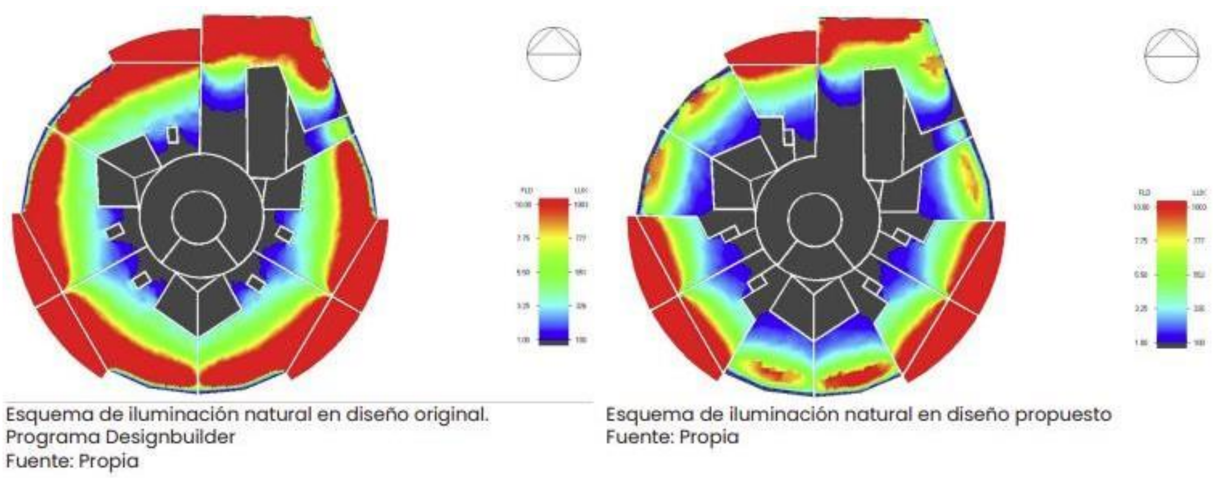



**Figure 10.** Natural lighting scheme with implementation of photovoltaic materials. Own source

## 5. Conclusions

Based on the compilation and analysis of information in this research work, the following general results can be defined:

- The Humboldt Hotel is a unique project (Unamuno, Miguel De. 1980)with significant historical value due to the country's situation at the time of its construction.
- The Humboldt Hotel is a privileged project with landscape value, thanks to its location allowing 360-degree views of the Caribbean Sea and the capital city, surrounded by fauna and vegetation typical of a protected natural park, according to the National Parks Institute of Venezuela.
- The hotel complex has great architectural value, and its possible preservation would allow this project to be classified as one of the most important modern landmarks in Latin America, as it possesses significant cultural, constructive, and historical value.
- On numerous occasions, attempts have been made to reopen the Humboldt Hotel. However, no detailed analysis of the project's problems, such as its profitability (one of the initial major issues), is evident, nor is there any indication of optimal building use or alternative accessibility plans in case of any failure in the cable car system.
- Due to its remote location, the project may be difficult for people with disabilities to access; however, ramps and elevators are observed in the rehabilitation process.
- The cable car system is essential for the operation of the Humboldt Hotel, and its use mitigates the environmental impact by 5% to 32%, depending on its use, compared to an SUV.
- The rehabilitation of the Humboldt Hotel follows the guidelines of the original design proposed by the architect Tomás José Sanabria, evoking a sense of nostalgia from the 1950s through the finishes, textures, materials, and furniture used, where every detail was meticulously studied and analyzed; however, environmental analysis was not one of the priority aspects for decision-making regarding the implemented reforms.
- The thermal performance of the hotel complex has deficiencies. The originally proposed envelope and reform do not optimize their possibilities to maintain temperatures within the thermal comfort range defined by ASHRAE (2017) standards.
- Regarding technological innovation, a home automation system for curtains is noted; despite this innovation, current equipment and systems were not considered for automated management for efficient climate control. The implementation of strategies, equipment, and/or materials focused on reducing the natural resource consumption of the hotel complex has also not been observed.
- Incorporating photovoltaic materials in the building could significantly reduce energy consumption, reducing around 136.92 TCO2 per year.
- The proposed photovoltaic glasses with low SHGC would provide more thermal comfort to users during peak radiation hours.

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# On the defence of patrimony: enhancing the value of fortified cities and their landscapes by creating a transborder smart tourism destination

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***Abstract***

*Cultural patrimony plays a primordial role in catalysing a rural world immersed in a bitter struggle to survive. Depopulation and a lack of incentives are just two of the most severe problems in this regard. La Raya, as the study area on the Spanish-Portuguese border is known, offers a clear case of this situation. Setting out from the transborder area between the western region of the province of Salamanca (Spain) and the eastern part of Beira (Portugal), an experimental laboratory was created to elaborate and implement specific solutions to the challenges threatening a space marked by certain particularities. The longstanding need to defend this zone now centres on a series of fortified cities whose historical and biocultural patrimony requires novel ideas to enhance their value and conservation efforts. To a great degree, achieving this goal entails integrating the elements and resources of their landscapes and including them in a process in which citizen participation is reflected in the territory's destiny. Combining these aspects has spurred the development of the proposal presented herein, one that addresses several key challenges: normalising the reality of two nations; enhancing the value of intangible patrimony as an additional component; conserving, above all, unpopulated spaces; and developing inclusive initiatives that respect the landscapes of the main population nuclei. The project culminates with the elaboration of geotechnological tools and solutions that offer valuable experiences while simultaneously capturing data on the most important aspects for residents and visitors. This arduous process is conducted by a multidisciplinary team linked to diverse local agents.*

***Keywords:*** *border, tourism, culture, territory, patrimony, geotechnologies*

## 1. Introduction

The territory's cultural inheritance and landscape resources constitute primordial assets for catalysing the rural world in the face of the demographic challenges it is currently immersed in. Depopulation, the ageing of territories, the lack of socioeconomic attractions, and issues of accessibility are just a few of the most visible, pressing problems that society as a whole, the political class, and researchers in diverse fields are striving to solve or, at least, to downplay the consequences they bring.

> The Demographic Challenge is a complex idea that encompasses numerous dimensions of the population [and] refers to the structure of the pyramid (by sex, age...), localisation (rural areas, cities, unpopulated zones, territorially dispersed areas...) [and] living conditions (difficult access to services, low-income levels...) *Ministerio para la Transición Ecológica y el Reto Demográfico*.

The Spanish-Portuguese border offers a paradigmatic case because all of these problems are rather unique there due to the geostrategic position the space occupies. La Raya, as is well known, plays the role of a dividing line – in some respects more imaginary than real– that residents on both sides of the border have been traversing for centuries. In the 20th century, the European Union began to support the creation of a common space by suppressing interior borders (Calderón, 2015), a goal that in some rubrics of everyday life is still distant from reality; for example, issues involving the mobility of public transport, to mention one case related to the topic explored in this paper. It is important to note that we are dealing with a peripheral area where external and internal mobility is an especially important element, and the dispersed nature of equipment and services is another. In the study area, the capillarity of the transportation network and the autonomy and flexibility provided by private vehicles are reflected in insufficient public transport services and the generalised use of automobiles by both residents and visitors. The result is a model of unsustainable mobility marked by high external environmental and climatic costs. This key feature reveals the difficulties in generating tourism itineraries that connect numerous but widely dispersed resources. The complexity of these challenges increases when efforts centre on transforming territories located in two countries into one sole space.

### 1.1. Towards the transformation of the border landscape into a smart tourist destination (STD): creating an experimental laboratory

In recent decades, tourism has played a transcendental role in society because it acts simultaneously –from social, cultural, and economic perspectives– as both an instrument and a phenomenon of globalisation. In 2019 in Spain (pre-pandemic), tourism represented 12.4% (154,737 million Euros) of the GDP and generated 12.7% of all employment (2,680,000 jobs). Figures for that year show that 83.5 million tourists visited the country. The main guidelines for tourism stress creating and consolidating vanguard tourism infrastructure that is highly focused on urban areas, but those principles are also perfectly adaptable to the rural world. This paper focuses on the transversality of tourism activity and the need to establish a tourism strategy as the basis for the economic catalysation of the territory under discussion (Baidal, J. A. et al., 2019).

The Spanish-Portuguese border is a large space with significant elements of union despite a certain heterogeneity in some areas that serves to increase the attractiveness and tourism potential that currently exists (Hernández-Ramírez, J. 2017). The main point of cohesion is the legacy of a past in which relations between Spain and Portugal were characterised by moments of intense conflictiveness that led to the militarization of the area (Lemos, 2020) and a process that has left behind a series of defensive elements among which the imposing figures of several fortified cities stand out. The remains of that hostile past stand in a territory where pastureland is the second-largest component, followed by other, more clearly delimited, landscape typologies. This area constitutes an enormous treasure that is being enhanced by diverse but largely isolated initiatives, a place still searching for a guiding thread. In this sense, the project proposed in this paper advocates converting this space into a “smart tourism destination” (STD). To support the project, an experimental laboratory has been set up, and a concrete space has been chosen for a pilot study. The plan is to begin work there and expand the scope to include the entire border area. From the approximately 1250 km$^2$ that delimited the proposed study area, we selected the space between Ciudad Rodrigo (Salamanca) and the Guarda (Beira) district as the pilot zone. Work there is already underway.

 

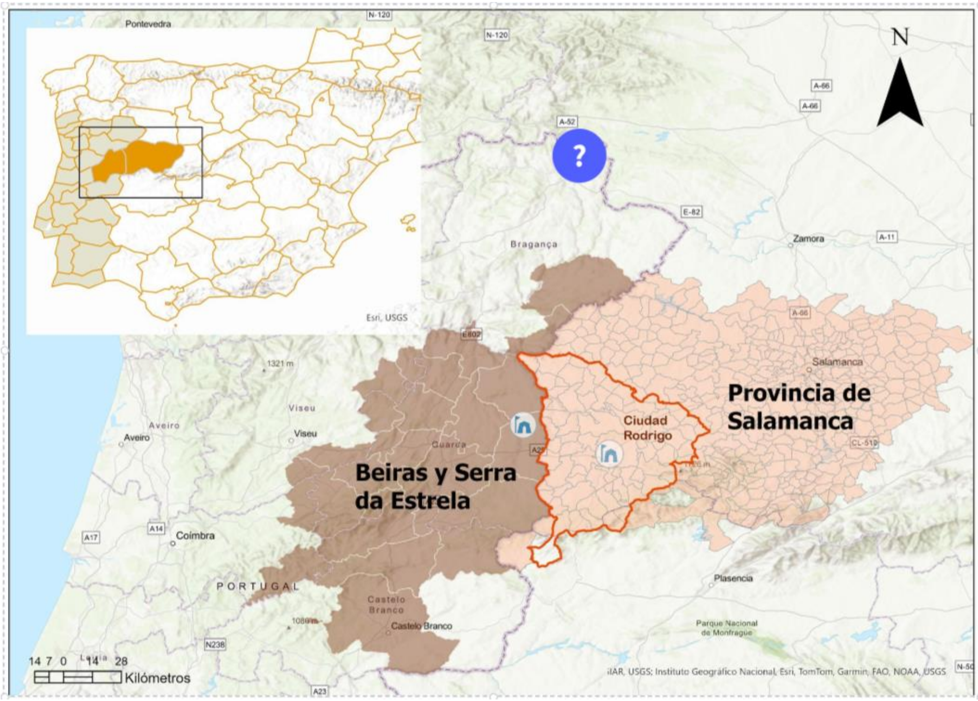


**Figure 1.** The area of Ciudad Rodrigo (Salamanca) and the district of Guarda (Beira). Source: García, L. (2024)

Ciudad Rodrigo will serve as the epicentre of the laboratory, a choice determined by the strong impulse currently directed towards catalysing tourism in that region and ongoing efforts to foster ties to Portugal, specifically the Andalusian locality of Almeida. This led to the birth of FORTLAB (www.fortlab.es). This proposal seeks to create a forum for the exchange of innovative ideas that include technology in the form of an open, participative community that includes researchers, local agents and citizens themselves from both sides of the border. This summary encompasses the principles and integral focus that the DTI methodology represents.

### 1.2. Objectives and Methodology

Under the umbrella of the methodology derived from STD, the main goal that this project strives to achieve is to unite research on issues related to socioeconomic aspects, like the study and analysis of cultural and intangible patrimony, with local development and a search for new options of catalysation, with tourism as the principal referent. The basic tools employed are technologies, as we explore how they can best be introduced into smart tourism due to their capacity to handle spatial results. Our research sets out from and finds its methodological reference in geography. As a result, the concepts of territory and people are the protagonists and support columns of an approach that also considers the evolution that the study area has shown throughout its historical evolution. Any variable that reflects this changing reality, the perception and valorisation that have emerged and, of course, the legacy of earlier stages transformed into a rich, varied patrimony will be referred to as a univocal position in the territory. On this basis, a large geospatial database is under construction to allow researchers to learn more about the demographic processes in this transborder zone and to analyse and establish policies designed to respond to problems as complex as the demographic challenges mentioned at the outset.

The fundamental requirement of this data model consists of integrating qualitative and quantitative data that are not circumscribed to the present but rely pre-eminently on information elaborated in earlier periods to contrast the area's past demographic tendencies with the present and trace the evolution of the activities that have formed the economic base of this transborder territory; that is, the elements that make up the cultural and landscape patrimony and that constitute the tourism potential.

In this context, the historical sources and data not only explain demographic tendencies over long periods but also provide key references to the peculiarities of socioeconomic life in the study area, including aspects like flows of commerce, merchandise, and people, and the sociocultural linkages and features of economic integration that have developed in these lands up to now. Other substantial aspects are the perspectives and knowledge of their territories that residents and local actors possess today. To document those perspectives, we have organised discussion workshops. To record people's collective knowledge and wealth of information, we have held training courses and workshops that allowed us to establish data-gathering procedures using geotechnological tools. All the data collected will be integrated into the geospatial database described below.

### 1.3. The role of geospatial databases and other geotechnologies

Implementing the ideas and principles proposed requires a specific series of tools to produce a concrete product. This is one of the novel contributions of our proposal: using geotechnologies, understood as a set of instruments, methodologies, and other components that are fundamental for handling geodata, given that the totality of the variables we work with fall into this group, distinguished by relating each element to univocal coordinates in the territory. Any project developed in this field will have three basic components.

The central protagonist is a geospatial database that is the driving force behind the entire system. Exploiting this database is carried out more extensively through the use of geographic information systems (GIS), which facilitate the application of various techniques of spatial analysis that enormously enrich the information gathered and stored. Finally, diverse instruments are required to assign values to the results. Here, geoportals provide a good example, but one that can be supported by other options, such as mobile applications. The latter is extremely useful for the normalised alimentation of the database by expert users or researchers, especially when operated under the logic of so-called citizen science, that is, open spaces that allow distinct users to contribute to nourishing the databases.

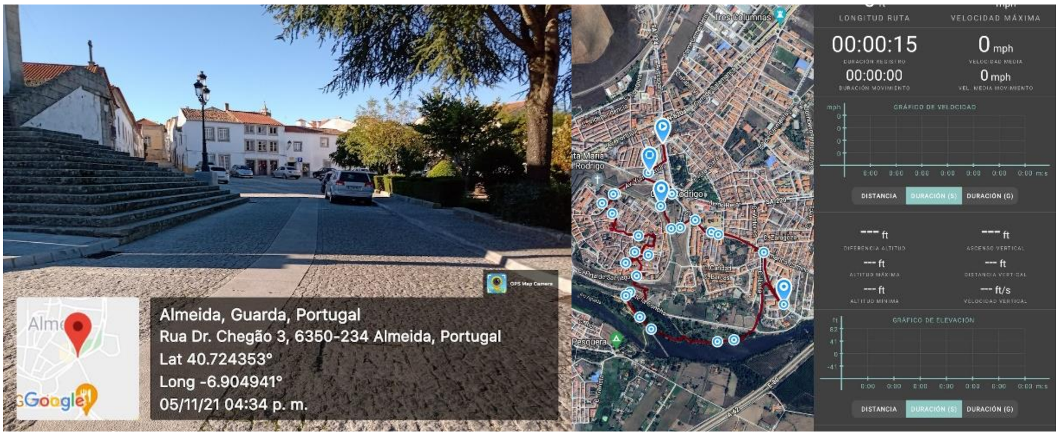


**Figure 2.** Data-gathering using mobile applications Source: Alberto, A. (2023)

Returning to the issue of the geospatial database, in the era of "Big Data", relational databases still show a great capacity for creating interconnections among diverse sources of information that, in our case, take territory as their guiding axis. Hence, we chose this model to develop our prototype, keeping in mind that the future will require scalability and transformation to other models that incorporate non-structured sources of information, including social networks (García Juan et al., 2019).

Together with the usual techniques and methodologies associated with the discipline of geography, tourism as a means of giving value to this legacy uses many other options, most significantly, virtual reality, a necessary step to remain at the vanguard and offer tourists experiences that lead them to understand the context, while at the same time creating virtual environments like digital twins that foster advances in the research program (Chías, 2023).

## 2. Result: FORTLAB, an integral information system for managing a smart territory

As indicated above, one notable achievement of this project is designing a relational model that facilitates storing, among other key elements, the potential resources in the study area. To this end, we have worked to construct an information system articulated through a series of subsystems that make it possible to store heterogeneous information organised in three broad thematic blocks: population, tourism, and mobility/accessibility. We added potential resources from the study area (Figure 3). The main challenge in developing this design was normalising the data from the two countries. Although much of the work has been conducted under the umbrella of the European directive, INSPIRE, some projects do not show continuity on one side of the border or the other.

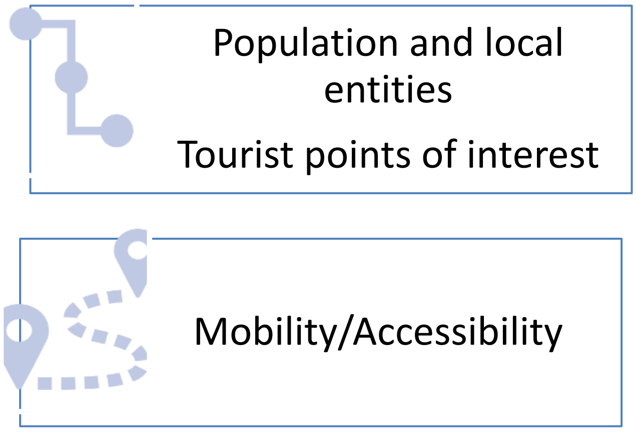


**Figura 3.** Thematic blocks of geographic information storage.

This issue has proven to be a significant handicap in the data analysis phase. On the theme of population, the model has integrated data from the 18th century to today, a long series that facilitates knowing and understanding the phenomenon of depopulation and its associated tendencies. The project includes data for studies of population structure and distribution. Normalising the information on this issue from the two sides of the La Raya has entailed fewer difficulties, and the challenges that have arisen have had to do mainly with the unit of analysis. Because the two nations have distinct administrative structures, normalising the data using NUTS does not generate a framework that allows us to accurately approximate reality.

The topic of mobility in the analyses of tourism and population movements has been approached through the experimental study by the Ministry of Transport and Sustainable Mobility (MITMA for its initials in Spanish) based on mobile phones and Big Data. This important work allowed us to identify the most frequented sites, visitors' tendencies, and features of their stays. The main problem is that we do not have comparable data with the same level of detail for the Portuguese side.

Finally, tourism constitutes another important block for which we have geolocalised tourism offices and other sites that provide information. We have also identified several campaigns conceived to foment tourism and included statistical data from the tourism office in Ciudad Rodrigo (Salamanca).

This work results in a large database with a wealth of information, which will be exploited using two broad instruments, one concerned with management and the other with enhancing the value of local resources. To this end, we have worked to construct an articulated information system comprising a series of subsystems. The block on management covers the principles of the DTI methodology, which establishes strategies based on sustainability and governance by offering public entities, associations, and local action groups useful tools for developing innovative proposals. Increasing the value of resources in tourism settings is being carried out through the design of an app that will transform the results of research into a specific product. These initiatives include modules that address major challenges, such as conservation. To accomplish this, by the principles of citizen science, users receive a novel experience and monitor and report on changes in the region's material inheritance.

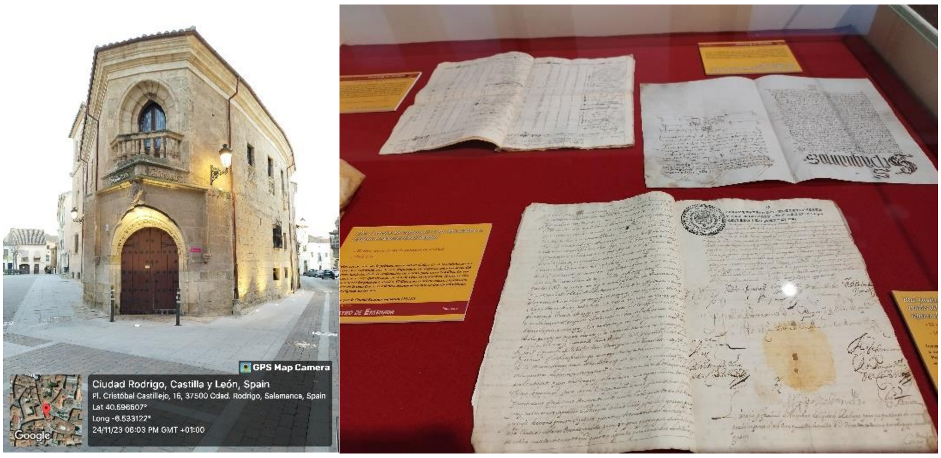


**Figure 4.** Historical patrimony and documentary sources. Source: Alberto, A. (2023).

Once all these elements are duly represented in a cartographic database, a digital representation of the potential of the study area will be generated as a key support tool not only for local institutions and associations that wish to develop plans to preserve and catalyse the historical legacy of these spaces but also to incite recognition of the territory by its inhabitants. This facilitates incorporating it into commercial endeavours and economic activities outside the tourism sector. Moreover, thanks to these advances, an ample database could be used to elaborate on and propose numerous tourism routes and plans. While working on its design, we focused on (i) developing alternatives to existing products and (ii) connecting spaces on both sides of the border and then those spaces to other zones in this unique space.

Other aspects considered simultaneously include population and demographic tendencies, factors of a socio-organizational character, and cultural practices along the border that can affect the viability of alternative activities.

### 2.1 Data entry

The data model was created so that it can be nourished by parties with diverse profiles and in distinct work environments. This will permit incorporating elements created through work in cabinets or laboratories and activities conducted directly in the field. Regarding who can enter data, the model emphasises the value of contributions from the field above of citizen science. To this end, the forms designed allow any interested person to register. Of course, this process must be simple, user-friendly, and easy to access. Based on these requirements, we tested various technological options involving free and proprietary software, all of which had communication channels to the Internet since they are based on products deployed in a geospatial server.


**Figure 5.** Forms and data recording. Source: García, L. (2024).

Concretely, two instruments were applied. The first was designed to record tourism assets, patrimony, and other resources with tourism potential while also highlighting points of interest that exist in the Comarca de Ciudad Rodrigo and the Portuguese part of La Raya (Distrito de Guarda) in three broad groups: cultural, natural, and mixed. The second goal was to register complementary services and collaboratively generate information on established businesses. The results of the two surveys will be integrated into a large database that will serve as key support for elaborating various routes and plans for the study area.

### 2.2. Formation and transference of knowledge to local agents

A significant part of the achieved objectives has been to design a series of training plans that allow the various local agents to both collaborate and establish new ideas. A starting point has been to establish communication with the officials of the municipality of Ciudad Rodrigo, particularly with the *Consejalía de Turismo*, in order to understand the programs and actions that they are undertaking so the project aligns with local actions. Another component is formed by associations, companies providing tourist services, and local economic development initiatives, aiming to gather different perspectives on the issues, proposals, and solutions directly from various local agents. This is where the project contributes elements of training and geotechnological tools.


**Figure 6.** Capacitation workshops and discussion panels involving local agents**.** Source: Alberto, A. (2023).

It could be said that knowledge of a territory carries, implicitly, a consensus with its actors and authors; that is, with all the people who live there, who are economically productive, and who participate in management. In this area, our team organised, on the one hand, presentations of the project with its objectives and scope, together with roundtable discussions and workshops involving various actors. On the other, we worked to construct the territorial database and gather field data in a collaborative way, which required providing basic methodological criteria and reaching agreement on knowledge and the application of the study instruments (the forms described in the Methodology and the technological applications of mobile devices). This was the focus of the formative process, which was of an open character as we worked with local agents, municipal officials, and the broader public.

## 3. Conclusions and future lines of research

In light of existing conditions, which lead us to affirm that the rural world is facing nothing less than an emergency about its future, the Spanish-Portuguese border area presents unique features that make it especially vulnerable, including its status as a peripheral space in the reality of both nations. Tourism, which is emerging as the tool most often employed to catalyse areas of this kind, has been the object of methodological developments that seek to ensure it is utilised sustainably concerning both local communities and the environment where it is instigated. These are some principles we found in the smart tourism destination approach. One goal of the FORTLAB project is to create an experimental laboratory dedicated to cementing the bases for converting the area around La Raya into an STD. In the pilot project between Guarda (Portugal) and Ciudad Rodrigo (Salamanca), we strive to construct the infrastructure required to begin tourist operations. The proposal presented herein is designed to obtain a holistic knowledge of this space, beginning with elaborating an inventory of potential resources. It is also necessary to develop a deep familiarity with the local population, the territory itself, and its potentialities before promoting concrete measures. Methodologically, we have tested various options, all linked to the field of geotechnologies. The results of this initial approach underscore the importance of working in tandem with local entities and agents, in fact, the entire population. In short, we have experimented with uniting research with citizen science as the only way to attain sustainable results acceptable to local populations while solving real problems. Moreover, we introduced a new perspective by designing an STD that establishes territory as the backbone. Of course, we understand that in attempting to enhance the value of an inheritance dispersed over a rural area, we run the risk of placing those very materials in danger. Our attempts to solve this dilemma strive to return the focus of attention to the citizenry. Thus, to ensure adequate implementation of the project, we have elaborated several initiatives for capacitation that share the goal of understanding the enormous potential of the patrimonial resources that exist in a space that has not yet triggered much interest among residents.

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# Protection, conservation and dissemination of integral heritage. The cultural project - ecomuseum "Legado Vivo" (Ricote Valley, southeasternSpain)

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**_Abstract_**

*The cultural project - ecomuseum "Legado Vivo" was born in 2013, within the Cultural Association "La Carraila" (https://lacarraila.blogspot.com/), which was joined in 2018 by the Association "Caramucel, nature and history" (https://caramucel.blogspot.com/). Its objective is the protection, conservation, recovery, signalling and dissemination of the integral heritage of the Ricote Valley (Region of Murcia). The cultural and natural assets comprise a unique cultural landscape, which is why this region has been included in the National Cultural Landscape Plan. The orchards, the irrigation ditches and their water wheels generate a geographical space full of cultural milestones consolidated over the last millennium. The fruit of the work carried out in recent years by the members of the aforementioned associations has made it possible to identify ten heritage itineraries of diverse nature in the municipalities that make up the Ricote Valley, the protection of 7 places with the category of BIC (Asset of Cultural Interest); or label, recover and promote the Valricotí toponymy, which provides information about the settlement and the language that originated them, constituting a rich intangible cultural heritage. International conferences, interpretive itineraries offered to the public, archaeological interventions have been held, and more than a hundred articles contained in six books have been published; likewise, the discovery of the first prehistoric paintings in the municipalities of Abarán, Blanca and Ricote has been held.*

*Finally, an interactive tool has been created (MAPACUVALLE - Map of the assets of the cultural landscape of the Ricote Valley) that, to date, allows 137 assets to be identified, update the state of conservation, and incorporate new heritage elements for dissemination and transfer of the knowledge to society (https://legadovivo.blogspot.com/p/mapacuvalle.html). This associative work has been prize-winning with the National Hispania Nostra Prize 2023 for the signalling and disseminating cultural and natural heritage.*

***Keywords**: cultural heritage, natural heritage, ICTs, comprehensive management, collaborative work.*

## 1. Introduction

The Ricote Valley is located in the southeast of Spain. From a geographical point of view, it is a region located in the central area of the Region of Murcia, with an NW-SE direction, integrated from north to south by the municipalities of Cieza, Abarán, Blanca, Ricote, Ojós, Ulea, Villanueva of the Segura and Archena River. From a historical point of view, after the conquest of the Kingdom of Murcia in 1243, the farmhouses of the Ricote Valley were granted lordship to Enrique Peréz de Harana in 1266. It was already in 1285 when King Sancho IV ceded these territories to the Order of Santiago, under whose rule it remained until 1873 when the First Spanish Republic suppressed the Order (Ballesteros, 1943; Westerveld, 1997; López, 2008).

These towns share a long evolution due to history or geographical proximity. In any case, from our point of view, they constitute a region and, as such, should be studied. For this reason, the cultural project - ecomuseum “Legado Vivo” (Figure 1) transcends the limits of the Ricote Valley in the strict (historical) sense and incorporates the study of the geographical region that constitutes it. It was created in 2013 by the “La Carraila” Cultural Association, joined in 2018 by the “Caramucel, nature and History” Association.

**Figure 1.** “Legado Vivo” logo. Source: cultural project - “Legado Vivo” ecomuseum.

## 2. Objectives

With the implementation of planned associative work, the “Legado Vivo” cultural project pursues the following main objectives:

- Value the heritage elements that make up the cultural landscape of the Ricote Valley;
- Actively participate in the protection, recovery and conservation of the integral heritage of the Ricote Valley;
- Mark and disseminate the most outstanding heritage elements of the Ricote Valley;
- Transfer to society of heritage wealth as an educational, cultural and tourist resource.

## 3. Methodology

The development of the project has involved the design of a rigorous methodology for the documentation, protection, conservation and dissemination of heritage. Disarticulated in different phases:

1. Documentary sources and systematic analysis of information:

- Compilation of documentary sources in various archives (municipal, regional or national), civil and ecclesiastical;
- Identification of heritage assets of diverse nature and systematic analysis of all available information.

2. Study and signalling of assets:

- Multidisciplinary treatment of information on each heritage asset;
- Analysis of the state of conservation and its degree of protection;
- Signage of heritage assets.

3. Design of heritage itineraries:

- Grouping of heritage assets by thematic itineraries;

- Linking each asset with its documentary information through QR codes.

4. Protection, recovery and conservation of Assets of Cultural Interest:

- Documentary reports for the BIC (ACI) declaration;
- Conservation and recovery of toponymy;
- Restitution or rehabilitation of emblematic places.

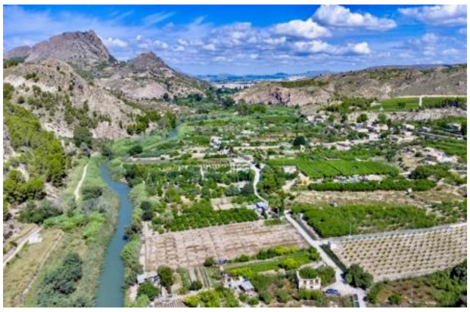
5. Dissemination and transfer of knowledge:

- Digital dissemination with website design as the main dissemination platform;
- Banners in public institutions;
- Social networks;
- Disclosure in physical format with posters of each asset inventoried and studied;
- Heritage conferences and seminars. Social awareness;
- Programming of guided and interpreted outings on the designed itineraries;
- Design teaching units based on heritage assets.

Collaborative work (experts, institutions, educational centres, local society...) has been and is essential since the participants of this methodology value group work, which is designed to approach different objectives (Tobón, 2013), mainly: (a) tackle exploratory issues; (b) pursue cumulative reasoning; (c) manage conflicts; (d) promote motivation; and (e) evaluate execution.

## 4. Results

Identifying the most representative elements of the cultural landscape of the Ricote Valley has been the priority, focusing on the traditional garden, which is the result of the efforts of generations of men and women who worked hard to build this imposing cultural landscape. Some examples are shown, such as the area of La Hoya de Don García, the Huerta de Darrax with the Cabezo de la Cobertera in the background, the Huerta de Blanca from the Mirador de Bayna, the Huerta de Ojós from the Estrecho del Solvente and the Huerta de Ricote (Figures 2-8). Once the heritage elements have been identified, various actions have been carried out to achieve the proposed objectives (Díaz, 2007; De Santiago, 2009).



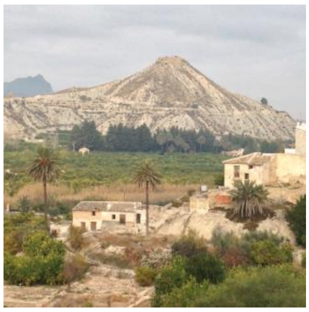


**Figure 2** (left). Hoya de Don García. Source: Miguel San Nicolás del Toro.
**Figure 3** (center). Segurariver, Huerta de Darrax and Cabezo de la Cobertera. Source: López-Moreno, J.J.
**Figure 4** (right). Huerta de Arriba, main irrigation ditch and Cabezo de la Cobertera Blanca. Source: Molina-Ruiz, J.

**Figure 5.** Huerta de Blanca (Buila and Bayna) from the Bayna Viewpoint. Source: Molina-Ruiz, J.



**Figure 6** (left). Huerta de Ojós from the Solvente Strait. Source: Source: López-Moreno, J.J.
**Figure 7** (center). Huerta de Ricote. Source: Héctor Manuel Quijada Guillamón.
**Figure 8** (right). Segura River as it passes through Ojós. Source: López-Moreno, J.J.

### 4.1. Protection and participation in conservation

The study of emblematic heritage places, the knowledge of their state of conservation and their level of protection is one of the main activities developed by the cultural project - ecomuseum “Legado Vivo”, channelled through its initiative PROBICUVALLE (Protection of Assets of Interest Cultural of the Ricote Valley). In this sense, applications for protection have been submitted, attaching the supporting documentation of the patrimonial interest, which has led to the achievement of some of the BIC figures that have been applied in this region, based on Ley 4/2007, of March 16, on Cultural Heritage of the Autonomous Community of the Region of Murcia:

- Decreto nº 194/2017, of June 28, of the Governing Council of the Autonomous Community of the Region of Murcia (CARM), by which the Cabezo de la Cobertera is declared an Asset of Cultural Interest, with the category of Monument, in the municipalities of Abarán and Blanca;
- Decreto nº 116/2018, of May 23, of the CARM Governing Council, declared Las Norias de Abarán, in the municipalities of Abarán and Cieza, an Asset of Cultural Interest with the category of Place of Ethnographic Interest;
- Decreto nº 159/2018, of July 4, of the CARM Governing Council, declared the Acequia de la Andelma, in the municipality of Cieza, an Asset of Cultural Interest with the category of Place of Ethnographic Interest;
- Decreto nº 188/2018, of December 10, of the CARM Governing Council, declared the Solvente Strait, in the municipality of Ojós, as an Asset of Cultural Interest with the category of historical site.

As a result of the citizen awareness campaign and the efforts of the local administrations involved, the municipalities of Abarán and Blanca have achieved the excavation and restoration project of the Cabezo de la Cobertera archaeological site. The “La Carraila” Cultural Association members have participated in these excavation and restoration works. In addition, cleaning and maintenance tasks for places and signage are organised with volunteers (Figures 9-11).


**Figure 9** (left). Restoration work at the Cabezo de la Cobertera archaeological site (Abarán-Blanca). Source: López-Moreno, J. J.
**Figure 10** (center). Toponymic tile and QR access to the content of the Solvente Strait Historical Site. Source: López-Moreno, J. J.
**Figure 11** (right). Cleaning and maintenance activities with volunteers. Source: Molina-Ruiz, J.

### 4.2. Signalling

The marking of heritage assets is another of the basic activities carried out. In this sense, 173 elements have been marked, most grouped into ten heritage itineraries. Signage on the ground has been done with signs, QR codes, posts with directional arrows or paint marks. All this with the own design of "Legado Vivo" (Figures 12-17) (Molina, 2014; López, 2022; López, 2023a).


**Figure 12** (left). Scanning the QR code of the Partido de la Romana next to the place's toponymic tile. Ricote Huerta Route. Source: Héctor Manuel Quijada Guillamón.
**Figure 13** (center). Posters on the itinerary "Hydraulic Heritage of Huerta de Blanca" will be installed by members of the associations "La Carraila" and "Caramucel, nature and history" and by volunteers. Source: López-Moreno, J.J.
**Figure 14** (right). Sign up for the start of the itinerary from Blanca to Negra. Source: Molina-Ruiz, J.

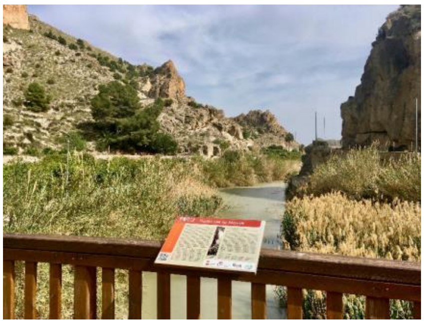


**Figure 15** (right). Information sign for Salto de la Novia on the homonymous route. Source: López-Moreno, J.J.
**Figure 16** (center). Signage to interpret the Solvente Strait. Ricote Castle Trail (SL-MU 26). Source: López-Moreno, J.J.
**Figure 17** (right). Sign at the beginning of the Hydraulic Heritage itinerary of the Huerta de Blanca and indicator post of direction and distance to the identified heritage. Source: Molina-Ruiz, J.

Table 1 shows the assets of the cultural landscape of the Ricote Valley marked by the cultural project - ecomuseum "Legado Vivo".

**Table 1**. Assets of the Ricote Valley cultural landscape marked by the "Legado Vivo" cultural project – ecomuseum. Source: "Legado Vivo" cultural project - ecomuseum.

| Heritage Itinerary | Municipality | Assets Marked |
|---|---|---|
| Route of the Norias (SL-MU 28) | Abarán | 46 |
| El Jarral | Abarán | 22 |
| Fuente de Benito | Abarán | 28 |
| Mirador de la Cruz trail(PR-MU 56) | Abarán | 8 |
| Hydraulic heritage of the Huerta de Blanca | Blanca | 15 |
| Itinerary from Blanca to Negra | Blanca | 12 |
| Huerta de Ricote route | Ricote | 10 |
| Castillo de Ricote trail (SL-MU 26) | Ricote | 6 |
| Salto de la Novia route | Ojós | 10 |
| Jaime "el Barbudo" territory | Abarán, Jumilla y Fortuna | 12 |
| Sign posted assets not associated with heritage itineraries: Pino del Solvente (Blanca), Estrecho del Solvente (Ojós), Cabezo del Algezar and El Carrerón (Ricote) | Blanca, Ricote y Ojós | 4 |
| TOTAL | Abarán, Blanca, Ricote, Ojós, Jumilla y Fortuna | 173 |

### *4.2.1. Route of the Norias (SL-Mu 28)*

Among the sign-posted itineraries, the Norias Route (SL-MU 28) stands out for its excellence. On this itinerary, you can visit four fully operational Ferris wheels, making Abarán the municipality with Spain's most functional Ferris wheels. As hundreds of years ago, these lifting devices continue to allow farmers to carry out traditional irrigation. Thus, we have the Noria Grande, the Noria de la Hoya de Don García, the Noria de Candelón and La Ñorica. In 2018, the agricultural landscape where they are located was declared an Asset of Cultural Interest with the category of Place of Ethnographic Interest (Decree 116, 2018) (López, 2021) (Figures 18-21).


**Figure 18** (left). Noria de la Hoya de Don García. Source: Quijada-Guillamón, H. M.
**Figure 19** (center). Gran Noria of Abarán and divider of the Main irrigation ditch of Abarán and Blanca. Source: López-Moreno, J.J.
**Figure 20** (right). Guiding the Route of the Norias from the cultural project - ecomuseum "Legado Vivo". Source: López-Moreno, J.J.

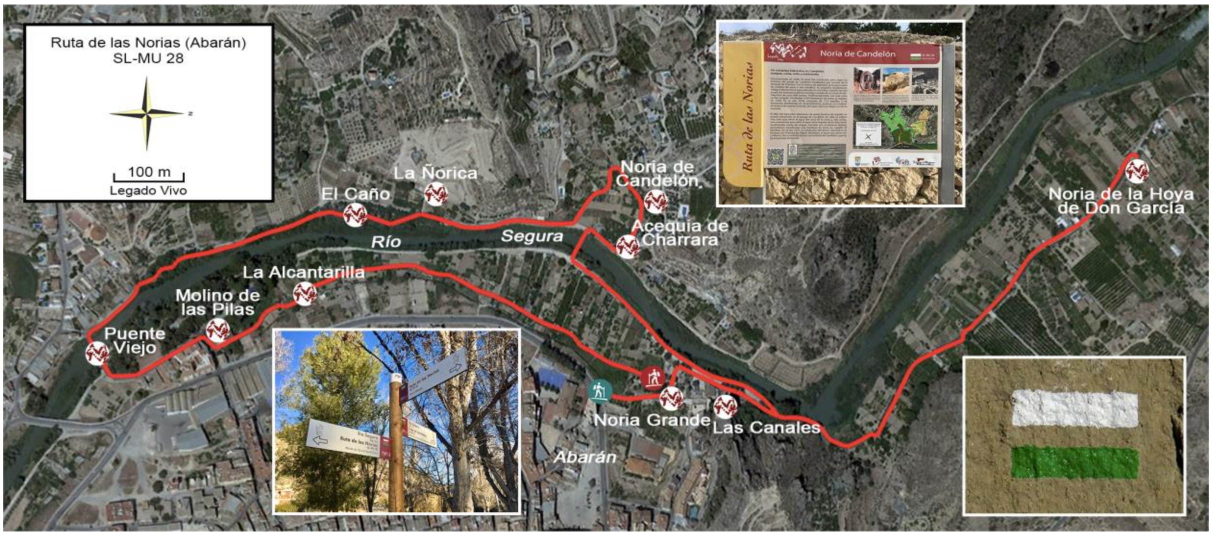



**Figure 21**. Heritage itinerary and signage of the Norias route. Source: cultural project - ecomuseum "Legado Vivo".

### 4.3. Disclosure and knowledge transfer

Over the years, numerous conferences, seminars, and congresses have been held, guided and interpreted routes by the itineraries marked by the cultural project - "Legado Vivo" ecomuseum, direction and tutoring of academic works, etc. (López, 2023b).

#### *4.3.1. Conferences, seminars and guided routes*

The Research and Dissemination Conference on the Ricote Valley has reached its seventh edition in 2024. Its objective is to disseminate and transfer knowledge acquired by researchers, veterans and novices on diverse topics, which shed light on historical developments and the environment of the Ricote Valley and its people. With that same motivation for the transfer of knowledge, the series of conferences "Las Noches en la Fábrica de la Luz" was born, co-directed by the Permanent Headquarters of the University of Murcia in the municipality of Blanca, as well as the successive Meetings of "La Carraila". In his conferences, topics of interest related to heritage, culture, ethnography, uses and customs are discussed, all related to the Ricote Valley and its long historical trajectory (Figures 22-25). These forums are always linked to the offer of guided and interpreted itineraries. They were born with the interest of disseminating and transferring knowledge both to the inhabitants of the Ricote Valley and to tourists and visitors in increasing numbers.



**Figure 22** (left). VI Research and Dissemination Conference on the Ricote Valley. Source: Gómez-Manuel, J.M..
**Figure 23** (center). Nights at the Light Factory (Noches de la Fábrica de la Luz), Pedro Cano Foundation, Blanca. Source: Molina-Ruiz, J.
**Figure 24** (center). Poster Nights at the Light Factory. Source: Molina-Ruiz, J.
**Figure 25** (right). X Meeting of "La Carraila". Source: Joaquín Caballero Soler.

#### *4.3.2. Cartography and open and interactive maps (MAPACUVALLE)*

The MAPACUVALLE (map of the cultural landscape assets of the Ricote Valley integrated into the cultural project - ecomuseum "Legado Vivo") collects the assets identified by members of the "La Carraila" and "Caramucel, nature and history" associations. It is an open map in which the work carried out continues to be collected, with the possibility that the society requests to try a newly identified asset. This cultural map can be consulted through the Legado Vivo website (https://legadovivo.blogspot.com/p/mapacuvalle.html). To date, it includes 173 assets belonging to different categories: Assets of Cultural Interest (BIC), tangible cultural heritage, intangible cultural heritage and natural heritage. Likewise, it includes the beginning and end of the marked itineraries, the information on the heritage of the itinerary and the viewpoints with panoramic views from which to observe the beautiful cultural landscape of the Ricote Valley. An intuitive, complete and open tool for the public (Figure 26).

## 5. Conclusion

The work carried out over the years by the associations "La Carraila" and "Caramucel, nature and history" has been a decisive boost to the enhancement of the rich heritage of the Ricote Valley. The associative work is manifested in numerous interventions related to protection, conservation, signalling, dissemination, and knowledge transfer. The set of actions has led to the organisation of up to 7 Research and Dissemination

Conferences on the Ricote Valley over 14 years, with more than 100 articles published and available openly to the public in the La Carraila blog (https://lacarraila.blogspot.com/).

This intense work is reflected in the Cultural Project - Ecomuseum “Legado Vivo”, which has designed and implemented ten heritage itineraries with the support of Municipalities Councils and other public and private entities. One hundred seventy-three assets have been studied and identified, 69 on the ground, with signage, QR codes, directional posts, beacons and signage with their design. The development of these itineraries has been a boost for cultural tourism in the Ricote Valley, organising guided routes along the different itineraries. Brochures have been prepared and deposited not only in tourist offices but also in different editions of the International Tourism Fair "FITUR". The scarce economic resources have been compensated with work, passion, and citizen, political, and business cooperation. Good practices have resulted in a cultural, environmental, educational, didactic and tourist resource so that inhabitants and their visitors can increase their knowledge about the integral heritage of the Ricote Valley.

For all of the above, we consider that the cultural project - ecomuseum “Legado Vivo”- can serve as an example of the implementation of similar initiatives in other places. This trajectory, full of work and enthusiasm, has been recognised with the award of the Hispania Nostra 2023 in the category of signalling and dissemination of cultural and natural heritage. It is the first of these awards to be awarded in the Murcia Region.

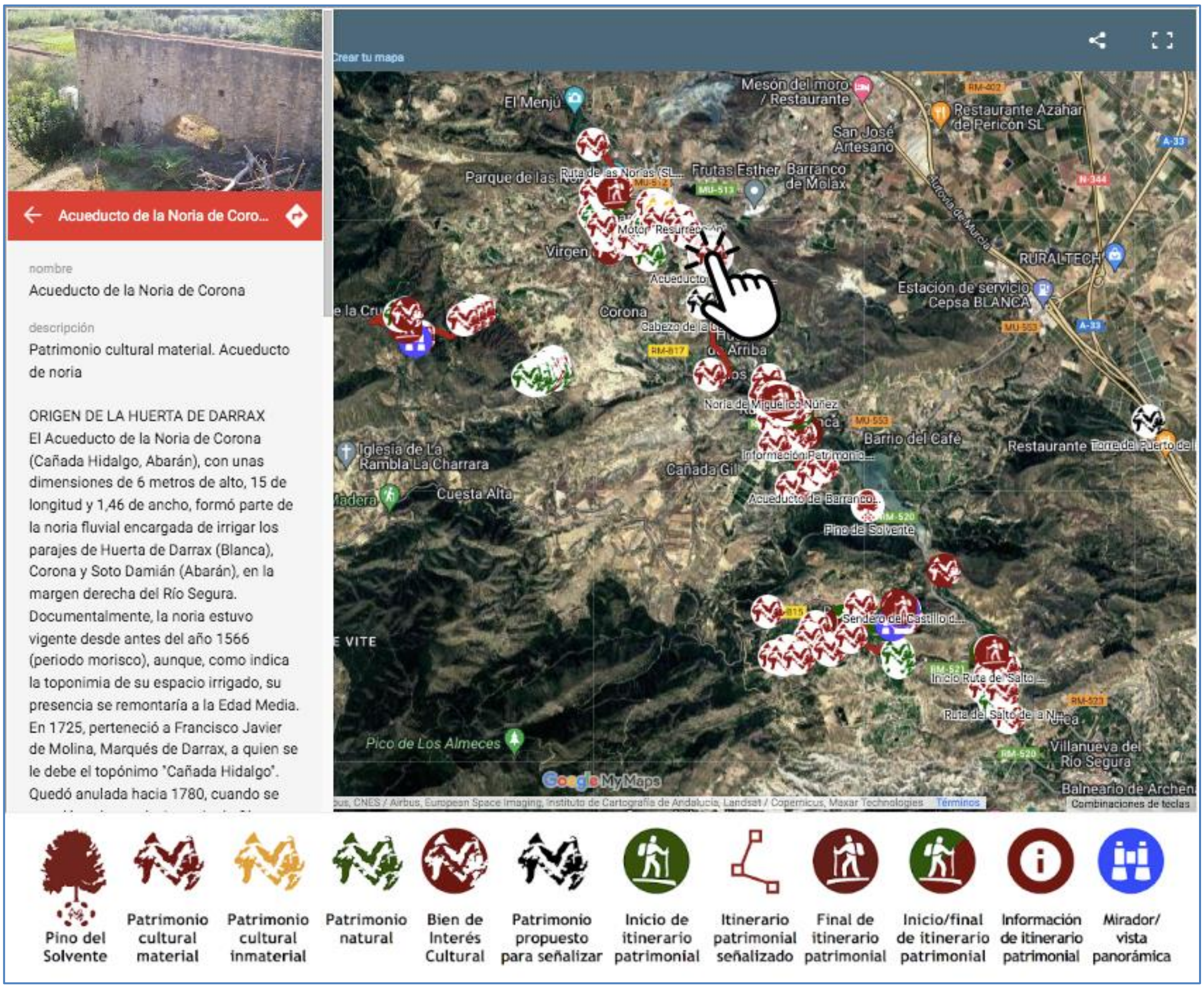



**Figure 26**. MAPACUVALLE. Source: cultural project - “Legado Vivo” ecomuseum.

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# Application of geographic information systems to the tourism enhancement of natural and cultural heritage. The study case of a scenic road in Canal de Navarrés (València, Spain)

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***Abstract***

*A methodological proposal is developed for the creation of a tourism product, with the aim of enhancing the tourist development of the study area, using the capabilities of Geographic Information Systems and public geospatial information to carry out the operations for decision-making. To achieve this, a scenic road is designed using a regional road as its main axis, which passes through different areas included in the Natura 2000 network and alongside places included in the UNESCO World Cultural Heritage List. The final result provides a comprehensive understanding of the territory, identifying those resources that may have greater tourism value and suitability to be part of the proposed scenic road and identifying the weak points that could represent a drawback for the management of tourism in this place, obtaining at last, a comfortable and satisfying experience for visitors to this place.*

***Keywords:*** *Scenic Road, Landscape Enhancement, Natura 2000 Network, UNESCO Site, Geographic Information Systems, Canal de Navarrés (Spain).*

## 1. Introduction

This study focuses on the design of a scenic road in the Canal de Navarrés based on the interactions between a road and the landscape as a tourism product. Landscape is a complex concept that the Valencian law conceives as: “Landscape is any part of the territory, as perceived by people, whose character is the result of the interaction of natural and/or human factors” (Ley 5/2014, de 25 de julio de la Generalitat, de Ordenación del Territorio, Urbanismo y Paisaje, de la Comunitat Valenciana, 2014).

To reach the aim of the study, it approaches the landscape through one of the broad range of points of view that this conception allows: the public use enhancement point of view. Thus, this study focuses on the scenic attraction of a road, but goes beyond, and it also analyses and evaluates the different cultural and natural assets, as well as the public use facilities and tourism services, in order to obtain as a result a quality tourism proposal, feasible and sustainable in terms of tourism aptitude and level of attraction.

To do so, the study proposes and applies a methodological process designed ad hoc, based on the use of GIS to combine and adapt different published methodologies for each step of the process: first, an official methodology to create scenic byways; second, the landscape analysis tools and the geographic software applications; and third, the evaluation of the resources and services aptitude in terms of tourism enhancement, as well as the scenic value of the landscape. The methodological process designed implies the pass from the “road” concept, as a mere physical nexus, to a “route” concept, used in tourism to define the intellectual nexus that heritage interpretation (natural, cultural and landscape) provides to a sequence of organised concepts and ideas capable of enhancing the destination heritage. Despite this study focusing on turning “road” into “route”, we will use the term “Scenic Road” in order to clarify that the core is a motorway road, and therefore, it focuses on cars.

The idea of this methodological process is not only to identify elements capable of welcoming visitors but also to propose a physically feasible visiting activity conceptually capable of enhancing the heritage of the area, and to dinamise the tourism activity, based on the concept of landscape.

This study case is developed in “La Canal de Navarrés”, a territory whose managing authority has among its objectives the tourism enhancement, and it is specifically mentioned in the principles of this administrative organisation (Mancomunidad de Navarrés, 2020), and it is also mentioned in its Tourism Development Plan (Hermosilla, et al., 2018)

Thus, as part of this tourism strategic plan, this study uses the Study case of a Scenic road in La Canal de Navarrés to test the GIS methodology due to its landscape values and using the only road connecting the different towns and heritage elements as the axis of the proposal.

The study case consists of the analysis and proposal of a thematic route, combining facilities, attractions, services and other resources already existent in the territory. The scenic proposal includes three main steps:

- The assessment and evaluation of the natural and cultural assets, among others, the Natura 2000 Network and the Archaeological site - Rock Art included in the UNESCO list of Cultural Heritage, to determine their tourism aptitude as visitor attraction elements as well as their aptitude to support tourism activity, such as the state of conservation, fragility or the accessibility.
- The inventory and evaluation of the tourism services and facilities, also from the tourism aptitude point of view, as they support the visiting activity.
- The analysis of the obtained results and assembling of physical and intellectual components, which implies a decision-making procedure.

Finally, it is proposed a scenic route with the regional road acting as the main axis, with recommendations that must be implemented before launching the offer as a tourism product.

## 2. Aim and objectives

The aim of this study is to design, evaluate and propose a methodology based on GIS for the decision-making process and design of a Scenic road in order to increase awareness of the natural and cultural values of this area. Beyond this, the core methodology aims to use public geospatial information provided by official public administrations and regularly updated, and the capacity of the open-source Geographic Information Systems.

To achieve this aim, it is necessary to accomplish specific objectives:

- To identify and choose the suiteable information sources and the open-source GIS software.
- To proceed with landscape analysis, identifying visual basins and potential panoramic observation points.
- To inventory and evaluate the heritage assets as tourism attractions and decide consequently those feasible to be included in the route, both natural and cultural, considering their aptitude to support public use.
- To assess the potential of existing tourism services in relation to their inclusion in the route.
- Identification and design of new facilities and improvements to the existing ones when necessary.
- Proposal of the Scenic road, with the resources and services to be included and the heritage-protected sites to be included due to their recreational value and aptitude.
- Proposal of the design and georeference of directional and information signage system.

## 3. Methodology

It is essential the design of a methodological process capable to turn a group of resources (landscape, cultural, natural and scenic assets, as well as tourism facilities) into a consistent scenic road proposal. The elaboration of the methodological process starts with the formal steps required to establish a scenic road under the US concept, published by the Forest Service as the Scenic Byways HandBook (USDA Forest Service San Dimas Technology and Development Center, 2002)(Figure 1). Beyond, this methodology works in parallel with landscape analysis techniques and tourism enhancement tools, adding value to the area and soundness to the proposal.

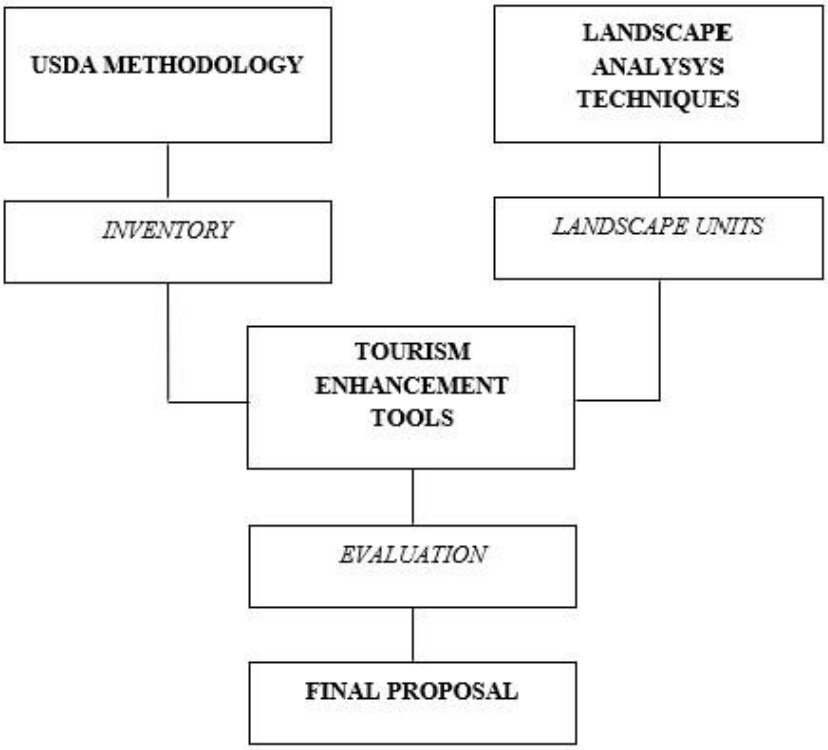


**Figure 1.** Outline of the proposed methodology. Source: Benito, R.M (2020)

An important part of this methodology has focused on the use of GIS tools, transferring the methodologies reference to GIS tools, basically to carry out spatial operations for the visualisation of the inventory of resources and services available in the study area (natural, cultural, etc.). On the other hand, other GIS spatial analysis tools were used to study and group different landscape units and to analyse the elevation profile of the road CV-580, very relevant to the study, as it shows the possibility of offering different alternatives to visitors to tour the area in more sustainable ways, using for example the bicycle.

The spatial data used to develop the analysis and processing information was obtained mainly from different public sources of geospatial information, official public sites, both regional (Institut Cartogràfic Valencià, 2020) and national (Instituto Geográfico Nacional, 2020). Other resources needed in the methodology were not available as georeferenced data, so it was carried out different georeferencing procedures beforehand in order to obtain this information as spatial data on GIS.

Therefore, the methodological process and tools used were as follows (Figure 1):

1. The study of the area and their characteristics from a physical **geography** point of view (geomorphology, hydrology, and vegetation), and the human geography. For this it was developed a cartographic and bibliographic review.
2. Resources and attractions **inventory**: natural, cultural, scenic and recreational facilities inventoried as the USDA methodology establishes (USDA Forest Service San Dimas Technology and Development Center, 2002). Beyond, it was combined with the methodology for the inventory of the tourism services providers, adding restaurants, guiding and information services and accommodation services, as they turn the tourism activity into local economic and social dynamisation (Viñals, et al., 2017).
3. **Visual** Analysis/Landscape Units: Landscape analysis techniques are necessary to obtain those areas visibiles from the road, combined with the typology of landscape and elements of interests, to define the landscape units. The tools used to develop the visual analysis were cartographic research and available GIS tools, mainly ArcGIS software.
4. **Tourism aptitude** evaluation of the attractions, facilities and services: the methodology used for the evaluation of the elements inventoried in this study is the one proposed by Viñals et al. (2017). And for the tourism evaluation of the scenic resources, it was applied the methodology proposed by Zuccarini & Geraldi (2019).
5. **Results and proposal** of the scenic road. The final process was to define the scenic road capable of connecting the space not only physically but also intellectually, with a distinctive and evident link between the nature, the culture and the landscape, capable to transmit the connection existing between these elements in the specific context of the Canal de Navarrés, and also feasible in terms of tourism activity.

### 3.1. Study Area. Resources and Attraction Inventory

The Mancomunidad de Navarrés is a group of municipalities (Bicorp, Bolbaite, Chella, Anna, Quesa, Estubeny and Navarrés) in the province of Valencia, a region located in the middle of the Valencian Community (Figure 2).

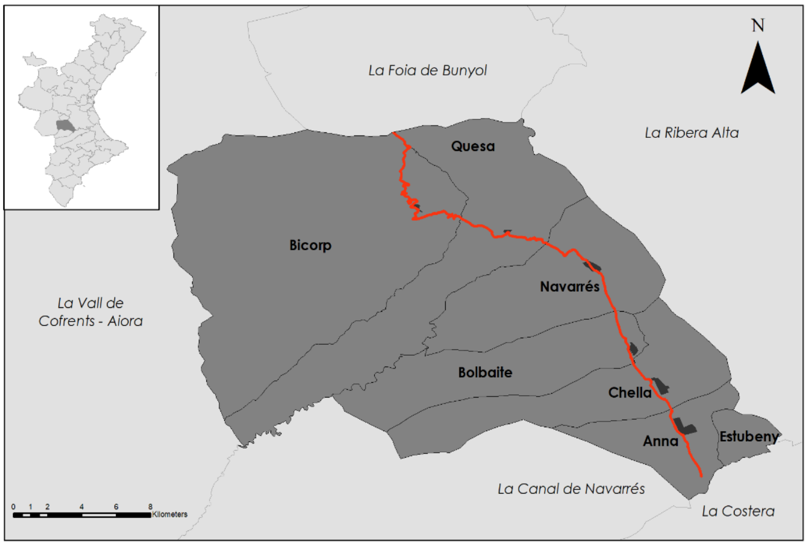


**Figure 2.** Map of the Study Area. Source: Benito, R.M. (2020)

Mancomunidad's aim is to share the management of certain public services such as waste or tourism. Those listed municipalities are part of the county of La Canal de Navarrés, except Estubeny which is part of the county of La Costera (fig.2). The municipality with the largest area is Bicorp (136.50 km$^2$), followed by Quesa (73.20 km$^2$), Navarrés (47.00 km$^2$), Chella (43.00 km$^2$), Bolbaite (40.40 km$^2$) and Anna (21.40 km$^2$) (INE, 2019). In total, the study area is 368,4 km$^2$.

### *3.1.1. Physical Geography*

Physical geography is a relevant element in order to understand the configuration of the landscape in scenic studies. In this section, it is necessary to study tree elements: geomorphology, hydrology and vegetation.

Geomorphologically, this area represents a tabular relief, which is formed by the erosion of geological materials and the influence of the hydrological system. This area is a flat-bottom valley, approximately 1 to 2km wide, decreasing the height and smoothening the relief from west to east, heading the coast. In the western part, there are the highest points, with the calcarean formation of Macizo del Caroche in the North-West direction and La Muela de Cortes in the South-West direction, in which is the highest peak; from the western part the relief descends eastwards, until the conformation of the Júcar River and the mountains of Sumacàrcer (Viñals, M., Morant, M., Alonso-Monasterio, P., & Teruel, L., 2015).

The hydrology of this area becomes very important due to the abundance of water-related forms, such as rivers, ravines, natural sources, etc. It is included in the Júcar river basin, and in this part, it forms a semi-endorheic basin, and consequently, the water tends to accumulate in the lowest levels of this area. The hydrological forms generate a double positive impact; on one hand, they confer the identity to the territory as a shaping element of the landscape units, and on the other hand, they increase the intrinsic value, contributing to social use as a recreative element.

### *3.1.2. Human Geography*

This area has a population of 10,711, who inhabit a total of 368,4 km2, and an average density of inhabitants is around 43 inhabitants/km2 being Bolbaite and Quesa are included in the demographic challenge programmes.

This data is relevant to the European standards that define the "rurality" degree of the territories being 43 inhabitants/km2 is a high level of rurality according to the definition established by the Organization for Economic Cooperation and Development (OECD) (Ministerio de Medio Ambiente, Medio Rural y Marino, 2009). This classification is useful in order to apply for certain European funds to develop initiatives, for example, Leader instrument, under de CAP (Common Agriculture Policy), that includes tourism dynamisation actions, even EU Recovery and Resilience Facility.

The level of rurality of the territory, when focusing on tourism planning, is relevant due to the need of certain services linked to visitors, such as hospitality ones or tourist info, so the evaluation of the working-age population is considered a main factor to be included in the development of a tourist area since it is an estimation of the capacity to develop local or regional projects related to promote services. Fortunately, in the case of the study area, there are some service companies.

### *3.1.3. Natural heritage*

Natural resources included in the area belong basically to those characteristic of the forest areas: rivers, ravines, caves, slopes, and fountains. In general terms, the importance resides in the water bodies and geomorphological formation created because of this hydrological system but also due to its social use, as the study area is well known at the regional level for the public access to these rivers in summer.

Other geological elements of interest are caves and ravines; examples of them are Abrigo de Voro, natural caves in Quesa and Barranco Moreno in Bicorp (ravine). Many of these caves are included in Lists of protection.

The area has an outstanding natural value, so for this reason, La Canal de Navarrés is included in the Natura 2000 Network to protect this heritage. As shown in Figure 3, all towns are included as SPA (Spatial Protection Areas), named Sierra de Martos-Muela de Cortes; however, only Bicorp, Quesa and Anna are the municipalities in which the SCI (Sites of Community Importance) surface is high, named SCI of Muela de Cortes - El Caroche.

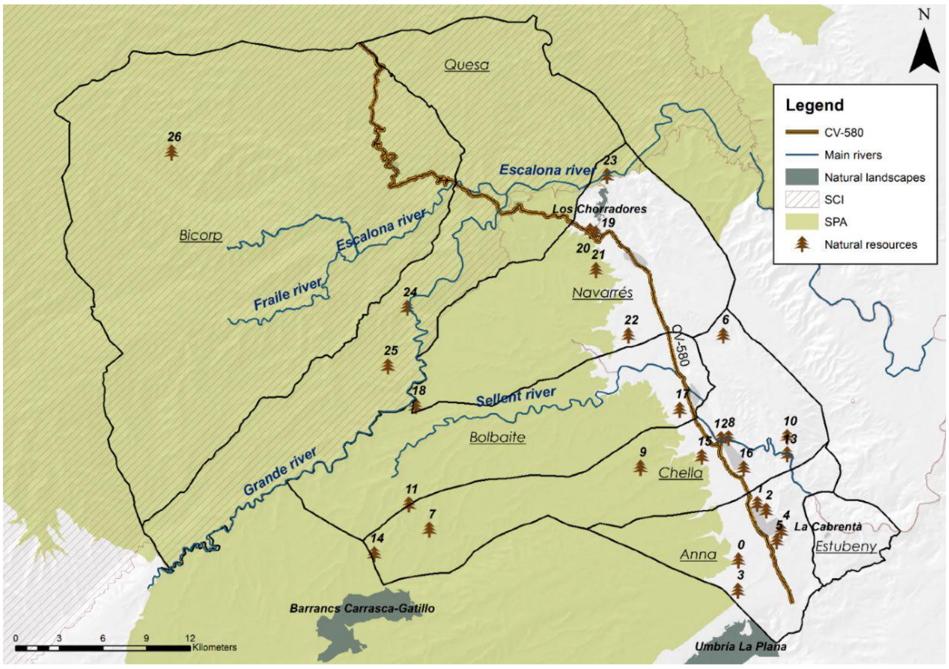


**Figure 3.** Natural heritage map. Source: Benito, R.M. (2020)

Regional protection sites included in the area also contribute to this area's high natural value and, therefore, its attraction: The "Paratges Naturals Municipals" (Local Natural Landscapes) are established in two towns of this study area, the first under the name of "The Estubeny Forest" or also called "La Cabrentà"·located in Estubeny, and the second one is in the locality of Navarrés named "El paraje de los chorradores".

### *3.1.4. Cultural heritage*

Cultural resources are outstanding in the study area, as they are one of the main tourist attractions. This group includes the most abundant and traditional, those who belong to religious buildings or castles, but those of greater relevance are the Cultural World Heritage List sites of "Rock-Art of the Mediterranean Basin on the Iberian Peninsula" in 1998 (UNESCO, 1998). Some of these listed representations are located in the towns of Bicorp, Quesa and Navarrés. Among the Rock Art representations in the study area, the most important is La Cueva de la

Araña (Spider's Cave). Its paintings were drawn by the ancient inhabitants of these territories between 9,000 and 14,000 BC.

Not only international figures of protection confer to this area its important cultural value, but also a couple of cultural resources catalogued by regional figures of protection in the Valencian Community:

- Group A: Element of Cultural Interest (Bien de Interés Cultural or BIC):ie: Palacio Condes de Cervellón.
- Group B: Element of Local Relevance (Bien de Relevancia Local or BRL's): i.e. Iglesia de San Antonio Abad (San Antonio Abad Church)

On the other hand, it has also been included in this study the traditional cattle routes of "Vías Pecuarias". Those paths had been used to move livestock, but they are still bearers of historical values, as there are numerous paths in this area due to the ancient Iberian Commerce Routes. In the Valencian Community, those elements form a network of more than 14,000 kilometres, and all of them are under the management of the Valencian Government, and they provide the territory an extra historical-cultural value as well as recreational one (Conselleria d'Agricultura, Desenvolupament Rural, Emergència Climàtica i Transició Ecològica., 2015).

### 3.2. Landscape Evaluation

As the name of the scenic road establishes, one of the most important characteristics to study is the analysis of the areas visible from the road, the scenery; for this reason, in this section, it is explained the procedure designed for the analysis, using as a tool a GIS, in this case specifically through the ArcGIS software.

The first step was to obtain the delimitation and characterisation of viewsheds in order to set the number of viewpoints. In this case, it is important to remark that the viewpoints were the nodes of the line forming the road axis of CV-580 in the cartographic information.

The basic operational procedure (Figure 4) to obtain the viewsheds starts by adding to the CV-580 line a value of 1,50 meters in height to represent the average height of a passenger car according to the height of the most purchased cars in Spain during 2019 (MAPFRE, 2019) from which an observer (visitor or tourist) in a car will be looking to the landscape. Then, with the tools Viewshed and Digital Elevation Model (DEM) in raster format and this line, the visual analysis was done. As a result, a raster map was obtained with information on the visible and non-visible areas of the car.

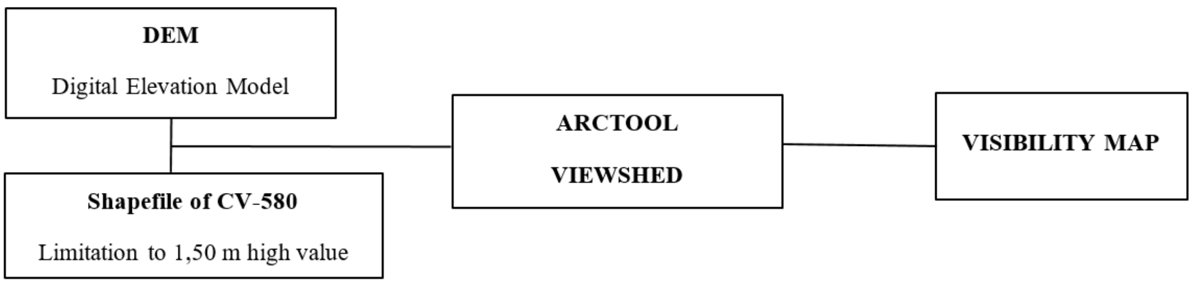


**Figure 4.** Process to obtain visibility map. Source: Benito, R. (2020)

Then, with the visibility and the scenic resources map, the whole area was divided into sub-areas with homogeneous characteristics (Figure 5). These sub-areas are called landscape units (LU), which appear in the Valencian law, and it is necessary to establish landscape units in all projects or studies whose aim is to promote an action related to landscape (Ley 5/2014, de 25 de julio de la Generalitat, de Ordenación del Territorio, Urbanismo y Paisaje, de la Comunitat Valenciana, 2014).

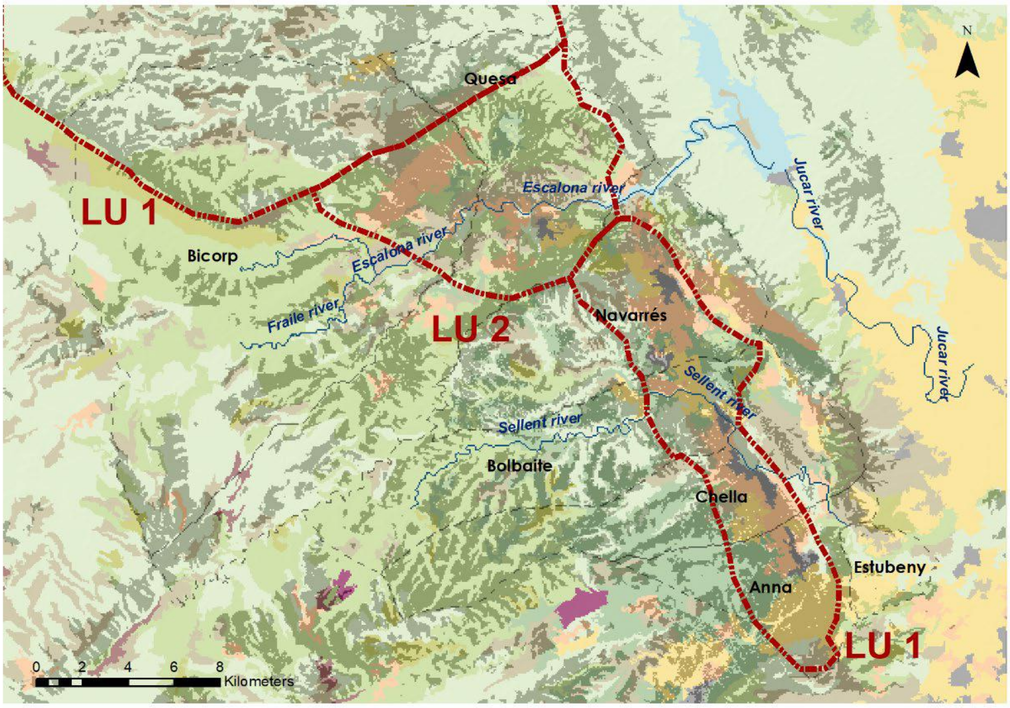


**Figure 5.** Landscape Units map. Source: Benito, R. (2020)

### 3.3. Evaluation of the Scenic Value From the Tourism Perspective. Tourism Aptitude.

The tourism evaluation methodology to design this proposal of a scenic road has been adapted from the Tourism Aptitude concept, which is related to the recreational evaluation of natural and cultural resources, considering the attractions that motivate the movement of the visitors but also the services, facilities and infrastructures capable to give the necessary support to the tourism activity.

Hence, tourism aptitude evaluation focuses on identifying those resources capable of offering the visitor of this area the visit to the most suitable elements after and while driving through the scenic road. Thus, this evaluation it is also an opportunity to identify those resources that have been unnoticed as important, but that for the specific proposal of a scenic road and the activities and visits linked to it, can be relevant and act as connectors, both physical and intellectual. The tourism aptitude is defined as the "*capacity of a territory and its elements to attract, host and manage visits under conditions that guarantee both the conservation of the resources and the visitor comfort while devevoping a proposed activity, or a group of activities*" (Viñals, et al., 2017).

To develop the evaluation of the Tourism Aptitude of each municipality (Figure 6) it was created a methodology, based on the work of Viñals et al. (2017), proposing the following basic combination of variables to be analysed:

$$\boldsymbol{TAM = AV + RE + TS}$$

| VARIABLE | Definition | Components included |
|---|---|---|
| **TAM** | Tourism aptitude of the municipality | - |
| **AV** | Attraction Value | Natural and cultural elements |
| **RE** | Recreational Facilities | Walking trails and MTB TRAILS |
| **TS** | Tourism Services | Elements that offers services to tourists |

**Figure 6.** Tourism Aptitude Variables. Source: Viñals, et al., (2017).

*3.3.1.Evaluation of the Attractions Aptitude*

The first element in the Tourism Aptitude of the Municipality "equation" is the intrinsic evaluation of the resources existing in the area, in this study the elements evaluated (Figure 7) are those:

$$\boldsymbol{AV = NR + CR + ACR + L}$$

The result of the equation was given thanks to the use of tables and the handling and management of data in Excel software. In total were evaluated: 34 natural resources, 30 cultural resources, 31 ancient cattle routes, and 3 landscape units.

| VARIABLE | Definition | Components included |
|---|---|---|
| **AV** | ATTRACTION VALUE | - |
| **NR** | Natural Resources | Resource Condition<br>Management and Availability<br>Legal Status |
| **CR** | Cultural Resources | Resource Condition<br>Ownership and availability<br>Legal Status |
| **ACR** | Ancient Cattle Routes | Legal Status<br>Ownership<br>Resource Condition<br>Importance<br>Distance to the scenic route |
| L | Landscape | Zuccarini & Geraldi, 2019 |

**Figure 7.** Variables for the evaluation of the Attractions aptitude.Source: Viñals, et al., (2017).

*3.3.2 Recreational Facilities Aptitude*

The recreational facilities, 45 included in the study area, were evaluated using a strategy similar to the attraction elements. The level of attraction (LA), the user profile (UP) and the distance to the road CV-580 (D) were the requirements to evaluate each recreational facility (Table 1).

$$\boldsymbol{RF = LA + UP + D}$$

The level of attraction (LA) evaluated the attractions existing in the routes and ways, giving more value to those ways with three or more cultural or natural elements and the minimum value to those routes which had none of these elements.

On the other hand, the user profile (UP) consisted of making a separation between the roads who had multiuser profile (minimum score) from those who only had one user profile (maximum score). Giving a higher score to the single-user equipment is because of the conflicts that can arise in multiuser paths due to those differences between each user profile, provoking discomfort and unsafety.

Finally, the evaluation distance (D) was introduced to give more value to those secondary roads next to the main road and decrease the value for those facilities far from the main road.

**Table 1.** Variables for the evaluation of the recreational facilities aptitude.Source: Viñals, et al., (2017).

| Level of attraction | User profile | Distance |
|---|---|---|
| 5 = 3 or more attractions | 5 = Only pedestrian | 5 = At the scenic road/town |
| 3 = 1or 2 attractions | | 3 = 15 minutes from the scenic road/town |
| 1 = No attraction identified | 3 = Multiuser (BTT shared with pedestrian) | 1 = More than 15min from the scenic road/town |

*3.3.3 Tourism Service Aptitude.*

A total of 92 tourism services (TS) were evaluated (Figure 8) according to the number of elements included in each municipality of the different typologies (A-accommodation, FAB – food and beverage, TSC- tourism companies). Those areas with more of these elements will bring the tourist or visitor a better experience.

$$\boldsymbol{TS = A + FAB + TSC}$$

| Accommodation | Food and Beverage | Tourist Services Companies |
|---|---|---|
| Total number of beds per municipality and accommodations typology. | Total number of bars, restaurants, and other companies offering this services. | Summatory of tourism services companies per municipality. |

**Figure 8.** Variables for the evaluation of the tourism service aptitude.Source: Viñals, et al., (2017).

## 4. Results

The methodological process used during the study is a combination and adaptation of different procedures, so the results obtained are shown separately for each methodological process step. Thus, showing the USDA methodology results and the landscape techniques results, and afterwards, those results (USDA and landscape) are the inputs for the next methodological step, tourism aptitude evaluation, whose results are also shown in this section.

The USDA methodology results show that this area has all the elements to be considered as a scenic route; according to landscape analysis methodology revealed that the three different typologies of the landscape visible from the road are included in the Natura 2000 Network as well as the UNESCO World Heritage-listed elements (Rock-Art Paints). In addition, the inventory revealed that there is a dense network of ancient cattle routes, so all of these aspects can be linked to promoting intellectual connections to enhance the territory, and also could serve as a basis to design and develop the parallel non-motorised routes such biking or hiking ones, with lower Carbon emissions.

According to the results of the tourist aptitude evaluation, the municipality with the higher attraction value is Navarrés, as it combines numerous natural and cultural attractions, followed by Anna with outstanding natural values and Bicorp, with a high value due to the cultural elements, particularly the UNESCO Site. Moreover, Bicorp is also rated as the higher value in the existence of recreational facilities, such as MTB and hiking trails. According to the tourism services, the municipality with more capacity to offer tourism services is Anna, followed by Chella.

The analysis and combination of all the partial results obtained in this tourism approach step of the methodological process shows the following tourism aptitude scoring for each resource typology, grouped by municipalities (Table 2):

**Table 2.** Final results of tourism potential.Source: Benito,R.M (2020).

| Municipality | Tourism aptitude | Resource type with higher score |
|---|---|---|
| **Anna** | 196 | Tourism services, Natural resources and Recreational water bodies (LU 1) |
| **Estubeny** | 32 | Non-remarkable resources (LU 1) |
| **Chella** | 156 | Tourism services, Natural resources (LU 1) |
| **Bolbaite** | 141 | All the resources are resent but any remarkable (LU 1) |
| **Navarrés** | 183 | Cultural and natural resources (LU1) |
| **Quesa** | 171 | Cultural resources, Recreational facilities and Landscape (LU 2) |
| **Bicorp** | 219 | Cultural resources, Recreational facilities and Landscape (LU 3) |

 

Thus, the results show the appropriateness of dividing the scenic route into three sections, coinciding with the three landscape units that were determined with the analysis of the road CV-580 viewshed. Beyond, the results identify the most recommended types of activities to be developed in each section (Figure 9) :

| Landscape unit associated to road's viewshed | Municipalities | High-scored resources accessible |
|---|---|---|
| **1-Agricultural landscape** | Anna-Estubeny-Chella-Bolbaite-Navarrés | River and ravine public use sites. Tourism Services |
| **2-Hydrological transition landscape** | Quesa | Landscape-Ravines/Recreation Facilities/Cultural-varied typology |
| **3-Forest Landscape Muela de Cortes** | Bicorp | Cultural resources, Recreational facilities and Cultural-Rock Art and Museum. |

**Figure 9.** Most recommended activities per Landscape Unit.

After assessing all resources and analysing the results established by the geographic information systems combined with the results of operational procedures, it was proposed to create the scenic route as a tourism product (Figure 10).

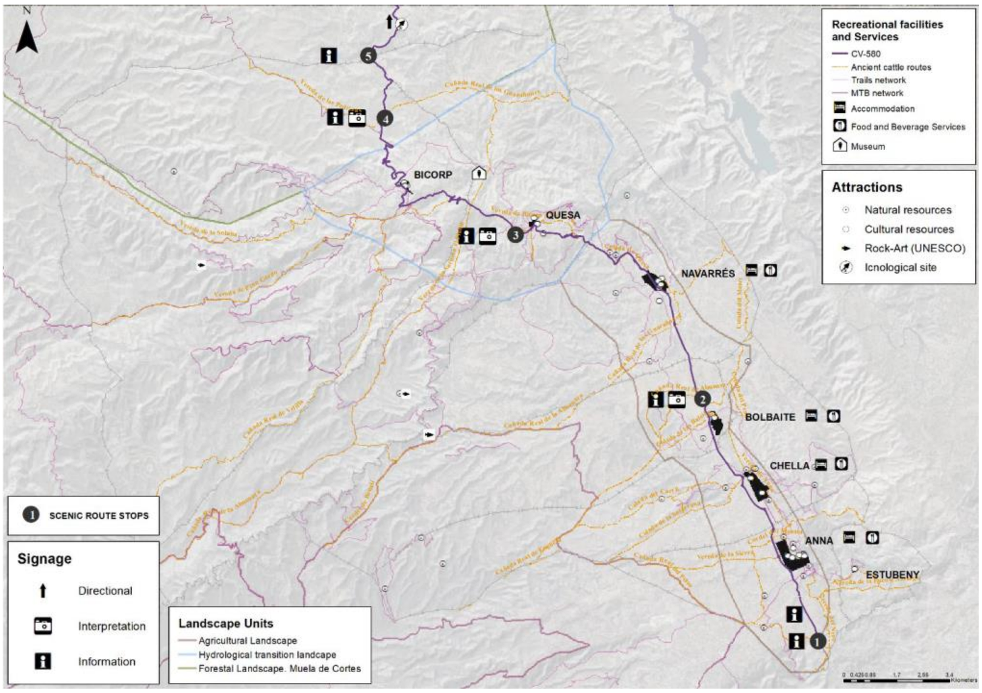


**Figure 10.** Scenic route elements. Source: Benito, R. (2020)

## 5. Conclusion

The main innovation of this methodology relies on the combination of three dimensions using GIS potential: first and more relevant, the incorporation of tourism aptitude criteria in the public use enhancement of the landscape, second to combine the aptitude with landscape evaluation methodology and third with the parameters of Scenic Route stablished by USDA.

However, the methodology is complex in terms of a number of elements to combine and the relative weights that need to be assigned to the variables. These make it essential for the processing that researchers have sound experience and background in both cultural and natural resources and the tourism activity planning and managing necessary to guarantee the good proceeding of the evaluation steps.

Though, the methodology results are flexible and appropriate to evaluate and proceed with the decision-making on the public use enhancement linked to the landscape. Beyond, the methodology uses mainly as inputs those informations of public use available and official databases, both cartographic and statistical, that are regularly updated by public administration, which gives an added value to the methodological proposal of the study.

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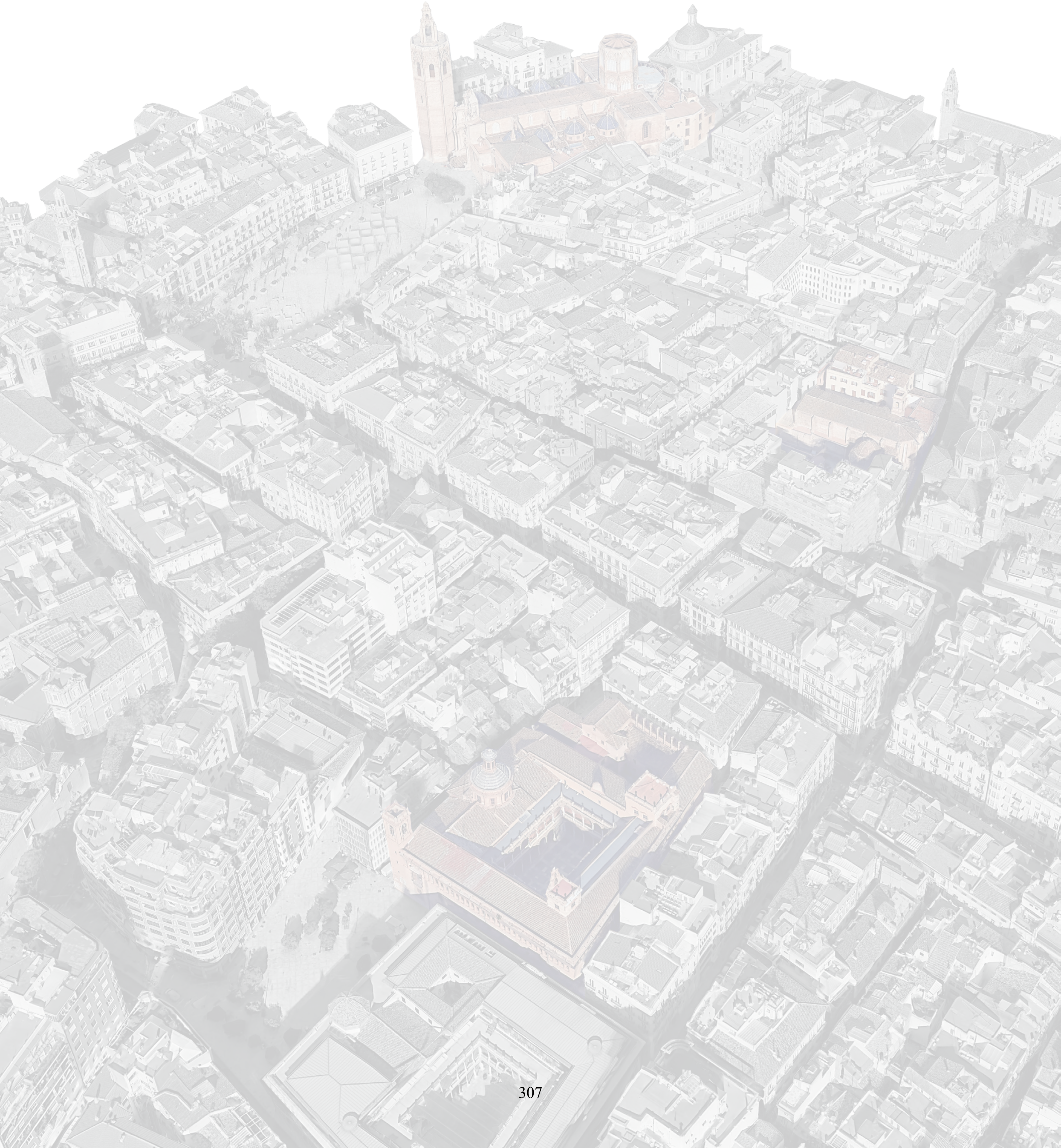
# TOPIC 3
*SMART TECHNOLOGIES FOR HERITAGE TOURISM PLANNING AND MANAGEMENT*



International Congress for Heritage Digital Technologies and Tourism Management
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Doi: https://doi.org/10.4995/HEDIT2024.2024.17651

# Digital technologies for accessible and sustainable cultural tourism. A project for the enhancement of Baroque Turin routes

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***Abstract***

*This contribution follows previous research about the recognition and geometric and morphological analysis of more than 70 Baroque atria covered by unitary and complex vaults in Turin city centre, the digital survey, and the AR experiments aimed at the presentation of the research's results.*

*The current proposal aims to communicate, spread, share, and finally, involve the community in the safeguarding and valorising of Architectural and Urban Heritage in Turin.*

*Turin Baroque atria are little known and rarely visited by the public, especially if intended as a system. This led us to think of creating thematic routes with a focus on accessibility and sustainability and dedicated not only to specialists but also to citizens, making them aware of and part of a common heritage and to the tourists looking for unusual cultural itineraries.*

*A dozen thematic paths aim to give back the complexity of the Cultural Heritage under investigation by linking the knowledge involved to allow different and personalised visit experiences concerning the type of user and his interests.*

***Keywords:*** *digital technologies, accessibility, sustainability, cultural tourism, Baroque Turin.*

## 1. Introduction

This contribution follows the author's previous research about the recognition and geometric and morphological analysis of more than 70 Baroque atria covered by unitary and complex vaults in the Turin Historic Centre (Spallone & Vitali, 2017a). The subsequent stages of the research involved the proposal of a route for tourists interested in mathematical disciplines (Spallone & Vitali, 2017b), the digital survey of a selection of the atria considered, and the experimentation of augmented reality (AR) for the communication and inclusive use of the cognitive content collected during the study phases. The latest activities were carried out in the ambit of the project "Nuevas tecnologías para el análisis y conservación del patrimonio arquitectónico" funded by the Ministry of Science, Innovation and University of Spain, which allowed Concepción López González (UPV) to join the Politecnico di Torino research group (López González et al., 2020; Spallone et al., 2021), and the AR experiments conducted in collaboration with Valerio Palma (Palma et al., 2019), from Shazarch, a start-up devoted to digital solution for heritage.

The current proposal aims to communicate, spread, share, and finally, involve the community in the safeguarding and valorising of Architectural and Urban Heritage in Turin. Digital technologies are involved at every stage of the process, from analysis through digital survey to interpretation through 3D models to communication and fruition through web, AR, and VR.

Between the 17th and 18th centuries in Turin, a highly innovative architectural season emerged, which, in the field of civil architecture, demonstrated unprecedented, pleasing spatial configurations for access and distribution spaces of noble buildings, conceived as a spectacular fulcrum at the acme of the ceremonial entrance. The atria realised with such spatial schemes present unified spaces without intermediate pillars, covered by composite vaults made of brickwork masonry. These were characterised by a remarkable geometric complexity, which gave them dynamism and airiness, allowing, at the same time and whenever necessary, the use of rather small rises (Figure 1). The interest in these spaces has been evidenced, among others, in the pages by Norberg-Schulz (1980) dedicated to the late Baroque palace, in which the Turin solutions are widely described.

Such a model of atria, in its extensive diffusion, is also of particular importance as a typical phenomenon of the city of Turin. The particular architecture with "open structures", so well highlighted by Pommer (1966), found extraordinary diffusion in Piedmont and Turin and prospered during the second half of the XVIII century also, contrary to other Italian and European realities where in the same years we are witnessing the return of soberer forms taken from the classical and sixteenth-century tradition.

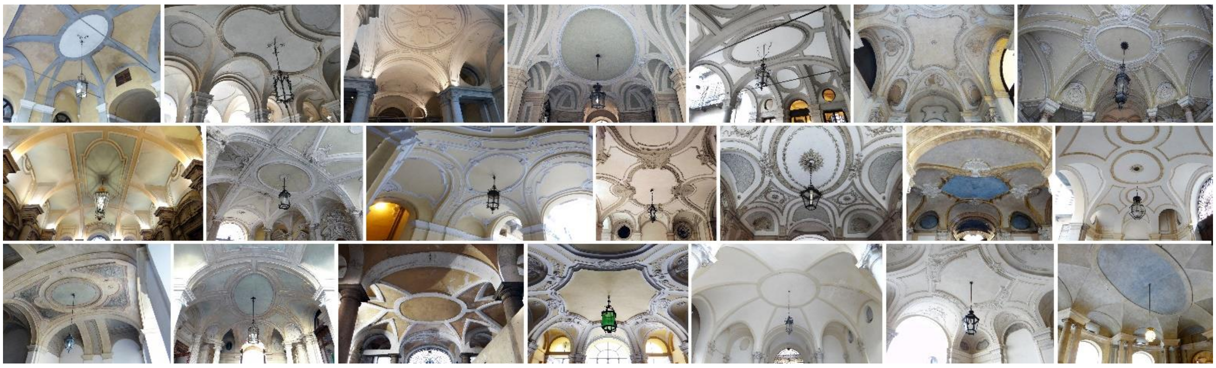


**Figure 1.** Overview of Baroque atria in Turin. Author: M. Vitali.

## 2. The Project

Through deep historical, morphological, and architectural analyses of the above-mentioned atria and an interpretive synthesis, it is possible to recognise and propose several cultural and touristic paths, which led to the hypothesis of a different fil rouge of connection between one atrium and the other. This last aspect makes it possible to imagine routes within the historical city. This led us to think of creating thematic routes dedicated not only to an audience of specialists, but also to citizens, making them aware of and part of a common heritage, and to the tourists who, more and more, are looking for unusual cultural itineraries. Therefore, it is a Cultural Heritage of great interest and a local peculiarity, but it is little known and visited by the public, especially if intended as a system.

This project is conceived and defined with a high level of scalability, not only related to other architectural heritage (e.g. industrial archaeology, modernism architecture...) but also to different kinds of Cultural Heritage, material and immaterial (e.g. museums, archives, theatrical representations, musical performances...). This means that research products could be the subject of future developments within the framework of partnership agreements, triggering a positive impact on the territory and fueling the initiatives of Territorial bodies.

The outcomes of the project consist of the creation of smart touristic routes enhanced by a website and a web app whose use will be strongly integrated. The website could link with Museo Torino, the digital museum of the city, which collects most of the city’s documentary heritage.

All these topics are intertwined with mobility, in the specific case mainly pedestrian (but also with a possible look at public transport and sharing of vehicles) and digital education, to which the project could contribute, also involving different age and cultural background groups in the creation of device interfaces. Objectives of inclusiveness imply attention to the realisation of a pilot route and the development of tools and special sections of the website and web app for accessibility related to: mobility, visually impaired, blind, and hearing, in desirable connection with existing apps.

The overall objective of cost containment will guide the research, thanks to: Low-cost devices (Mobile first), Low-cost Solutions, and Free and Open-Source Software.

At the current phase of the project development, the thematic paths have been created, and the first one is adjustable from the accessibility point of view.

## 3. The State of the Art

In recent years, the rapid development of low-cost digital devices and technologies for heritage communication has massively affected sustainable tourism. In particular, the field of eXtended Reality (XR), which includes augmented, virtual, and mixed reality, is today demonstrating its potentiality with respect to the continuum between real and virtual that characterises our daily life.

Among the extensive scientific literature that has recently related sustainable tourism to the latest AR and VR technologies are reviews by Cranmer, tom Dieck & Jung (2023) and by Talwar et al. (2023).

The first deals with the role of augmented reality for sustainable development in the scope of Cultural Heritage tourism and reveals that AR presents strategic opportunities to achieve social, economic, and environmental sustainability.

The second noticed the heightened activity in VR tourism, which has been touted as “alternative tourism” and “eco-tourism”, during the COVID-19 pandemic and wonders if this shift is temporary or will persist after the pandemic is over and concludes theorising VR tourism as a sustainable tourism solution long into the future.

Among the case studies, we could mention two studies that take stock of issues related to the use of AR and aim to enhance Cultural Heritage, including tourism experiences. They favour and support guided tourist experiences through the implementation of itineraries and visiting routes, linking the application of the AR to specific elements of a widespread heritage that provides anchorage mechanisms that do not rely on markers. The first work bases on the real-time visualisation of computer-generated virtual content (models, drawings, and documents) on mobile devices such as smartphones and tablets and systematises the main issues and challenges and some of the latest trends in the search for simple and accessible solutions without the use of too advanced tools, such as the development of new marker-less systems that uses local feature-based image registration and structure from motion (SfM) technology (Sato et al., 2016). The second work constitutes a specific experience of the application of AR for the construction of one complete mobile tourist guide for the enhancement of Cultural Heritage sites located in the old town of Chania, Crete, Greece (Panou et al., 2018). The experience appears particularly interesting for the opportunity to interact with historical monuments in non-intrusive ways, and for the aim to provide for future additions of digital content with a moderate amount of development and technical expertise. Moreover, one aspect that we consider particularly important is linked to the possibility for users to give feedback on their visit and to share information and experiences with other users.

## 4. Aims and objectives

The project intends to follow some of the 2030 Sustainable Development Goals (SDGs) defined by the UN. In particular:

SDG 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all, Target 8.9: By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products;

SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable, Target 11.4: Strengthen efforts to protect and safeguard the world's cultural and natural heritage;

SDG 12: Ensure sustainable consumption and production patterns, Target 12.b: Develop and implement tools to monitor sustainable development impacts for sustainable tourism that create jobs and promote local culture and products.

Concerning local actions framed in the "Agenda Digitale della Città di Torino" – Digital Agenda of the City of Turin –, issued in 2016 and whose time horizon refers to the Strategic Plan "Torino Metropoli 2025" – Turin Metropolis 2025 – this project can contribute to the participation and inclusion of citizens in the life of a smart city, which cannot ignore a progressive growth of digital skills. These will be facilitated through mobile devices, tablets, and PCs for Cultural Heritage fruition, to accompany users and increase their ability to interact online and use the tools in an informed way. Furthermore, the concepts of "culture" and "digital innovation" expressed in the Agenda are fully shared and preserved in the project. In the project, culture represents a prime factor in the development of the territory, based on its enhancement, in addition to its protection. It allows citizens to benefit from a heritage that is common and needs to be communicated. The project develops this concept on architectural artifacts diffused throughout the central area of the city, whose value as a system is affirmed beyond that of individual monuments. As said, the consistency and artistic quality of this system are little known today. The re-discovery, the construction of personal cognitive paths, and those provided by the research team can fuel in the citizenship the sense of belonging and active participation in the safeguard and lead to the triggering of crowdfunding and crowdsourcing initiatives.

Waiting for the Turin Metropolitan Strategic Plan 2024-2026, the current plan 2021-2023 "Piano strategico Metropolitano di Torino" called "Torino Metropoli Aumentata" – Turin Augmented Metropolis – in the Line 1, Digitisation, Innovation, Competitiveness and Culture, Strategy 1.5 is promoting the enhancement of the territory's potential for tourism promotion and fruition thanks to new technologies, both in terms of direct communication to new media and in terms of material and immaterial accessibility of the metropolitan territory's tourism products.

The challenge, therefore, is to create a "value chain" of attraction, allowing the city of Turin and the metropolitan area to make the city's "heritage assets" available and accessible: tangible ones (landscape, urban space, culture, art, products and brands, services, skills of its inhabitants) but also intangible ones, that is, information assets and IT assets. In this way, we will promote and witness a momentous passage, that is, the transformation of the "public heritage", including the cultural one, into the "common good". Such a transformation will define an interesting, accessible and usable resource, promoting at the same time the dynamics of active participation in the protection and enhancement of this heritage (e.g. through the activation and promotion of social ways of finding resources and funds for cultural and tourism projects).

## 5. The paths

The creation of on-site visit paths offers users different thematic itineraries, to specific interests.

At the moment, a dozen thematic paths have already been structured, which aim to give back the complexity of the Cultural Heritage under investigation by linking the systems of disciplinary knowledge involved (history of architecture, drawing, and three-dimensional digital representation, construction technique, etc.) to allow different and personalised visit experiences concerning the type of user and his interests. These paths are oriented to the deepening of specific themes.

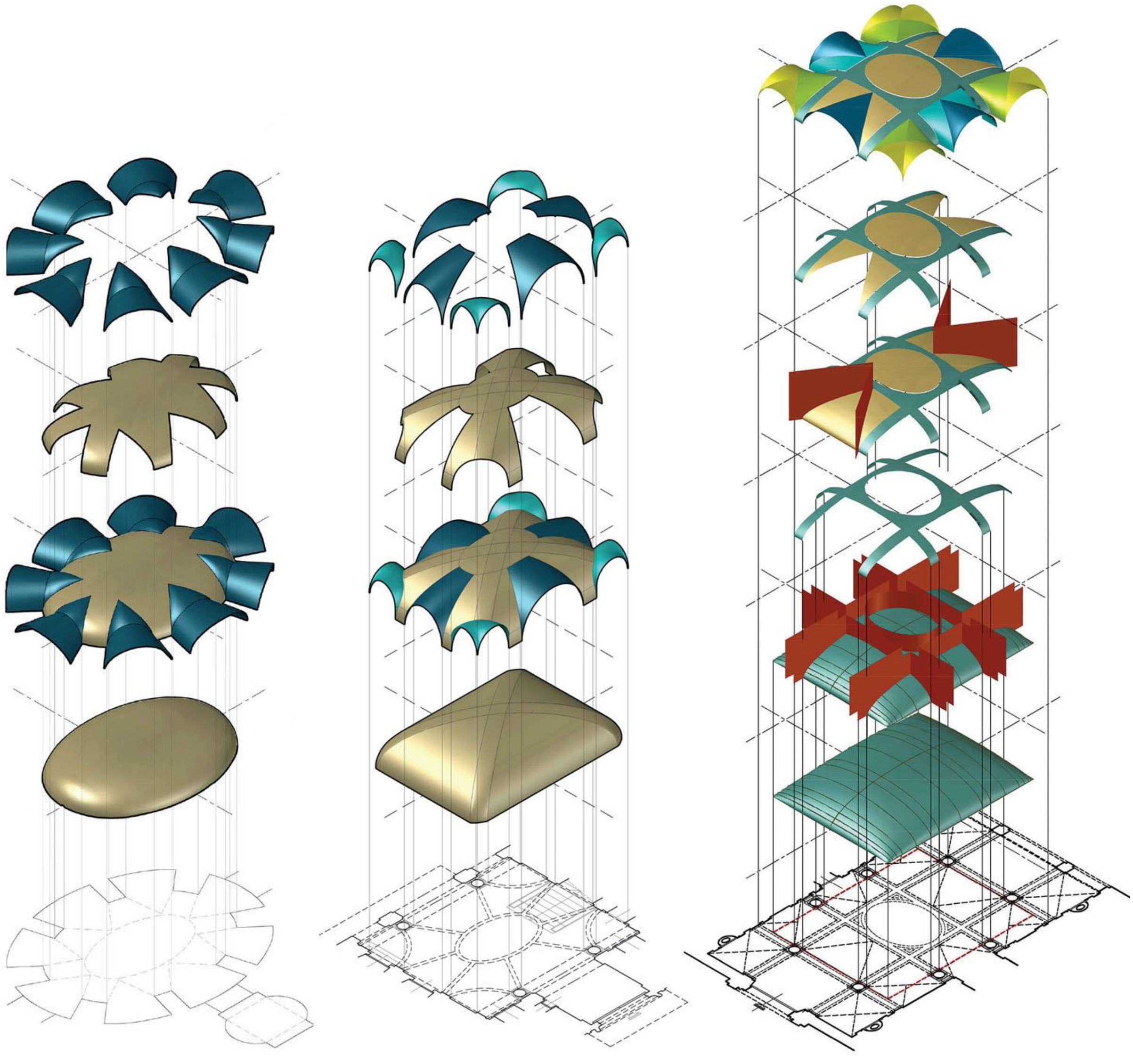


**Figure 2**. Geometric Analysis of Star-shaped (Palazzo Carignano), Planterian (Palazzo Cilgliano) and Banded vaults (Palazzo Coardi di Carpenetto). Palma, et al. (2019).

For example, paths have been envisioned related to:

- the transformation over time of the entrance and distribution spaces of the noble palaces of the city centre (Path 1: “The atria of the Baroque era in Turin: complex unitary vaults as a Cultural Heritage”) developed concerning: (i) the evolution of construction techniques; (ii) the changes in requirements linked to the entrance ceremonial; (iii) the changes in architectural taste;

- the architectural production linked to a specific period in the wider reference time-frame or a single type of vaulted atrium (Path 2: “Star-shaped vaults”; Path 3: “The planterian formula"; Path 4: “Banded vaults”);
- the production of a specific author (e.g., Path 5: “Guarino Guarini and his epigones (Gian Francesco Baroncelli, Michelangelo Garove)”; Path 6: “Gian Giacomo Plantery and planterian vaults”; other paths may be structured on architecture masters as Amedeo di Castellamonte Filippo Juvarra, Bernardo Vittone, etc.);
- the relationship between complex vault shape, geometries, and decoration (path 7: “Geometry, shape, and decoration: a relationship not always taken for granted”), between their construction techniques and their structural behaviour (Path 8: “Shape and structure: north-west path”; Path 9: “Shape and structure: south-east path” (Figure 2);
- the relationship between the urban transformations of the baroque city and the diffusion of atria with homogeneous characteristics (e.g., Path 10: “The ‘dirizzamento’ – rectification – of via Dora Grossa”; other paths may be structured concerning the diffusion of the different types of atria in the areas of the historical centre and the realisation of the three baroque enlargements of the fortified city walls or to the important reshaping interventions in the minute fabric of the historical city, etc.);
- unusual atria, which emerge from a homogeneous panorama of models established in relevant buildings and repeated according to a 'fashion' (Path 11: “Singular atria”);
- digital reconstruction of atria (in their totality or only partially) that no longer exist today or have been heavily transformed, fragmented, or hidden by superfetations (Path 12: “C’era una ‘volta’ ” – once upon a time –).

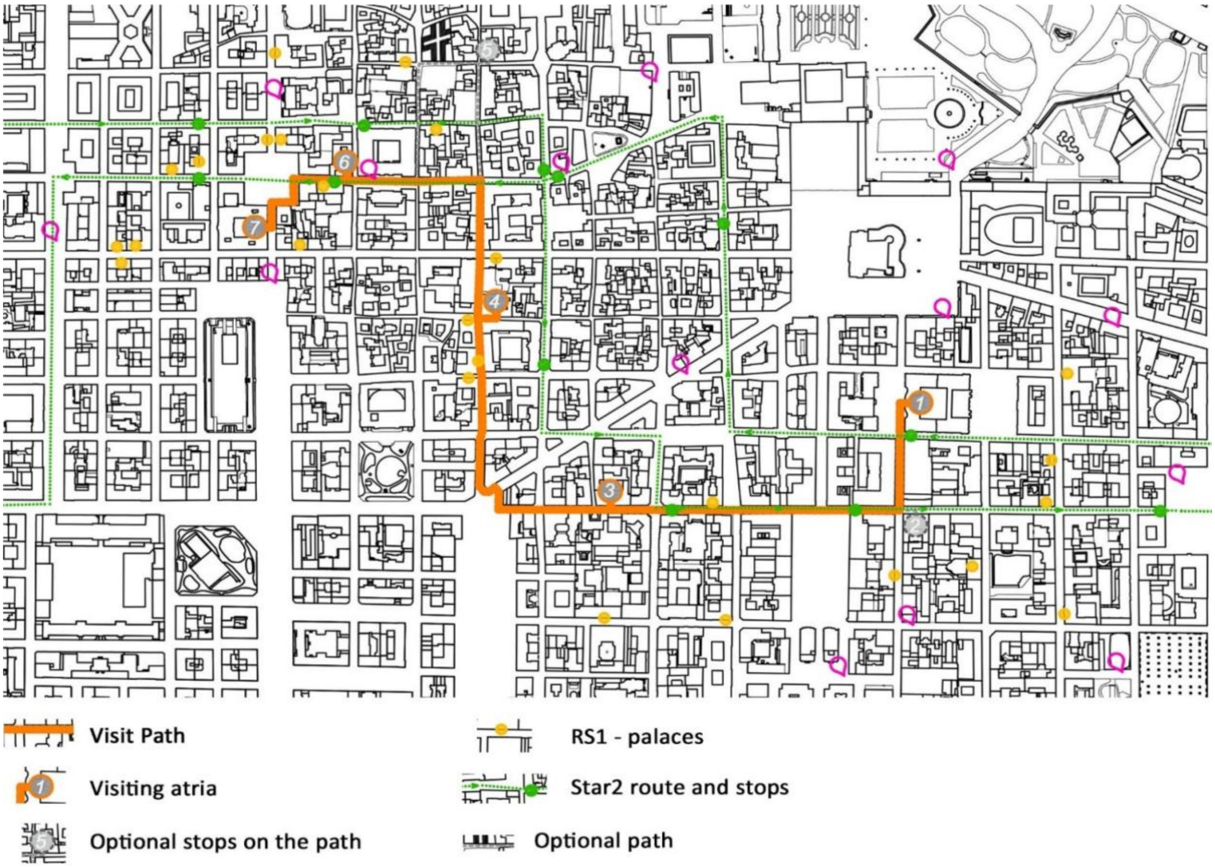
All the paths have been studied to guarantee the visitor to lead an architectural walk in the fabric of the historical city, customisable and intended both as single and sequential experiences, concerning:

- time available for the visit (some of the buildings may or may not be included in the itinerary without changing its purpose, as well as specific contents related to each atrium may or may not be activated to vary the duration of the stay in each building);
- to the different availability of walking, updating the length of the route according to the different customisations, and including in the map the most significant public transport routes (e.g. Star 2 line provided by electric minibuses);

In addition, the contents that could implement a recommendation system concern: 1– atria belonging to the same Cultural Heritage; 2– museums and visit routes inside the building, archives; 3– bookshops, historical shops, and cafés.

Concerning the issue of disabilities, the project aims to structure entirely one of the proposed paths, taking into account motor and sensory disabilities, to ensure appropriate routes for people with motor disabilities and to provide the web app contents structured for people with sensory disabilities.

For demonstration purposes, the full description and map of the “basic” route of the project, path 1 (“The atria of the Baroque era in Turin: complex unitary vaults as a Cultural Heritage”), conceived as a first approach to the system of Baroque unitary vaults in Turin (the most general and representative of this Cultural Heritage as a whole).




1. **starting point: Palazzo Carignano** –Piazza Carignano 2 (Recommender system (RS) 1: Palazzo Bogino – Via Bogino 8, Palazzo Baroni di Tavigliano – Via Bogino 31, Palazzo Graneri – Via Bogino 9; RS2: Museo del Risorgimento, Appartamento di mezzogiorno, Appartamento di mezzanotte, Biblioteca nazionale; RS3: Luxemburg Bookshop, Burlot Antiques bookshop, Gilibert gallery, Calderan Antiques, del Cambio Restaurant, Mulassano Historical cafe, Baratti &Milano Historical cafe, Carignano theatre, Circolo dei Lettori);

   **2 min walk (200m)**

2. **Palazzo Asinari di San Marzano** – Via Maria Vittoria 4 (optional stop) (RS1: Palazzo Birago di Borgaro – Via Carlo Alberto 16, Palazzo Isnardi di Caraglio – Via Lagrange 6, building in via Maria Vittoria 19*; RS3: Guido Gobino Chocolate shop, Eataly, Stratta cafe, *Turismo Torino);

   **5 min walk (400m)**

3. **Palazzo Provana di Collegno** – Via S. Teresa 20 (RS1: Palazzo Riche di Coassolo – Via S. Teresa 10, Palazzo Galleani di Canelli e di Barbaresco – Via Alfieri 6, Palazzo Valperga di Masino – Via Alfieri 18),

   **6 min walk (450m)**

4. **Palazzo Cigliano** – Via Barbaroux 28 (RS1: Palazzo Capris di Cigliè – Via S. Maria 1, Palazzo Perucca della Rocchetta – Via Barbaroux 25, Palazzo Villanis – Via Botero 8, Palazzo Durando di Villa – Via Garibaldi 23; RS2: Historical Archive of Turin; RS3: Tamborrini cafe, Venier pastry shop),

   **5 min walk (400m)**

5. **Palazzo Novarina** – Via S. Chiara 8 (optional stop) (RS1: Casa Martino Monteu Beccaria – Via S. Chiara 20, Palazzo Mazzonis (MAO) – Via S. Domenico 11; RS3: AL Bicerin cafe, Barolino Cocchi cafe, Consolata herbalist's historical shop),

   **4 min walk (300m)**

6. **Palazzo Barolo** – Via delle Orfane 7 (RS1: building in Via Corte d'Appello 13, Palazzo Martini di Cigala – Via della Consolata 3, Casa d'affitto dell'Orfanotrofio – Via della Consolata 8; RS2: Palazzo Barolo museum, Palazzo Barolo Historical Archive, Archivio di Stato – Sezioni Riunite; RS3: Levi Aprile Historical stationery shop, Peyrot Antique Bookshop),

   **4 min walk (300m)**

7. **Palazzo Saluzzo Paesana** – Via della Consolata 1bis (RS1: Palazzo Fontana di Cravanzana – Via Garibaldi 28, Palazzo Cotti di Brusasco – Via Bligny 5, building in Via del Carmine 4, building in via Garibaldi 38, building in Via Garibaldi 40, building in Via Garibaldi 53; RS2: Palazzo Saluzzo Paesana – cultural events and apartments.

**Figure 3.** Path 1: "The atria of the Baroque era in Turin: complex unitary vaults as a Cultural Heritage". M. Vitali.

## 6. Future development

The virtual visit will be based on the collection of textual, iconographic, and interpretative materials through a dedicated website which could be linked e.g. with MuseoTorino website, with the TurismoTorino website, and other cultural tourism-dedicated websites, including those dedicated to accessible tourism. It could also imagine the link with Archivio Storico della Città di Torino and Archivio di Stato di Torino, which kept iconographic and textual documents about the historic city. Finally, the website in project could be able to collect visitors' feedback, through comments, photographs, videos, shared by them.

As anticipated, using the tools offered by the digital revolution, we intend to work in the direction of an enhancement, valorisation, and sharing of the Cultural Heritage, mixing and merging real and virtual documentary materials and fruition experiences. This will happen during the on-site visits using a mobile device app that will enable object recognition processes, tracking, and AR applications.

In particular, during on-site visits, webAR will enable the display of information (also through the connection to the website) through portable devices. The information, for example, will consist of short descriptions, iconographic documents, bibliographic references, and links to the historical context, diagnostic analyses, geometric models of the vaults, BIM models, survey drawings, results of diagnostic, and structural analyses. Not all the atria of the palaces included in the paths are accessible because some of them are private buildings and, in any case, are subject to specific opening hours. For this reason, the recognition and tracking of information can take place within the atria or through the facade elements of the buildings, in the latter case, carrying out a particular exploration of digital models.

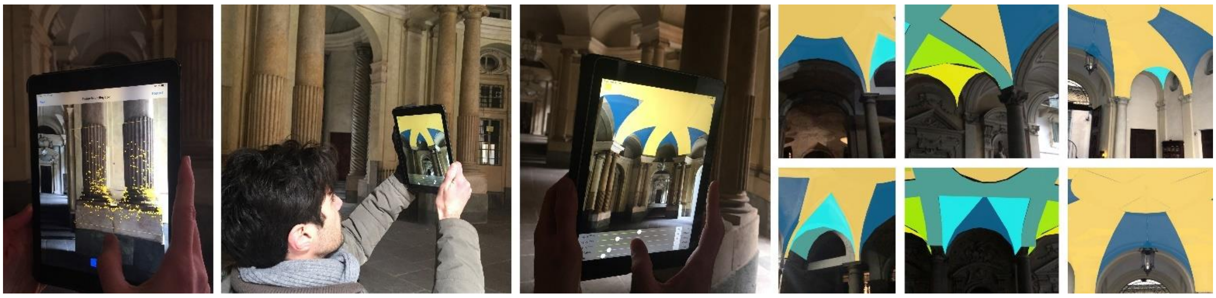


**Figure 4.** AR experience in Turin Baroque atria. Source: Palma et al. (2019)

## 7. Conclusions

This contribution presents the construction of cultural routes in the centre of the city of Turin, aimed at sustainable tourism and attentive to motor and sensory disabilities. The rapid and continuous development of digital technologies to support heritage communication is the focus of the author's attention so that when the project is ripe for the development of webAR and VR, and today in a broader sense of eXtended Reality (XR) modalities, the dissemination of architectural heritage, cultural occasions, and related intangible assets will be implementable, updatable and connectable to institutions, associations, stakeholder groups.

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# The Water Mine of the Casa del Rey Moro in Ronda (Málaga, Spain): a case of reconciling private tourism promotion and the generation of heritage knowledge

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***Abstract***

*The tourist exploitation of heritage assets often generates tensions between the economic interests of their private owners and the demands of the protection exercised by public administrations. However, the generation of heritage knowledge, in addition to an unavoidable action of protection, can result in an increase in the tourism potential of the property: on the one hand, it consolidates and expands its cultural interest and, on the other, it produces documentation that can be used to optimise the promotion of its values.*

*The work carried out in the Mine that connects the Casa del Rey Moro with the Tajo in the town of Ronda is a case of this desirable conciliation between private tourism promotion and the generation of heritage knowledge. In a building of great geometric and constructive complexity, a vaulted staircase embedded in the cracks of the Tajo de Ronda, archaeological activities are proposed to reveal some of its historical keys. These archaeological activities require geometric documentation work and architectural analysis of the heritage, which is approached by combining analogue and digital resources (digital capture by scanner, photogrammetry, HBIM modelling).*

*The results obtained have made it possible to improve the tourist exploitation of the property both directly, by enriching the visit with explanatory material in different formats, and indirectly, through promotion in different media using techniques specific to this research.*

***Keywords:*** *heritage, graphic analysis, tourism, management, HBIM*

## 1. Introduction

The city of Ronda (Malaga, Spain) is one of the main tourist attractions in Andalusia and, as such, tourism is one of its main economic drivers. The richness of its cultural heritage and, in particular, its architectural heritage, is a fundamental part of its attraction for visitors and, therefore, its dimension as a cultural asset goes hand in hand with its consideration as an economic resource, especially in cases where it is privately owned. This double dimension sometimes generates tensions between the economic interests of its owners and the public cultural administration responsible for its protection. However, the generation of heritage knowledge, in addition to an unavoidable action of protection, can lead to an increase in the tourism potential of the property: on the one hand, it consolidates and expands its cultural interest and, on the other, it produces documentation that can be used to optimise the promotion of its values.

The Casa del Rey Moro is one of the representative buildings of the city's architectural heritage and is presented as such in its official promotional media (Tourism Delegation of the Municipality of Ronda, 2024).

Although the house that gives its name to the entire property is not open to the public at this time, its historic gardens (Vigil-Escalera Pacheco, 1995) and a unique architectural structure, the Water Mine, the subject of this communication, are open to the public (Figure 1).

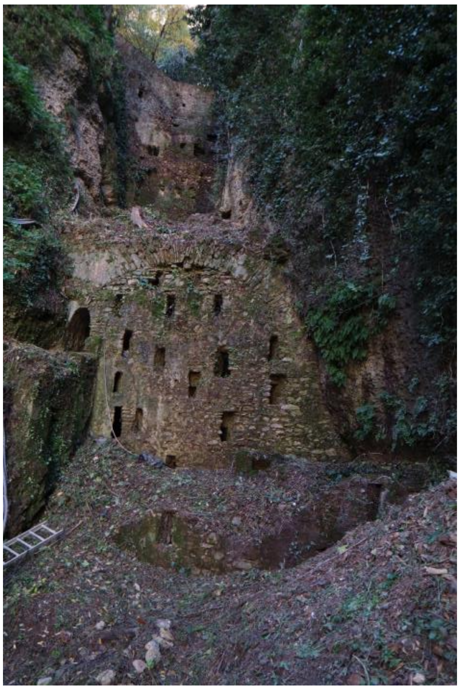
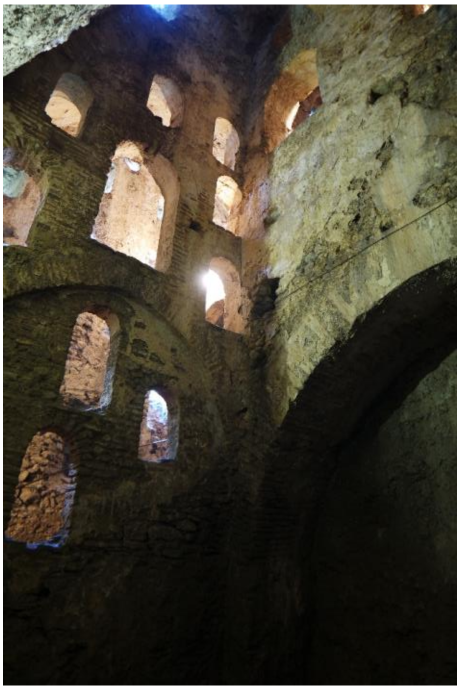

**Figure 1.** Water Mine: outside (left) and inside (right).

The Water Mine is a structure designed to collect water from the Guadalevín River to supply the city and is fortified to protect its use in the event of a siege. Its construction dates back to the 14th century, during the Nasrid kingdom, and its uniqueness lies in the complexity of its structure, resolved by taking advantage of one of the cracks in the escarpments between the riverbed and the city platform, by means of flights of stairs covered with vaults that are interspersed between natural caves, excavated areas and built rooms forming a zigzagging linear route that links surprising spaces due to their contrasts in scale and constructive solutions.

The architectural complexity of the building makes it difficult to manage at different levels. Such is the case of the administrative authorisations for interventions on the estate, which required a precise spatial definition in order to obtain the corresponding favourable reports. In 1997, archaeological work was carried out (Amores Carredano, 1997), and progress was made, with the techniques available at the time, on a basic planimetry drawn up by the architect Fernando Mendoza, which inevitably had numerous inaccuracies, given that the data could only be taken with analogue and direct means of measurement.

 

For this reason, the management of the Water Mine and the actions of its owners for its conservation and adaptation for public visits required adequate graphic documentation, carried out with the means currently available. The definitive impetus for the work came from an archaeological intervention campaign planned as part of the general archaeological research project: "La Mina (Ronda, Málaga). Archaeological and architectural analysis of the Merinid monument" (Jiménez Martín, 2018). The work carried out, beyond fulfilling a documentary and administrative requirement, represents an opportunity to improve the knowledge and dissemination of the building as a heritage object and, at the same time, as a tourist resource.

## 2. Aims and objectives

The main objective of this work is to show a case in which the requirement for precise geometric documentation, architectural analysis, and archaeological study results in increasing the potential of a heritage asset as a tourist resource.

To achieve this objective, the architectural survey of the building was proposed, understood as a strategy of heritage knowledge and not as a mere capture of formal attributes, in line with its definition in the *Carta dil Rilievo*, which expressly states that *"the critical path of the construction process, and also the design process"* should be verified (Jiménez Martín & Pinto Puerto, 2003).

Firstly, therefore, the aim was to obtain the geometric documentation of the building, using advanced digital resources for metric capture. Simultaneously, it would be characterised by its spaces and construction systems by means of architectural and archaeological analyses.

Once these results had been achieved, completing the general objective, graphic documentation would be produced to support the dissemination of its values and the experience of the tourist visit to the building.

## 3. Methods

In order to achieve the proposed objectives, four phases of work were proposed: the compilation and study of the documentation, the elaboration of an architectural survey, the creation of an HBIM model and the production of graphic documentation for the dissemination and enhancement of the knowledge obtained. The compilation and study of the available documentation on the building includes, in addition to the references included at the end of the text, the photographic collection by Fernando Amores Carredano on the archaeological intervention carried out in 1997 and the planimetry carried out by Fernando Mendoza in the same year.

In order to begin the architectural survey phase, it was necessary to wait for the company that owned the Mine to clear and clean up the external undergrowth that had accumulated in recent years, which prevented visual recognition of the external elements and an adequate photographic record. Similarly, in order to take data from the interior, visits to the complex had to be interrupted for a day in the morning, in addition to removing objects and elements that hindered access to all parts of the building.

Once the preconditions had been resolved, and given the complicated accessibility of the building, various combined resources were used: from the handheld laser scanner for the interior to the photographic capture and the use of a topographic total station for the exteriors. Several captures were made in response to the different constraints imposed by the building:

- Interior point cloud made by handheld scanner (ZEB-REVO from GeoSLAM, with a capture speed of 43,000 points per second, range of 30 metres, relative accuracy of 6 mm and real-time processing)
- Point cloud resulting from a photographic shot of the exterior from distant points on the other side of the Tagus, which was subsequently processed using photogrammetry software (Samsung NX 3000 camera with 20 MP resolution and Samyang 14 mm f/2.8 lens).
- Point cloud resulting from a close-up shot of the exterior taken from the accessible roofs (Camera mentioned above).

- Photographic shot of the interior which, oriented by photogrammetric means (Leica TS02 FlexLine plus topographic total station), was used to add the textures to a mesh generated from the interior point cloud, resulting in a textured model.

After this, with the support of the control points taken with the topographic station, the clouds and the model were adjusted, oriented, georeferenced, and linked, which were the basis for obtaining a total of 35 projections, including plans, sections and elevations in a CAD software. Simultaneously, an analogue capture was carried out in which the constituent construction elements were identified and discretised, naming them and coding their basic heritage parameters (levels, construction function, material, chronology).

The third phase consisted of founding an HBIM model of the building in which the complexity of the insertion of the staircase into the terrain was presented. The model was created using the AUTODESK REVIT software. This model is required to be able to evolve over time, allowing the management of additional information that is generated as a result of its maintenance and conservation, or specific interventions that are developed.

Finally, the production of graphic documentation for the dissemination and enhancement of the knowledge obtained was resolved, enriching the visitor's experience. In the first instance, this work was carried out in an analogue form on visualisations of the point cloud model in various straight cylindrical projections.

## 4. Results

The presentation of the results is ordered according to the different actions proposed in the methodology for the achievement of the general and specific objectives set out.

### 4.1. Analogue capture

The analysis of the existing documentation was complemented with the exploration of this singular building by means of analogue drawings that made it possible to recognise the geometry and articulation of the constructive elements, to name elements and to detect situations of difficult interpretation that would require the support of digital capture. The usefulness of these drawings, which belong to the most established disciplinary tradition, is not invalidated by the exhaustiveness of the digital capture but complements it insofar as they represent a preliminary proposal for interpreting the complexity of the architectural space (Figure 2).

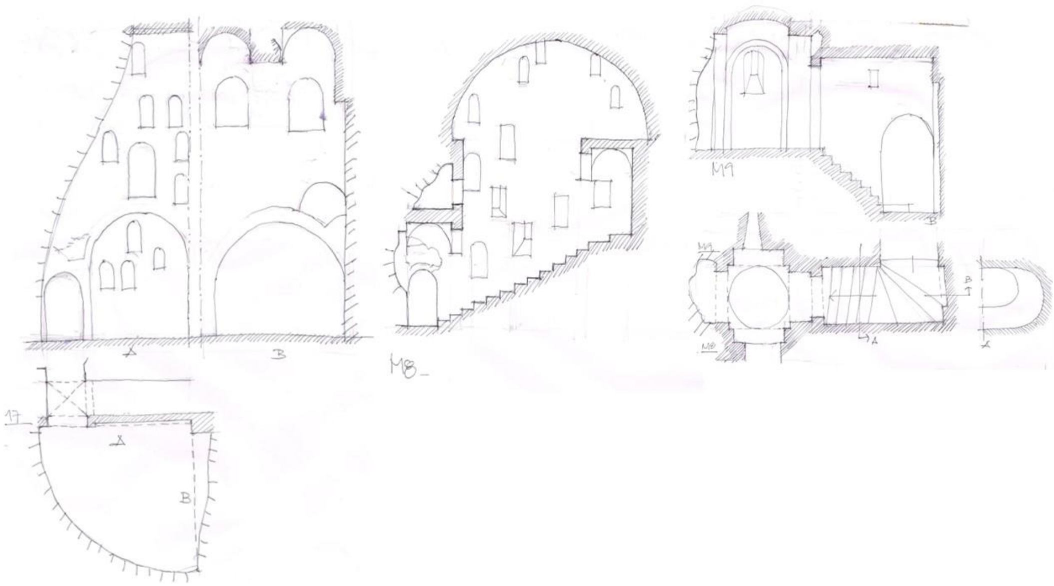

Figure 02. Analogue capture of the Water Mine spaces. Source: the authors (2019)

 

### 4.2. Digital capture

Digital capture was the fundamental resource for achieving the proposed objectives. The geometric and constructional complexity of the building required a precise capture of the sequence of spaces generated by the fusion of the natural elements of the steep terrain and the architectural structures embedded in its nooks and crannies.

Digital capture by handheld scanner provided a point cloud that, although devoid of colour and texture attributes, offered geometric characterisation. This cloud was complemented by photogrammetric capture, from which the most representative orthophotographs were obtained (Figure 3).

**Figure 3.** Left: Plan view of the result of the point cloud of the handheld scanner. Right: Orthophotography resulting from the photogrammetric treatment of the photographic shots. Source: the authors (2019)

### 4.3. Architectural analysis

In parallel to the analogue and digital captures, a constructive analysis of the complex was carried out, producing a data table that catalogues and serves as an inventory of all the elements identified and analysed. Through this analysis, the existence of four parts or buildings with homogeneous characteristics has been determined, which appear to be linked to each other with a great deal of continuity. This continuity is the result of the use of similar construction techniques, even though they responded to different historical stages, from the initial Merinid construction to the intervention of the 19th-century garden or the later alterations to facilitate tourist visits. Initially, the La Mina building has been related to the rest of the property by differentiating between three large groups of buildings:

- The Mine, designated as ED-000
- The Garden, designated as ED-001
- The House, designated as ED-002

These three groups are closely related and interdependent, as the Garden reformed the access to the Mine and incorporated it as part of its structure, the Mine penetrates the House, and the latter is the result of successive reforms that have resulted in the current state.

Within the "mine" building ED-000, we have differentiated three parts: by their orientation, internal constitution, and homogeneity in the constructive and spatial treatment. These three parts do not correspond to different construction stages since, in principle and based on the available data, they have been developed with great continuity. Following the description made in 1997, four parts have been distinguished (Figure 4):

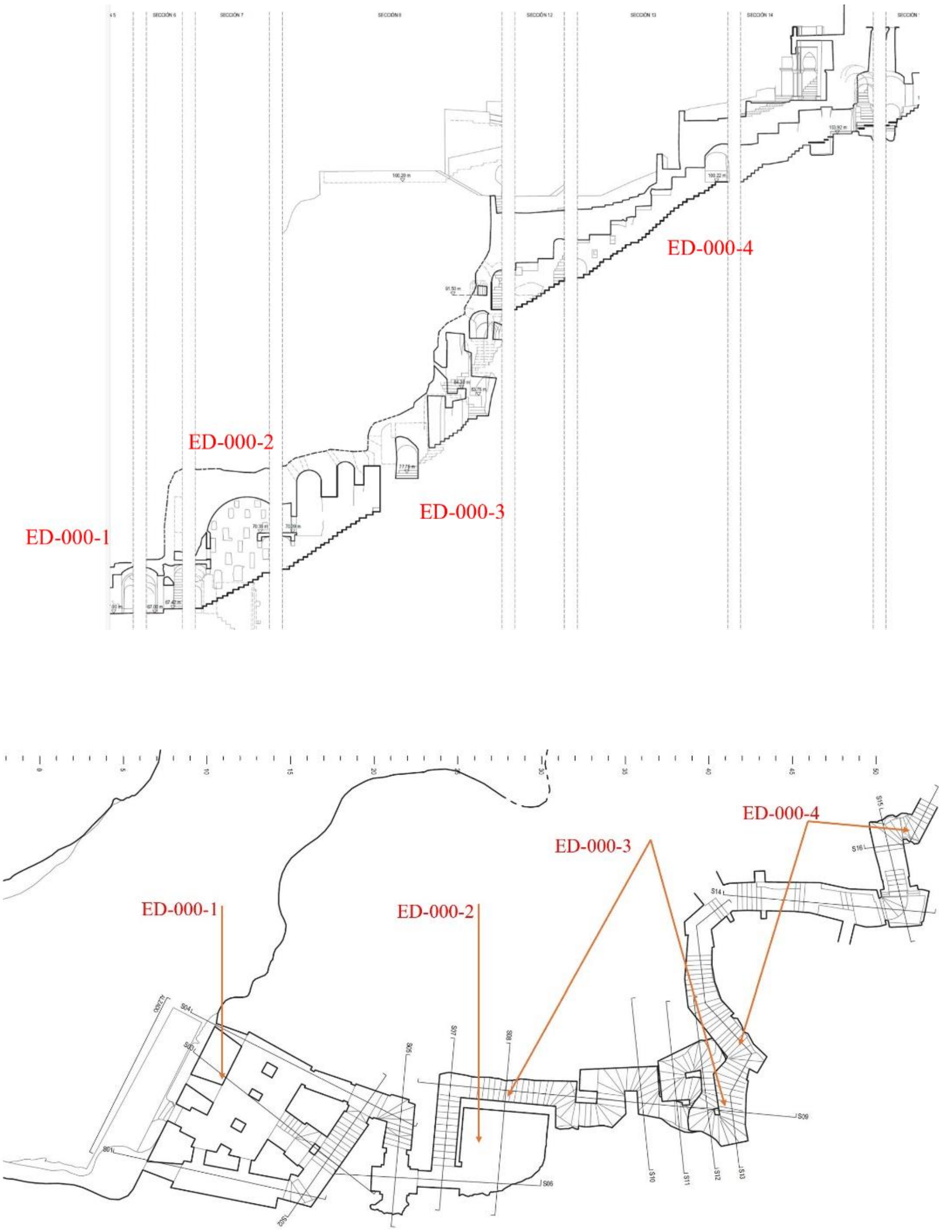


**Figure 4.** Section and plan of the complex where all the partial projections have been superimposed and unfolded in horizontal and vertical projection. Identification of the parts of the Mine (EC-000). Source: the authors (2019)

 

- The Tower, which we have identified as ED-000-1, formed by the two-storey defensive structure closest to the bottom of the Tagus. It is made up of rooms on two levels and connecting staircases between them.
- The building of the Sala de la Aguada, labelled ED-000-2, consists of a large central room, perimeter stairways, and transit and connection spaces with the previous one.
- The zigzagging staircases, labelled ED-000-3, are formed by a set of flights of stairs that span the greater height between the previous hall and the garden terraces, adjusted to the narrower space between the two crags, which makes it necessary to turn numerous times to allow them to develop. This is the most complex area in terms of construction, but it is where the greatest ingenuity and skill on the part of the builders can be seen.
- The stairway of the inclined tunnel, marked ED-000-4, is made up of much more continuous and less broken flights of stairs, covered by stepped barrel vaults that rise up to the highest space between the crags, where they separate again. It is the part most transformed by the garden project.

### 4.4. Planimetric survey and HBIM model

In addition to the documentary value of the point clouds of the complex, the textured model and the associated orthophotographs, a collection of plans, an HBIM model and an associated data table have been synthesised.

The planimetry has been produced in CAD and consists of horizontal plan projections (floor plans), vertical projections (elevation-sections) and identification plans of the construction elements. This collection provides the basic material for the development of the archaeological intervention project and for any of the administrative management and maintenance operations of the building. The collection printed in PDF is made up of 38 plans in A3 format, the result of graphic surveys carried out in CAD. Each plan depicts a horizontal cross-section of the rock and the building, as well as vertical sections.  One of the sections has been laid out in A2 to describe the complete development of the staircase by unfolding the previous vertical sections. Four sections of the most singular spaces have been included, incorporating the orthophotos corresponding to the vertical faces.

In addition to the collection of descriptive plans, there is a collection of 15 floorplans where the building complexes and construction elements are identified by means of the symbols, up to a total of 146 construction elements (Figure 5). These elements are presented in a table in EXCEL format, where the basic properties and characteristics of each building element are listed (Figure 6).

This table, which can grow with each analysis developed or new data to be incorporated, reports the characterisation of the elements in the HBIM model (Figure 7). The HBIM model was initially developed to solve the fitting of the stairs in the terrain and is currently being developed to complete the rest of the Mine's structures.

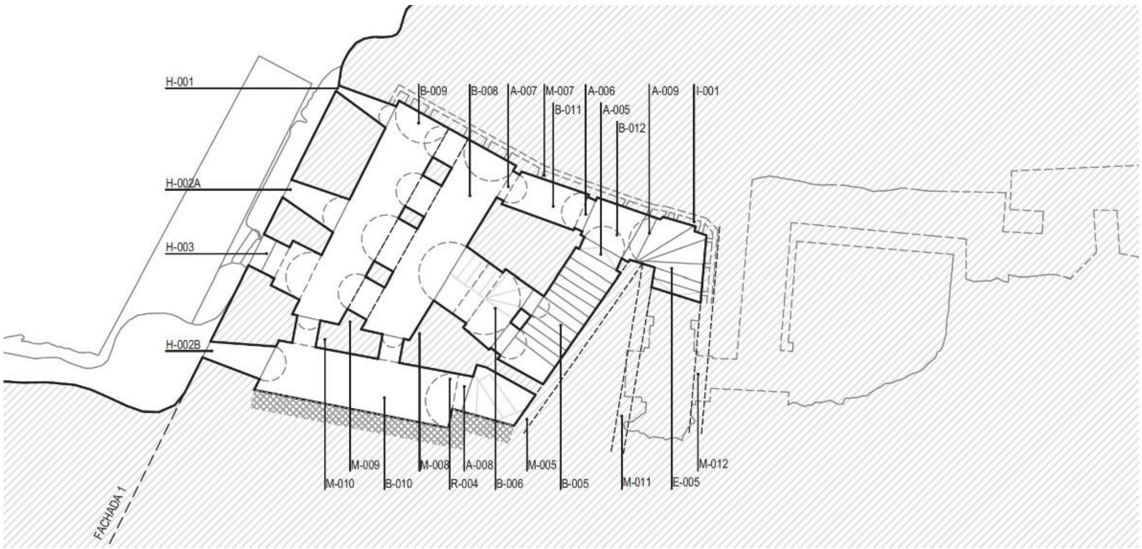


**Figure 05.** One of the plan projections of the Mine's spaces with the code of each architectural element identified, registered and catalogued. Source: the authors (2019)

| LAVE LEMENTO | CLAVE EDIFICIO PERTENENCIA | ELEMENTO | SUBELEMENTO | MATERIALIDAD | SISTEMA CONSTRUCTIVO | DESCRIPCIÓN | OBSERVACIONES |
|---|---|---|---|---|---|---|---|
| C-001 | ED-000-1 | Cimiento | Alambor | Compacto de calicostrado | Carga y defensa | Base talud alambor hacia el rio que sirve de cimiento de la torre y defensa ante crecidas. El achaflanado del alambor en el centro para batir el acceso a la puerta | Conserva huellas de agujas, mechinales y tablazón del encofrado del talud del alambor. Los escalores E-001 están labrados sobre el alambor. |
| C-002 | ED-000-2 | Cimiento | Plataforma | Compacto de calicostrado | Carga y nivelación | Base de nivelación del terreno natural para asiento dela torre | Borde interior indeterminado |
| M-001 | ED-000-1 | Muro | Fachada | Ladrillo y mampostería | Carga y defensa | Muro de fachada de la torre hacia el río. | La parte superior del muro se encuentra arrasada. Esta parte formaba un pretil de la Terraza de la Conquista. En su extremo este presenta un chaflán. |
| H-001 | ED-000-1 | Ventana | Saetera | Fábrica de ladrillo | Iluminacióny defensa | Hueco vertical asaeteada de gran altura | Sirve de evacuación de desague de Sala del Manatial |
| H-002A | ED-000-1 | Ventana | Medio punto | Fábrica de ladrillo | Iluminación | Hueco bajo arco circular abocinado | Iluminación de sala de armas |
| H-002B | ED-000-1 | Ventana | Medio punto | Fábrica de ladrillo | Iluminación | Hueco bajo arco circular abocinado | Iluminación de anexo a sala de armas |
| H-003 | ED-000-1 | Ventana | Medio punto | Fábrica de ladrillo | Iluminación y defensa | Hueco bajo arco circular abocinado de acceso al matacán que lo protege | El hueco se encuentra parcialmente cegado con fábrica de ladrillo a modo de pretil deprotección ante la desaparición del matacán |
| H-004A | ED-000-1 | Ventana | Saetera | Fábrica de ladrillo | Iluminación | Hueco simple vertical asaeteado y abocinado | Ilumina escalera E-002 |
| H-004B | ED-000-1 | Ventana | Saetera | Fábrica de ladrillo | Iluminación | Hueco simple vertical, decorado con alfil y sobrearco, asaeteado y abocinado | Ilumina escalera E-002 |
| H-005 | ED-000-1 | Ventana | Saetera | Fábrica de ladrillo | Iluminación | Hueco simple vertical, decorado con alfil, asaeteado y abocinado | Ilumina la Sala del Pozo |
| H-006 | ED-000-1 | Desagüe | | Fábrica de ladrillo | Desagüe de aguas | Hueco simple vertical | Salida de agua de exceso de Sala del Pozo |
| H-007 | ED-000-1 | Ventana | Saetera | Fábrica de ladrillo | Iluminación | Hueco simple vertical | Iluminación de la Potera |
| H-008 | ED-000-1 | Puerta | Medio punto | Fábrica de ladrillo | Acceso | Hueco de Poterna formada por arco circular | Hueco en espesor del muro con reundido para recibir portón fortificado. |
| H-009 | ED-000-1 | Ventana | Saetera | Fábrica de ladrillo | Ventilación e iluminación | Hueco abocinado de iluminación y ventilación delespacio de tránsito a Sala de Aguada | El exterior se observa en el informe de la intervención realizada en 1997, actualmente semienterrado. |
| M-002 | ED-000-1 | Muro | | Ladrillo y mampostería | carga | Muro lateral a escalera E-001 sobre elel carga la bóveda B-002 | Alinea la escalera con el otro muro que es la peña |
| M-003 | ED-000-1 | Muro | | Ladrillo y mampostería | carga | Caja formada por cuatromuros que recibe las cargas de la bóveda B-007 | Presenta huellas de mechinales o entregas de estructura complementaria del ingenio que servía de noria delposible pozo allí existente |
| M-004 | ED-000-1 | Muro | | Ladrillo y mampostería | carga | Muro sustentante de la bóveda B-005 acodalado por los arcos A-004 y A-005 | Tiene practicado varios huecos de medio punto hacia la escalera de acceso a la Sala de los Secretos facilitando su iluminación desde la fachada |
| M-005 | ED-000-1 | Muro | | Ladrillo y mampostería | carga | Muro sustentante de la bóveda B-005 acodalado por los arcos A-004 y A-006 | |
| M-006 | ED-000-1 | Muro | | Ladrillo y mampostería | carga | Muro sustentante de la bóveda B-011 acodalado por los arcos A-006 y A-007 | |
| M-007 | ED-000-1 | Muro | | Ladrillo y mampostería | carga | Muro sustentante de la bóveda B-011 acodalado por los arcos A-006 y A-007. Contiene una canalización de evecación de aguas sobrantes de la Sala de Aguada que transcurre empotrado | Muro de regularizacion de la peña. |

**Figure 6.** Table of registration and cataloguing of identified architectural elements related to the planimetry. Source: the authors (2019)

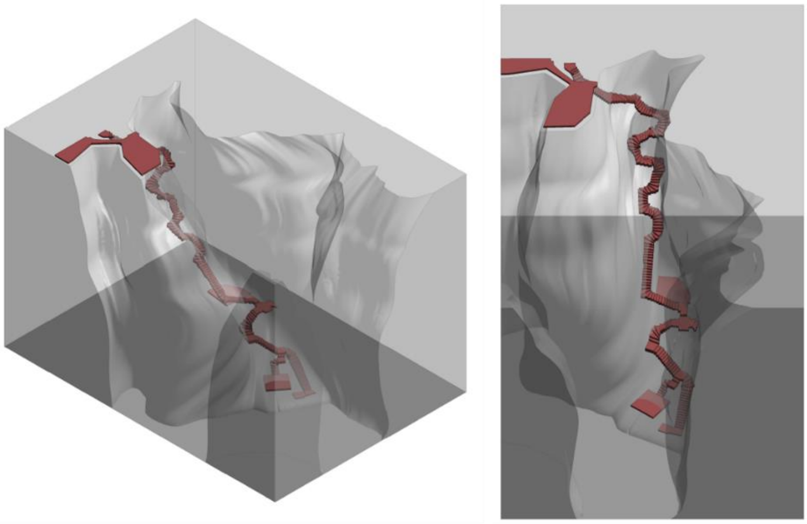

**Figure 7.** Water mine stairs HBIM model. Source: the authors (2019)

### 4.5. Production of materials for dissemination

The work carried out has made it possible to contribute to the knowledge of a building as unique as the Water Mine and, with this, to have historical data, architectural information, and graphic resources with which to produce material for the dissemination of its heritage values and to enrich the visitor's experience. The archaeological-architectural analysis has made it possible to specify the denomination and interpretation of the different spaces. The graphic documentation has been useful in the preparation of explanatory panels of the various interventions that have been open to visits (Figures 8 and 9).

 

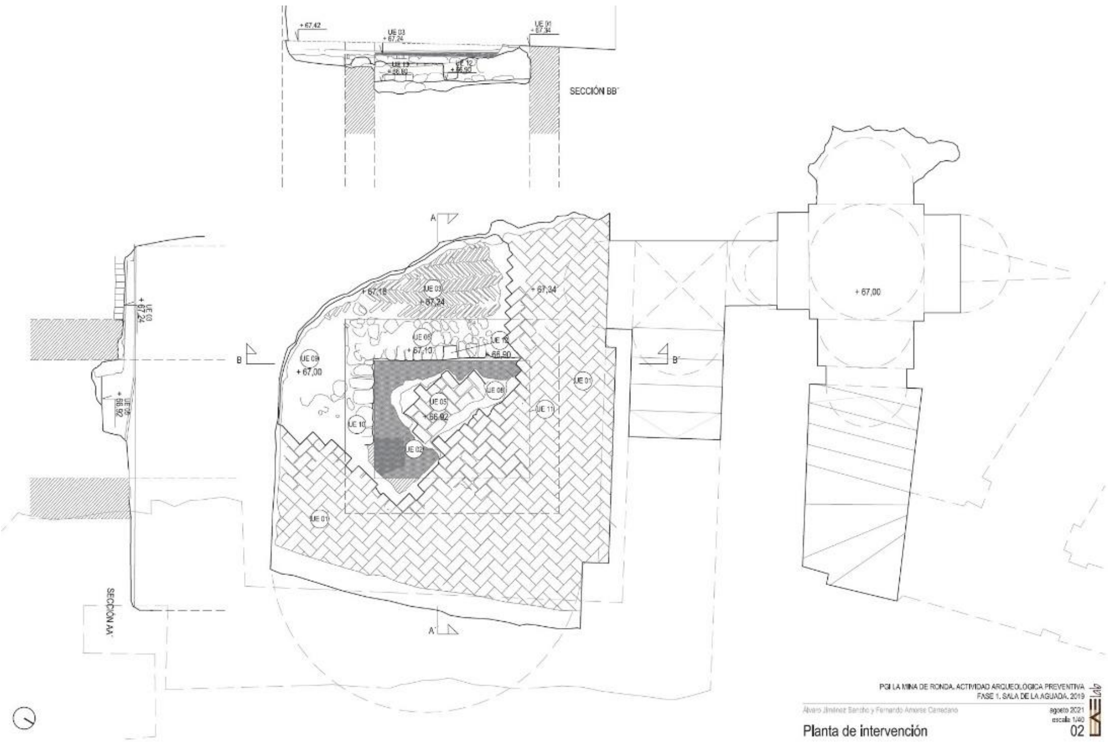


**Figure 8.** Planimetry of the archaeological intervention carried out in the spatial area E-000-2, Sala de la Aguada. Source: the authors (2022)

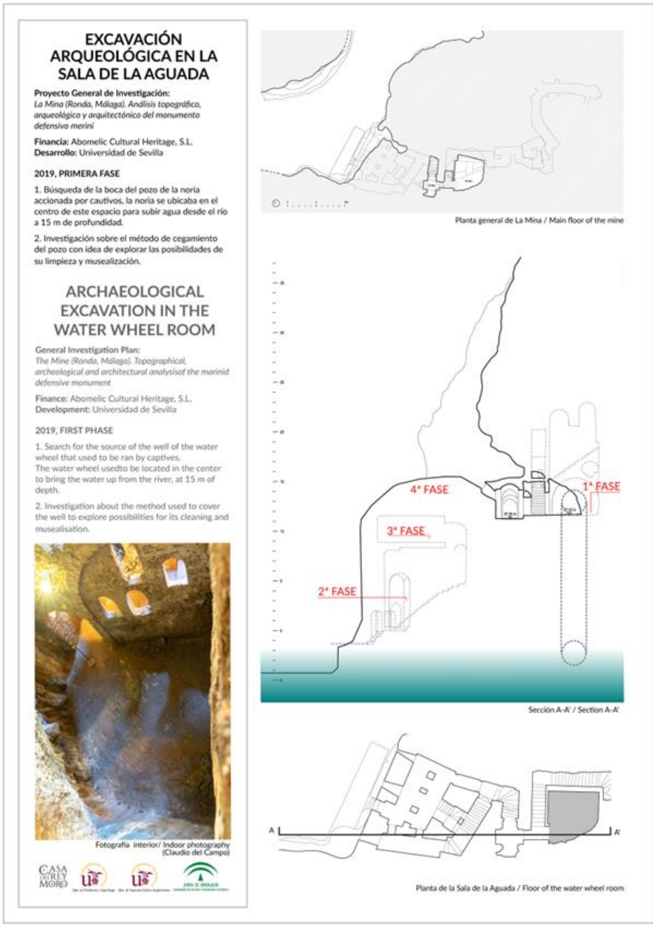


**Figure 9.** Explanatory panel based on the architectural survey. Source: the authors (2019)

Also, to disseminate the results of the analyses, allowing an understanding of the whole as the result of a complex constructive process, difficult to understand if not through a synthetic but rigorous graphic representation, in this case, developed analogically based on metric data obtained from the point cloud (Figure 10).

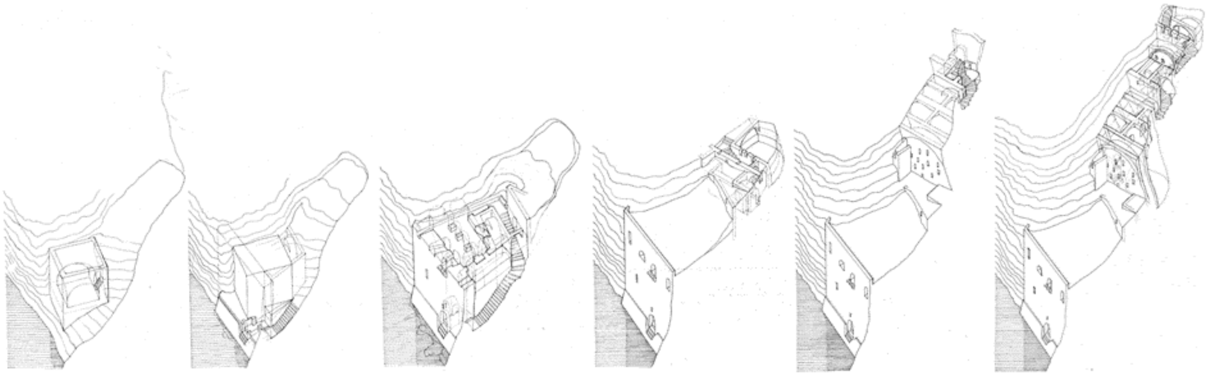

**Figure 10.** Architectural analysis drawings. Six of the ten steps explaining the construction process of the architectural structure of the Ronda Mine. Source: the authors (2019)

The resonance of the uniqueness of this work has reached the media, such as television, with the production of programmes in which the narration about the building is supported by a point cloud (López Pulido & Pecos Palacios, 2023).

## 5. Conclusions

Digital techniques for the geometric capture of immovable cultural heritage properties are becoming increasingly faster, more accurate and easier to use. However, the documentation of cultural heritage goes beyond simple geometric recording, requiring the analysis of graphic and non-graphic sources to support the generation of models. The integration of analysis and geometric capture, expressed in terms of "architectural survey", requires the integrated and non-exclusive use of analogue and digital techniques. Based on these principles, a graphic model of the Water Mine of the Casa del Rey Moro in Ronda (Malaga, Spain) has been generated, in which analogue and digital capture (3D scanning, photogrammetry) is integrated with analogue and digital architectural analysis (HBIM model) to produce documentation of a property of great heritage complexity (geometric, accessibility, visibility due to the growth of vegetation, archaeological, historical, etc.) aimed at improving its knowledge and facilitating the conservation and musealisation actions promoted by its managers.

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# Applications and technology for the dissemination of heritage: the app of the historic cemetery of San Miguel de Málaga

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***Abstract***

*The historic cemetery of San Miguel, in addition to being a funerary space, constitutes a monumental complex that combines numerous and diverse heritage values. After its closure and after a period of abandonment, it is being recovered and rehabilitated in successive phases and currently constitutes a cultural and tourist resource, the scene, in turn, of numerous cultural activities. Among other initiatives, the management company, PARCEMASA, sponsored the creation of a mobile app containing routes, short articles, augmented reality and 3D recreation clips as a formula for transmitting the content. This work analyses the situation in which it was created, its objectives and the different degrees of achievement of its objectives.*

***Keywords:*** *app, historic cemetery, augmented reality, virtual reality, heritage dissemination, Malaga, smartphone, graph analysis*

## 1. Introduction

The city of Malaga has experienced a radical change over the last three decades that we can consider a change in route or specialisation of economic activity, which now has one of its main points of support in cultural tourism. The so-called *City of Museums* has created a favourable atmosphere for cultural activity, which has led to some heritage elements considered resources due to their potential, becoming successful products. One of them is the historic cemetery of San Miguel, which, closed for its natural function, has been the subject of rehabilitation and is currently not only the scene of cultural activities of various kinds (teathre, concerts, conferences, etc.) but also the scene of Guided tours that disseminate its varied heritage values linked to the idiosyncrasy and history of the city.

Among the media enabled for its dissemination is a mobile application, which can be downloaded for free from various platforms. In this work, the circumstances in which this contribution was produced will be analysed, and an attempt will be made to determine the possible validity of this technological tool to contribute to the purposes of heritage dissemination.

The work methodology involves drawing a panorama of the city and the changes experienced in recent decades, the synthetic definition of the values treasured by this historic cemetery using specialised bibliography, an analysis of the change in profile experienced by tourists in recent years, and an analysis of the application to determine how the contents have been poured into it.

## 2. A new situation: Cultural tourism in Malaga

Three millennia of history have given the city of Malaga a rich but, at the same time, diverse cultural heritage. In relation to tourism, the capital city of the Costa del Sol brand maintained an ambivalent relationship, while the tourist flow was summer and focused on the sun and the beach. The thousands of tourists who arrived at the airport each year barely visited the city, which consequently maintained a minimal hotel infrastructure. However, since the nineties of the last century, a series of steps were adopted that have led the city towards a very different path: the pedestrianisation and recovery of the historic centre can be considered the starting point, the Spanish film festival It rose in international prestige and the opening of new and substantial museums, such as the Picasso Museum, Carmen Thyssen or the Pompidou Center, ended up specialising Malaga within the cultural tourism sector. Currently, the number of museums or exhibition spaces that can be visited exceeds thirty, and they receive a very estimable number of visitors. The consequence of this tourist success is that the city has been transformed, not only in its appearance but also conceptually. Sources from the tourism area of the Malaga City Council estimated the number of visitors received by the city's main museums at 500,000 (García & García, 2016, p. 131).

Contrary to what a simplistic reading might indicate, museums and cultural spaces do not compete but rather support each other by configuring, as a whole, a more attractive offer when choosing a travel destination. Although not all of the city's cultural offerings can be consumed, the atmosphere and environment constitute a favourable environment that attracts the profile of the cultural tourist, more interesting than other forms of tourism because it does not generate seasonality, is characterised by greater spending per visitor and day and respond to a profile that contributes to revaluing the image of the city as a destination.

These changes have generated a beneficial effect on the rest of the heritage since once the benefit that the commitment to culture has brought to the city has been reliably confirmed, it has encouraged the rescue and enhancement of previously neglected heritage or even the creation of new museums and visitable spaces.

## 3. Historical background

Throughout the 19th century, most Spanish cities were equipped with an outside cemetery, which they had lacked until then. The Royal Decree issued by King Charles III on April 3, 1787, was inspired by the principles of the Enlightenment, seeking the health improvements that cities needed once it was demonstrated that the custom of burying inside churches had caused serious public health problems. Compliance with the new norm was not immediate, as it was resisted by the lack of budget of the municipal councils. Often, the effort to comply with the law without the money necessary to acquire land in a suitable location generated what later became known as *provisional cemeteries*. This does not mean that they arose with this purpose, but rather that driven by necessity, cemeteries were inaugurated in locations that were later shown to be unsuitable due to their location or characteristics. Malaga had several of these.

The historic cemetery of San Miguel today would probably have been no more than one of these: the place where the general grave was located where those who died from the yellow fever epidemic that devastated Andalusia in 1804 were buried. With the high level of contagion that characterised this disease, it was advisable to dispose of the corpses as quickly as possible, burying them in a place that was far from the population. This land, known as Haza del Capitán or Cabello, met the location and characteristics requirements set out by the Royal Decree of April 26, 1804, with which Charles IV reiterated the obligation to create cemeteries outside of town, given the slow pace with which was complying with the previous order. The port engineer, Joaquín María Pery, hired as an expert, after touring the surroundings of the city, determined that this was the ideal place to build the city's general cemetery. Although the attempted purchase of the land caused a lawsuit with the owner, who was dissatisfied with the assessed price, 1805 can be considered the starting point of funerary activity in this location, which had already been used as a mass grave the previous year (Rodríguez, 2011).

## 4. The cemetery as a mirror of the city's history

As with the city of the living, necropolises also have their own evolutionary dynamics: construction, remodelling, expansions, etc. The San Miguel cemetery experienced this same process. In its initial stage, it was nothing more than an extension that lacked a boundary and surveillance wall, raising misgivings among the first users who had to use it. The dignification process came with the actions of the brotherhoods and brotherhoods, who, in addition to worship, had been burying their brothers in the vaults of their chapels in the churches, an activity that was already prohibited. In order to comply with their statutory obligations, starting in 1821, they acquired land from the Municipal Health Board to build blocks of niches to bury their brothers. The attached and contiguous construction of the niche blocks constituted the first enclosure of the cemetery, which was configured as a large rectangle inside which the rest of the people were buried in graves in the ground (Rodríguez, 1997).

In the improvement process, the next step was the construction, in 1837, of the chapel on the central axis of the cemetery, aligned with the doorway. Octagonal on the outside and circular on the inside, it is covered with a monumental dome topped by a dome. Before it, a triumph of the Immaculate Conception was installed, coming from the convent of San Pedro Alcántara, which had been disentailed and which today has been transferred to the municipal museum.

It persisted despite the disorganised appearance caused by the burials in the ground, which soon filled up. In 1847, the philanthropist José Marín García commissioned the municipal architect Rafael Mitjana with an ambitious and profitable plan. Inside, the grave burials were interrupted, and the space was reorganised, giving it a regular layout through rectilinear streets that delimited blocks that, in turn, were subdivided into plots that were put up for sale for the construction of private mausoleums. Towards the middle of the 19th century, Malaga was at the height of its industrial development, becoming one of the most industrialised Spanish cities. The families enriched by trade and exports that left the port or by industry were the ones who acquired the plots, generating a profit for the municipality that was invested in expanding the cemetery in its northern area. The funerary buildings that were erected ended up giving the cemetery the monumental appearance it has today. The successive extensions that the cemetery underwent were destined for burials in niches or pits, leaving the initial patio and that of the first extension reserved for the funerary activity of the upper classes (Figure 1).

Curiously, the Passionist brotherhoods that began the process of dignifying the cemetery, once they exhausted the available niches, also began to build monumental mausoleums. The brotherhoods of souls that existed in each parish acted in the same way (Rodríguez, 2005).

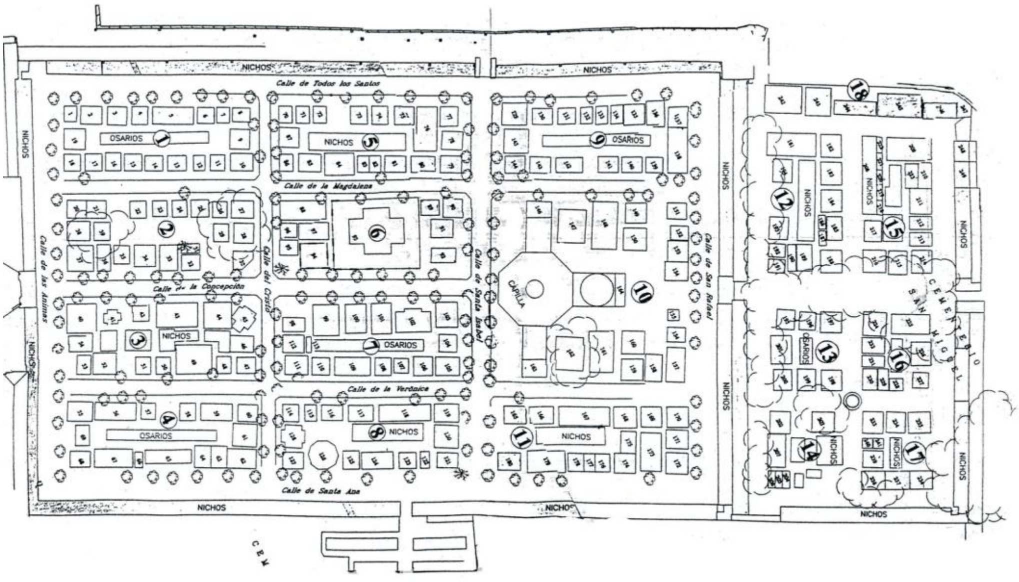

**Figure 1.** Current cemetery plan. Source: PARCEMASA

Since the city itself has been transformed, as it is logical to think, this space is presented as a time capsule in which the diversity of aspects that have constituted the history of the city for almost 200 years has been reflected: the history itself, represented by the figures who have been buried here, art (architects and artists buried here), artistic activity (buildings, sculptures or paintings made by Malaga artists), catalogue of architecture from different historical moments, the urban layout of the cemetery and the implicit symbolism, the presence of brotherhoods and brotherhoods that represent local devotions, the cult of souls, the language of symbols, funerary customs interpretable from the discipline of anthropology... Twenty of the mausoleums are enriched by stained glass windows depicting religious motifs. Some of them present a considerable level of artistic quality, and were made by prominent workshops, such as Maumejean and La Veneciana (Rodríguez, 2022).

## 5. Deterioration and recovery: from burial place to cultural space

San Miguel functioned as the city's main cemetery for almost two centuries. In 1987, it was close to saturation, and urban growth meant that the requirement of minimum distances from inhabited areas determined by the mortuary health police law was not met, so when a new necropolis was inaugurated, it was closed. Unfortunately, the heritage values treasured by the site were not taken into account. The lawsuit initiated by the owners of mausoleums deprived of the exercise of their inhumation rights without any compensation contributed to worsening the situation. Many heirs, deprived of their use, abandoned the maintenance of their properties, and some of them reached a worrying level of deterioration.

The role played by civil society in the recovery of the now-protected monumental space cannot be ignored. First, the Association of Friends of the San Miguel Cemetery was established, which in 1996 requested from the competent authorities its declaration as a BIC, in addition to participating in and promoting various dissemination and advocacy actions. The first protection initially affected only one mausoleum, that of Félix Sáenz Calvo, which was registered in the catalogue of contemporary architecture of Andalusia. It was later granted comprehensive protection in the PGOU, and, finally, in 2015, the Junta de Andalucía registered it in the General Catalog of Andalusian Historical Heritage.

But more interesting is the recovery and rehabilitation process that brought the cemetery out of the state of abandonment in which it was found. The first step was cataloguing all the mausoleums and historical elements of interest that, at the request of the Municipal Urban Planning Management, was carried out by the author of this work.

 

The first action was the project of the engineer Francisco Merino and the architect Adolfo Egea, who maintained the two monumental patios and built a park on the rest of the site, once unoccupied. From a heritage perspective, this action can be considered harmful, but it marked the starting point for the recovery of the rest of the complex.

The next action was in 2005: with a project by architect Javier Candela, the cemetery was provided with a new enclosure, eliminating the initial blocks of niches that were in poor condition, except for the one that flanks both sides of the main façade. An important push was the creation of a Workshop School, which, from 2007 to 2009, trained 42 students in four modules: masonry, forging, gardening and painting. The students' learning was parallel to the recovery of numerous elements of the cemetery. Especially notable was the recovery of the perimeter fences of some mausoleums since elements that had disappeared were even reproduced (Rodríguez, 2012).

The redevelopment of the Plaza del Patrocinio – which extends in front of the main entrance of the cemetery – and the rehabilitation of the old condolence rooms as cultural spaces were important advances, which was followed by the rehabilitation of the chapel and its interesting movable assets.

The approval of the sacramental use of the cemetery (deposit of ashes in mausoleums and niches of private property) was also a very positive fact, as many families regained interest in the properties. Since then, numerous rehabilitations have been carried out privately, some of them especially praiseworthy for the rigour with which the restoration was undertaken.

## 6. Cultural and citizen use

The author of this work began guided tours for his university students in the nineties of the last century, when it was still in poor condition, and has maintained them regularly to this day. But this perseverance has also helped, joining the White Night circuits and directing academic work, some of which have led to the creation of cultural companies that have taken on guided tours of the cemetery as part of their service offering. Today, there are several companies and associations that guide visits there.

The cultural atmosphere that the city emanates has helped both the authorities and the citizens to become aware of the high heritage interest that this cemetery has. In particular, we must mention PARCEMASA, a mixed capital company that was created to manage all cemeteries in the municipality of Malaga. In the initial moments of the claim, it seemed that its interest in this cemetery was only that of an obsolete space to be dismantled, but it has progressively changed its attitude to lead the recovery of the cemetery for cultural use through various means and initiatives.

Although advertising advertisements have already been seen in various parts of the city, the number of visitors cannot be compared to other cultural spaces found in the historic centre. The cemetery is located in a historic neighbourhood but off the beaten path for foreign visitors. We believe that the planned opening of an interpretation centre will contribute to improving the statistics, which since the data became available has not stopped increasing positively, as seen in Table 1.

**Table 1.** Number of visitors in the last 8 years. Source: PARCEMASA

| Year | Visitors Number |
|---|---|
| 2016 | 1774 |
| 2017 | 3719 |
| 2018 | 4819 |
| 2019 | 5195 |
| 2020 | 1513 |
| 2021 | 3632 |
| 2022 | 6292 |
| 2023 | 5604 |

The visitor statistics only confirm the solidity of the use of the cemetery in its new function as a historical and heritage space of the city, passing the restricted funerary use (sacramental) to a very secondary role. The chapel, however, has maintained continuous worship, simultaneous with the cultural events that take place there, such as conferences, concerts and book presentations. PARCEMASA, in turn, manages a program of cultural activities throughout the year, exemplifying the awareness that in the case of historical funerary spaces like this one, it assumes a responsibility, not only in terms of conservation but also of cultural dissemination and reactivation.

## 7. Technology as support for heritage dissemination

Caro et al. (2014) analysed the changes that have occurred in tourism in recent years, in which the traditional tourist has been replaced by the so-called 2.0 tourist. This is characterised by an intense use of technology to choose the destination, to obtain information once there and, subsequently, to give an opinion and value the resource. He is, therefore, an active tourist, which is why it is mandatory to pay attention to concepts that are no longer new today, such as online reputation. Web platforms, such as TripAdvisor, are leaders in consultations and in motivating users to participate by leaving their comments and ratings. This platform allows users and visitors to rate their experience voluntarily and, if desired, anonymously at the end of it.

The 2.0 tourist travels with his smartphone always in hand and uses it for everything. Taking advantage of this circumstance is a great success.

## 8. The San Miguel Historical Cemetery app

One of the keys to heritage interpretation, according to all professionals who follow the discipline created by Freeman Tilden, is that the worst heritage interpreter is always better than the best interpretation centre. This statement that refers to interpretation centres could also be applied to the technical means on which an interpreter can rely. Indeed, human beings have the possibility of transmitting and sharing emotion, something that an artificial medium cannot do. However, the current reality is that the continuous and permanent presence of a guide-interpreter in the San Miguel cemetery cannot be maintained. The proposal to create an app (Figure 2) seeks, precisely, that the visitor who comes freely and without having arranged a visit can take advantage of his experience, given that the tour of the cemetery, without the expert hand that identifies the elements and articulates them in a coherent interpretive discourse is not in the hands of the non-specialist. A tour without support will have the undoubted benefit of the aesthetic experience but deprived of the content and substance that can be expected from a space in which the diversity of aspects that have integrated the history of the city for more than 200 years can be interpreted.

The initiative to create this app was endorsed and funded by PARCEMASA for its purpose of contributing to the dissemination of heritage values and entrusted to the company 3intech. This company, directed by computer engineer Alberto Ruiz Aguilar, is based in the Tabacalera Digital Pole, a space that houses companies from the audiovisual sector installed in the building of the old Tobacco factory and which represents a commitment by the city to technology. The app (first version) was presented to the media on October 23, 2017 (Medina, 2017) and offered to citizens completely free of charge. Initially it existed only in the Android version but later the IOS version was also added. From the Android Play Store, it can be downloaded and installed on your mobile phone (Figure 3). In the interface of a smartmobile phone, it generates a blue icon in which the unmistakable silhouette of the domed chapel of the cemetery stands out, thus making it intuitive to locate it among the icons of other applications. In the search engine of the chosen platform, it was enough to type keywords such as *cemetery historical San Miguel* in the search engine to locate the app. However, at various points in the cemetery, advertising posters were displayed that reproduced a QR code that allowed the application to be downloaded and installed on the fly.

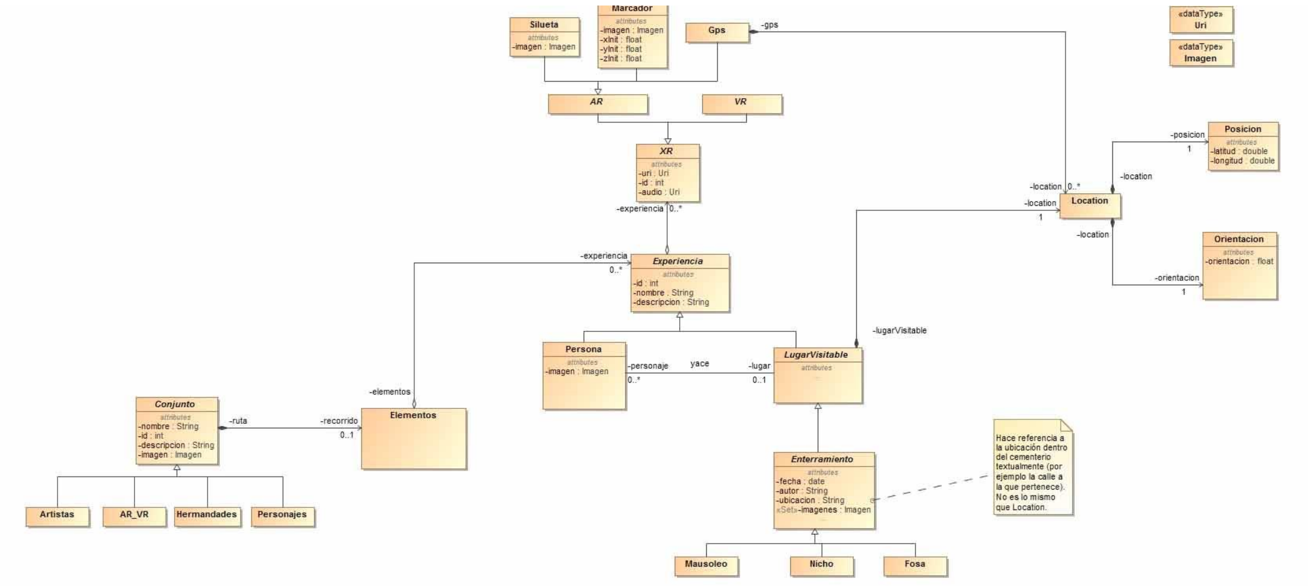


**Figure 2**. Hierarchy of content in the app. Source: 3intech


**Figure 3**. Poster announcing the app. Source: 3intech

## 9. A virtual guide with augmented reality

The app's tour starts from a home screen that reproduces the interior of the cemetery's most iconic mausoleum: the tomb of industrialist Manuel Agustín Heredia. The four main sections that make up the application are identified on horizontal bands of different colours: *Burials*, *History of the cemetery*, *Thematic routes* and *Experiences* (Figure 4). Pressing each of them opens as many bands of the same colour, varying its gradation, to identify the subsections. For example: History of the cemetery includes *Background, Origins, Constructive process and evolution* and *Funeral customs and uses*. Each of these sections is conceived as a small article with accessible language and an image (Figure 5).

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**Figure 4.** Main interface of the app. Source: 3intech


**Fig. 5**. App main page. Source: 3intech

The *Burials* section is subdivided, following the same pattern, also into four subsections or tabs: *List of mausoleums, Characters, Brotherhoods* and *Map* (Figure 6). In turn, the *Brotherhoods* tab gives way to a new subdivision: *Burial Mutualities, Brotherhood Niches, Brotherhood Mausoleums, Brotherhoods of Souls* and *Brotherhood Presence.*


**Figure 6.** Access to mausolea in the app. Source: 3intech

Despite the formula of short articles, the accumulation of information becomes very estimable, but offering the advantage of interactivity and that the user, depending on their interest, can choose between one option or another. The app is conceived not only as a companion during the tour but as a complement that can be consulted at home, before and after the visit, or even as a source of information independent of physical presence.

One of the most attractive aspects is the *Experiences* option, which uses location: 9 options are marked on an aerial photograph that correspond to specific points in the cemetery. Eight of them are about illustrious people who are, or were, buried in the cemetery. The idea is that the user, in front of the mausoleum in question, clicks on the caller, which will activate a one-minute video in which the character in question explains, in a synthetic way, the main events or achievements of his life, reason for its postmortem presence in this application (Figure 7). The videos starred actors from the company Eventos con Historia, dressed according to the time and social nature of the character. The recordings were made in the studio using the chroma system, so the character moves, speaks and gestures without any background. Hence, when the experience is activated in front of the corresponding mausoleum, it simulates the idea of the appearance of a *historical ghost* (Figure 8).


**Figure 7**. Location of augmented reality experiences on aerial photo of the cemetery. Source: 3intech


**Figure 8.** Holography of the character Jane Bowl before her grave. Source: 3intech

There is another aspect that illustrates the didactic possibilities of technology applied to the dissemination of historical heritage. One of the most monumental mausoleums in the cemetery is that of the magnate Manuel Agustín Heredia, leader of the steel sector in Spain in the 1940s (he died in 1846). The funerary construction has a privileged and dominant position within the cemetery, attached to the chapel and connected to it (Figure 9). Its interior houses the tomb of the character, which is made of marble by the famous sculptor Lorenzo Bartolini and can be seen from the chapel through a gate. However, the funerary construction also includes an underground crypt accessible from the outside. It is a rectangular vaulted space with a brick barrel and connected to the upper floor - at street level - through a lattice oculus that provides overhead light. The crypt contains an officiating table and candelabra in the shape of kneeling angels, all made of cast iron, as corresponds to the origin of the character's fortune. On the side walls, there are burial niches covered by tombstones of prominent figures in local life, descendants of the Heredia family or their consorts, in the case of the merchant Jorge Loring or the engineer Rafael Benjumea, count of Guadalhorce.

**Figure 9.** Aerial photography of the cemetery. Author: F.J. Rodríguez Marín

This space, still pending restoration to alleviate the deterioration caused by the passage of time, is a private space and is not accessible to the public. But there is no doubt that it is of great interest to the citizens of Malaga and visitors in general, who add to the interest in the characters the mystery component provided by a space usually closed and intended for burial. The app provides the possibility of viewing it in 3D so that by sliding our finger on the touch surface of the phone, we have the possibility of viewing the space in 360º and even zooming in to see details or read the tombstones of those buried there. Spatiality is one of the aspects of architecture where technology provides didactic potential when it comes to apprehension of space that improves its understanding, even if this space were accessible. The total number of monumental mausoleums in the cemetery is 252.

The application includes only a selection of the most notable and interesting, of which authorship, date, location, description and history of the buried characters are provided. The purpose of the project was to complete the entire contents of the cemetery in successive stages. Unfortunately, not only could it not be completed, but due to lack of maintenance, the most attractive features of the app stopped working. However, this initiative has confirmed the possibilities of access and dissemination of heritage that technology can provide. Although the existence and availability of this free application have not been widely publicised, it has had a good level of acceptance and an acceptable number of downloads (Figure 10).

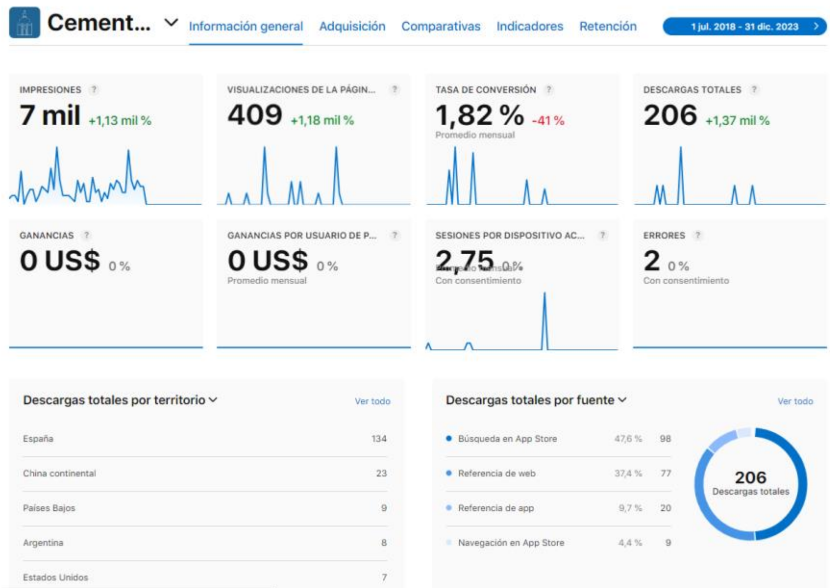


**Figure 10.** App download statistics. Source: 3intech

## 10. Conclusions

Funerary spaces often support considerable heritage values. Sometimes, due to prejudice or lack of sensitivity, they allow themselves to be ruined when they can no longer be used. In the case of Malaga, its commitment to cultural tourism has led to new circumstances favourable to the recovery of cultural heritage to make it available to citizens. This is the case of the historic San Miguel cemetery.

On the other hand, the new generations of tourists, the so-called 2.0 tourists, are characterised by a high degree of autonomy and support in technology, present in all phases of the travel experience. Additionally, the Millennial and Z generation is characterised by a high use of smartphones, which they use continuously in all moments of their daily lives.

Among other initiatives, the management company of the historic San Miguel cemetery has sponsored the creation of an app as a tool to access the content and values treasured by this funerary site. The brevity and concision, the illustrations and, above all, an intuitive and easy-to-use interface, have made this app an attractive and easy-to-use tool, which can also be downloaded for free in both the Android and IOS versions. The use of augmented reality and virtual reality for spaces that are usually not accessible have given the application additional attractiveness, demonstrating the usefulness of this technology as a vehicle for disseminating cultural and heritage values. After a few years of full operation, the application has begun to fail, demonstrating in turn that these investments require continuous effort and attention parallel to that allocated to the conservation of material heritage. The purpose of this project is to expand it in the future to include all of the cemetery's mausoleums.

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# Digital Graphic Survey of Funerary Architecture - The "Museum of Silence" of the General Cemetery of Valencia

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***Abstract***

*Currently, techniques for obtaining 3D models are booming due to the infinite applications of these models. Photogrammetry by SfM (Structure from Motion) is a whole new subject that is emerging in this field of modelling, as it is a technique that allows us to obtain high-resolution 3D models with a camera. This project will address the study of this new subject and its application in the development of 3D models, as well as the workflow with other capture techniques, such as laser scanning and its possible virtual applications.*

*Currently, the most precise method to capture 3D information is the laser scanner, but it has weaknesses, which are precisely one of the strong points of SfM photogrammetry.*

*A brief tour will be made of all the techniques that exist to give photorealism to a terrestrial laser scanner (TLS) scan, to then present the developed and proposed technique on a real example and, in this way, obtain conclusions.*

*In the end, the solution is proposed to the Museum of Silence, where, with augmented reality, options are proposed to safeguard the Funerary Heritage from theft with the creation of virtual models, 3D reproductions of sculptures and other elements that are victims of vandalism.*

***Keywords:*** *digital, funerary architecture, Museum of Silence, cemetery, Valencia.*

## 1. Introduction

With this presentation, we want to show the problems that occur with a Heritage that is abandoned, that is of no interest and that some politicians (with positions in Culture) went so far as to say that "these constructions, the best thing was demolish them and make them disappear" in order to help the urban growth of the "Cities of the living".

Yes, we are referring to the "Cities of the Dead", our Cemeteries. Spaces that bring together a variety of architectural styles and that bring together all or almost all of the so-called "Fine Arts".

We talk about Cemeteries but not about the Cemetery as a container; we want to talk about the "Content" of those constructions that, as we mentioned before, bring together almost all the Fine Arts, although in Latin American countries (much more respectful than us in the protection of this heritage), they do use all the Fine Arts, since paint is used to give life and colour to these spaces. In this way, in Latin America (in a large part of it), when painting these constructions, they give joy and life to these spaces; spaces that in Europe are overshadowed by a feeling of sobriety and austerity. This sensation is perhaps caused by using nobler materials, which are not used in Latin America and which force the periodic painting of their walls.

But in order to do what we want, we must carefully study how to graphically construct these small constructions and make clear how to name them.

If we go to the Royal Academy of the Spanish Language, it tells us:

Pantheon: *Funerary monument intended for the burial of several people*.

Mausoleum: *Magnificent and sumptuous tomb.*

For Spain, it is clear. We can say that in Europe, the constructions of our cemeteries are Pantheons, and the very large constructions are Mausoleums, but in Latin America, that difference of very large -or for them large- is where a clash of lexical variation occurs. To avoid creating confusion, let's talk about the fact that those constructions of more than 4-5 meters in height or width are called Mausoleum.

Once this point has been clarified, we will make it clear that we care little or nothing about differentiating between these two terms; we care about their artistic quality. We will not go into the possible economic aspects of these constructions and whether they demonstrate or define the economic power of the family buried in this space. We look for artistic quality.

Let us make it clear that in a Cemetery you can find constructions worthy of being classified as truly monstrous or worthy of a "Museum of Horrors". We want to stay with what truly has quality or with those elements whose complements, outside of architecture and within the fine arts minors, give quality and originality to these.

As we indicate in the summary of this Communication, currently, the techniques for obtaining 3D models are booming due to the infinite applications of these models. SfM photogrammetry is a new topic that is emerging in this field of modelling since it is a technique that allows us to obtain high-resolution 3D models with a camera. This project will address the study of this new topic and its application in the development of 3D models, as well as the workflow with other capture techniques, such as laser scanning and its possible virtual applications.

Currently, the most accurate method for capturing 3D information is the laser scanner, but it has weaknesses, which are precisely one of the strengths of SfM photogrammetry.

A brief tour will be made of all the techniques that exist to give photorealism to a scan with a terrestrial laser scanner (TLS), to then present the developed and proposed technique on a real example and, in this way, obtain conclusions (Bonafé Cervera, 2016).

In the end, the solution proposed is the Museum of Silence, where augmented reality options are proposed to safeguard the Funerary Heritage from looting, with the creation of virtual models, 3D reproductions of sculptures and other elements that are victims of vandalism.

Many of us think that looting ends in an undesirable end for these constructions; we are talking about vandalism in Cemeteries, where political graffiti occurs on Pantheons of politicians or renowned figures, destruction of sculptures due to attempts to steal them, etc. A lack of respect not for the person who is buried there but for the Heritage.

## 2. Aims and Objectives

### 2.1. Purpose. Choose the most appropriate method

The purpose is to apply most of the known systems for the graphic survey of this heritage, but little or nothing is studied. Abandoned on many occasions by administrations because "the dead person does not vote", and it is not interesting to invest money in a space where it cannot be seen.

Photo modelling, through its different techniques, constitutes today a valuable photogrammetric method that offers reliable results because its means are within the reach of anyone and because it has enormous versatility in the field of 3D modelling (Beraldin et al., 2002).

Until recently, close-object photogrammetry, known as such, aimed to model objects through a few photographs, in which homologous points could be observed in three or more frames. Knowing the calibration of the camera with which the photographs had been taken, through the marking of these homologous points, the orientation of the cameras was obtained through the collinearity and coplanarity equations. This technique encountered serious limitations due to the number of cameras due to manual point marking.

With the appearance of the new Structure from Motion (SfM) technique, they overcome the limitations of manual intervention in the process.

SfM is derived from developments in artificial vision with automatic feature recognition. Although these were initially focused only on aerial photogrammetry and robotics, in the last twenty years, efforts have been made to resolve the complexity of the sets of convergent shots and, in turn, respond to the demand for an acceptable visual quality in the results. Thus, in a few years, a good number of applications have been developed in fields such as photogrammetric surveying, reconstruction of objects from video sequences, and automatic reconstruction of virtual reality (so that, for example, computer-generated objects can be integrated with real scenes), or macro-panoramic, based on these principles. Above all, the field in which this technique is and will be emerging is in modelling with drones, since today it is only possible with photogrammetry since the use of a laser scanner mounted on a drone is unfeasible until sufficient technology to create a light enough emitter.

SfM works with different types of algorithms, and within each type, there are many versions since each developer contributes improvements through an unstoppable evolution process. Different phases can be differentiated in the alignment of the cameras:

We will talk:

- Key point detection with SIFT Algorithms;
- Matching key points found between groups of images;
- Refinement by robust fitting algorithms;
- Camera orientation.

To talk later about the techniques for the integration of photogrammetry and laser 3D scanning.

Briefly knowing the SfM algorithms interests us to the extent that it can help us in our purpose of developing an adequate operational technique for the digitisation of buildings and urban scenarios from photo sequences or video sequences depending on the destination and the accepted precision. of our work.

Very broadly, the operation of the Scale Invariant Feature Transform (SIFT) algorithm, which happens to be the first to be published, is based on the search throughout the entire image for pixels with high contrast in relation to the surrounding ones, such as belonging to edges or corners. The results are called keypoints and are defined by their pixel coordinates and by a "descriptor", which is a vector that represents a three-dimensional histogram of the characteristics of adjacent pixels according to certain directions. Most applications generate a file for each frame that contains the image coordinates of the detected key points of said frame; many authors call these files as .sift files. (Figure 1).

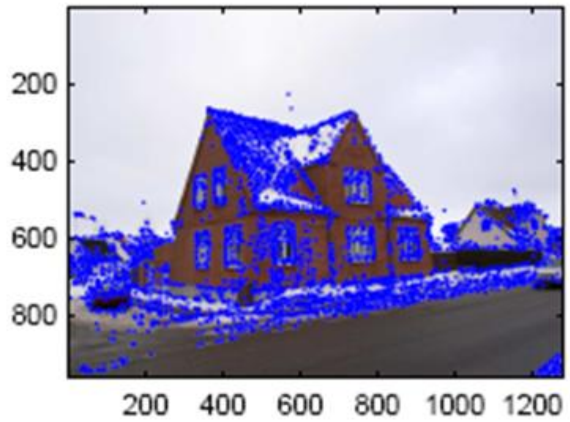


**Figure 1**. Keypoint Detection with SIFT.

Next, correlation algorithms (matching) are executed between the corresponding points of the different pairs of images, generally known as area-based or signal-based type, and which, in the case of SIFT, are specified in the "method of the nearest neighbour." This essentially consists of calculating the coincidence between the descriptor of a key point of the initial image and those located in the second image, within a certain search area, according to their gradients in multiple directions, and considering the correspondence good when the divergence is minimal.

The matching between keypoints is done between two .sift files (containing the coordinates and characteristics of the keypoints). Each .sift file will match all the remaining .sift files that we want or that the program or application requires. For example, the Photoscan software offers three matching quality options, depending on whether each one will relate everything to everyone or follow a correlation order (Figure 2).

The inevitable errors of this experimental process in this first matching, due to occultation, reflections, or other causes, are then refined using robust adjustment algorithms. If enough points have been obtained for the next orientation phase, this phase will be concluded; otherwise, more co-correlations will be searched. In this way, a loop will be formed that will be closed when the need for correlated points for the orientation of the cameras is satisfied (Cabanes, 2020).

**Figure 2**. Matching with 12 Images. Romanesque door of the Cathedral of Valencia.

With these data, it is possible to approach the "projective reconstruction" of the image sequence, starting with the estimation of the Fundamental Matrix F, which is based on the existing projective correspondence between the epipolar lines. The epipolar lines are determined by the intersection on each image plane of the plane, which is determined by two cameras (their O centres) and an image point (Figure 3).

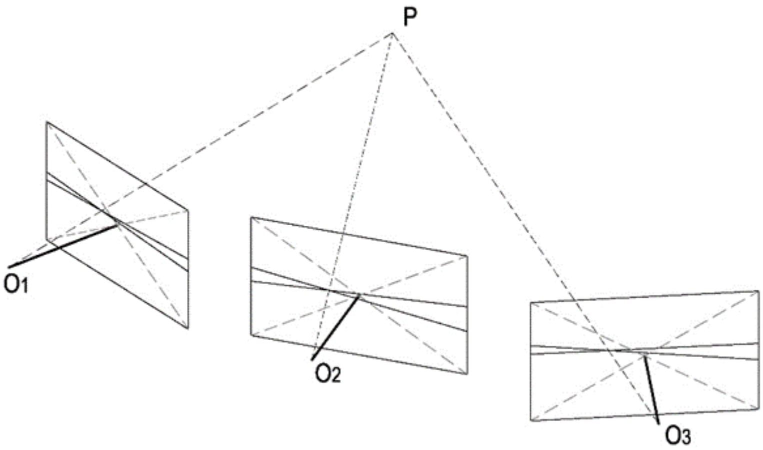


**Figure 3**. Three-frame "epipolar" lines.

Once you have a first estimate of the cameras, you continue with re-triangulation, which is carrying out the same process but with coordinates of the cameras already estimated a priori.

The integration of Photogrammetry with 3D Laser Scanner depends on the registration of the data of the two models, which constitutes its foundation. Manual registration will normally be necessary since individual models are created in different coordinate systems, and common points are problematic without pre-signalling.

We will talk here about several possible approaches:

- Photogrammetry aided by Laser Scanner (LS);
- LS with the help of photogrammetry;
- LS integrated with Photo Images;
- Integration into "object".

To talk later about the 3D Modelling resulting from the integration of photogrammetry by SfM to obtain textures.

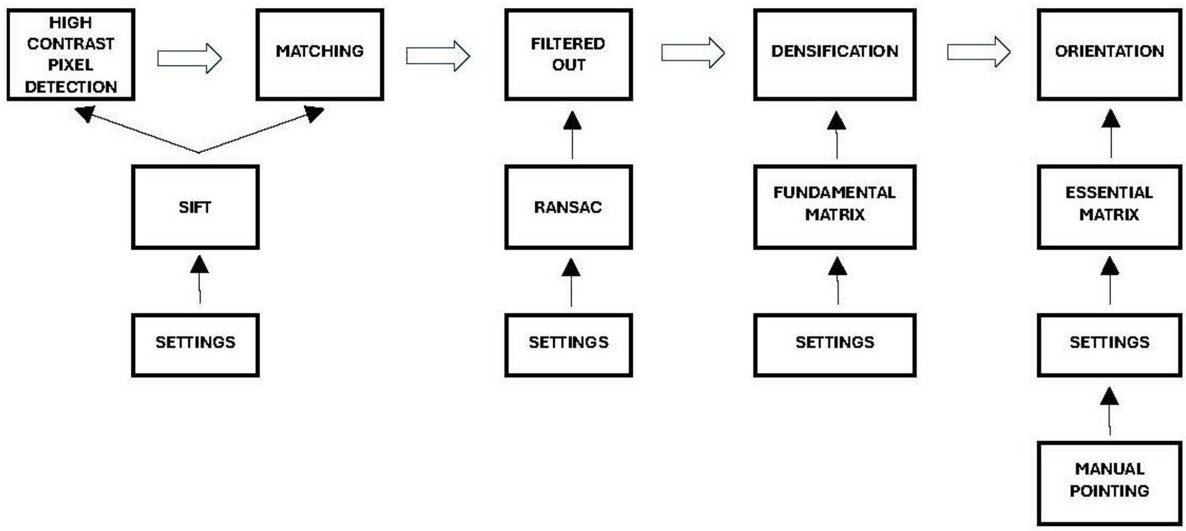


**Figure 4**. Basic scheme of the process of determining the structure of the model from the movement of the cameras (SfM).

In Photogrammetry helped by LS approach the principle is that the depth information is selected from the laser data, while the rest can be obtained from the images, so registration in a common coordinate system is essential.

Using laser scanning with the help of photogrammetry, the primary model is LS point clouds, although image data allows for texturing. The base model for co-registration is always the more reliable scan, while the more detailed LS mesh texturing is obtained from the images. This approach is useful for creating very detailed final models and is what we will use for the 3D survey of the Pantheon, the example that we will show, where the exterior of the Pantheon and its crypt appear.

With Object-Level Integration, LS (Laser Scanner) and photogrammetric, data are processed and interpreted separately so that integration occurs in the final stage. Orientation to the common coordinate system is usually done separately for LS and images. Although, if the object is small, it may be limited to the use of photogrammetric means, excluding LS. This will be the result of the last example. Well, Photogrammetry is only applied for 3D surveying and texturing. Subsequently, augmented reality will be applied to the result (AR is an interactive experience that improves the real world with perceptual information generated by computers. Using software, applications and hardware such as AR viewers, augmented reality is superimposed on digital content in environments and real-life objects).

### 2.2. Specific objectives. The rising of the Pantheons. Data collection

#### *2.2.1. The Pantheon of the Cortina family*

In the external survey of the Cortina Family pantheon, two teams have been used: a ground team as the main source of information and an aerial team as support to fill in information impossible to capture by the first, which caused serious security and safety problems schedules.

The ground equipment is made up of two professional cameras, with a tripod so that the shots are not out of focus, and a terrestrial laser scanner.

The aerial equipment formed by Drone F550, with 6 arms and 6 motors (at 960 kV) with a load capacity of up to 500 grams, had 3 batteries of 5200 mAh each, therefore, a flight time of 35 minutes.

For the interior survey on the stairs to the Crypt and inside the Crypt, the terrestrial laser scanner is used, making four parking lots, the first at the farthest point from the stairs, the second next to the stairs, and the third at the start of the stairs and the room at the end of the stairs, the latter could be joined to the exterior.

For the photogrammetric capture of the interior, a double photographic ring was made with displacements and a two-meter ladder to provide elevation and reduce the shadows of the laser scanner placed on the floor.

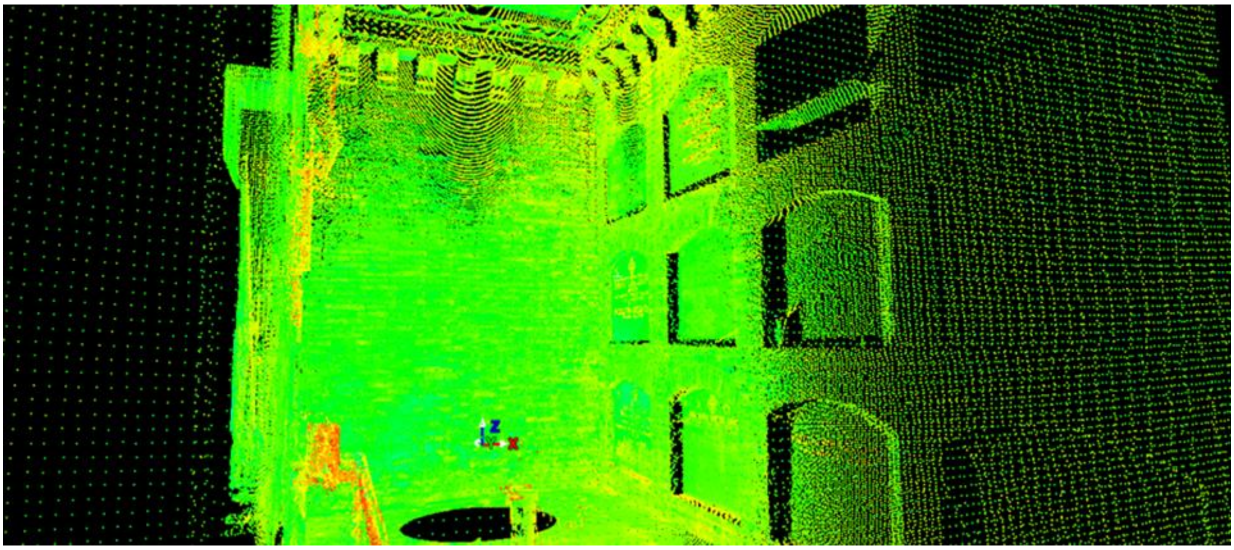

**Figure 5**. First scan of the Cortina family Pantheon

 

**Figure 6**. Exterior photographs of the Cortina family Pantheon

For the exterior survey, the photographic survey was carried out with a drone between 7:30 a.m. and 8:15 a.m. since the fundamental condition was that no one from the Cemeteries staff or visitors should be present during the flight.

Then, it started with the laser stations. The fifth parking lot (first exterior) was under the lintel of the door to join with the fourth station that had some exterior points; then, there were three more stations (all the parking lots were levelled), covering the entire Pantheon.

The exterior photogrammetric survey was carried out with the cameras and a ladder from the Cemetery itself that reached 3 meters plus the 1.5 m tripod, so a height of 4.50 m was reached. In Figures 6, 7 and 8, we can see the different photographic surveys.

**Figure 7**. Cortina family Pantheon exterior photographs and drones

**Figure 8.** Aerial exterior photographs (drone) of the Cortina family Pantheon

The camera settings for data collection and the way in which photographs are taken are also very important. A tripod is used, being necessary to avoid any movement and blur when taking the photograph. Close the lens to the maximum within the focus range to increase the level of detail. The ISO level and exposure will be constant, giving priority to the aperture since it is shot with the camera supported in order to obtain the best results.

Subsequently, the external point clouds were recorded and linked to obtain the result of Figure 9. The aerial point cloud was not very dense and was also located in another reference system and at another scale, which is why it was registered with respect to the data from the laser point cloud (Figure 10).

Once the orientation files of the hybrid model and the corresponding images with their orientation data with respect to the general reference system were obtained, both were imported into the Meshlab application to perform the texture mapping with the option of best matching of the normals of the mesh triangles.

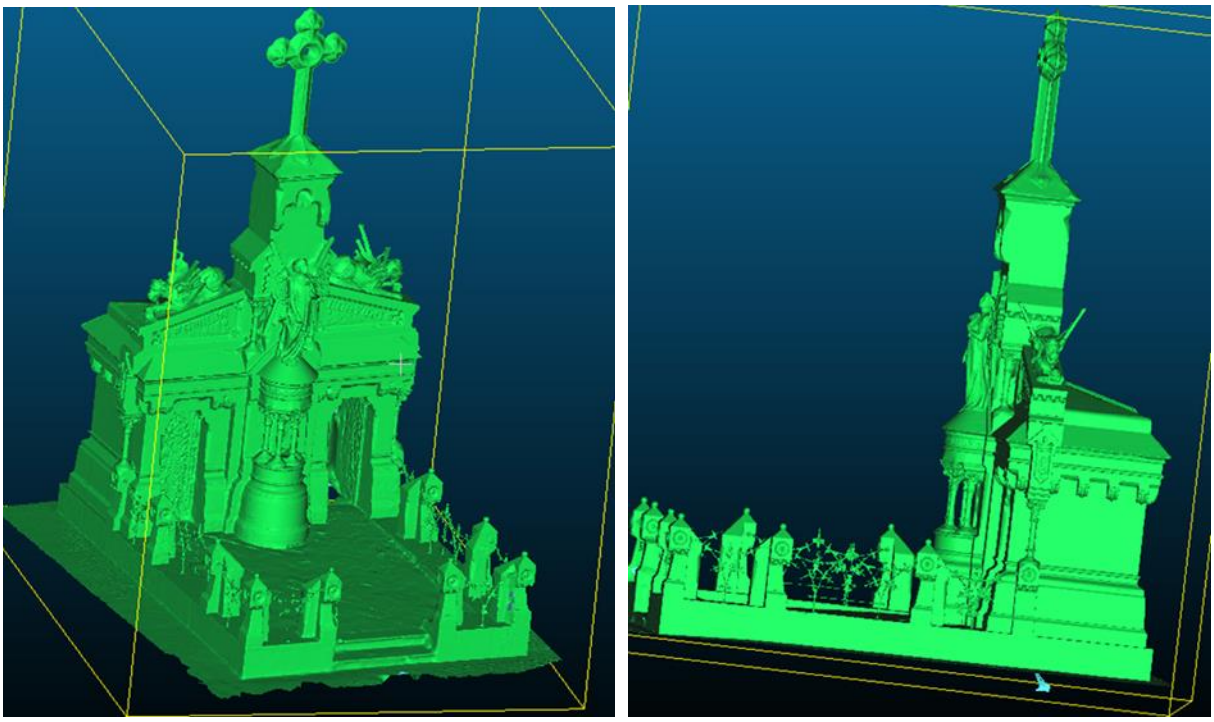

**Figure 9.** External point cloud of the Cortina family Pantheon

 

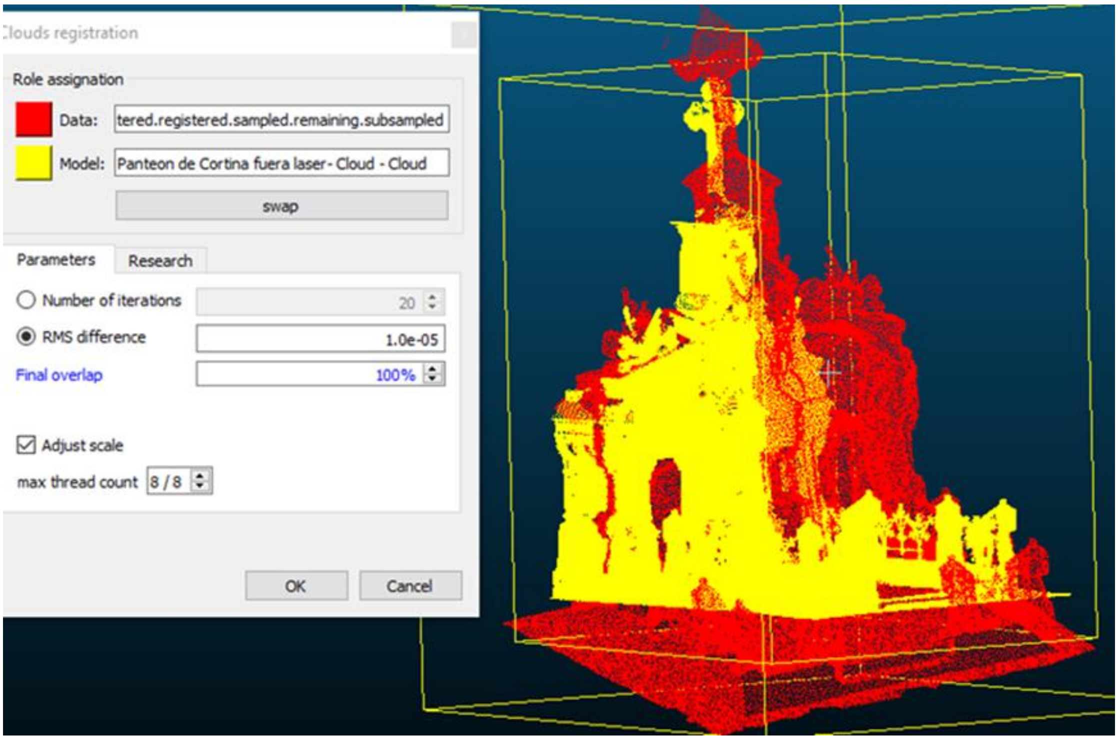


**Figure 10**. Registration of Cortina family pantheon aerial point cloud (in red) with the external laser one (yellow).

The only thing left to obtain the final model is to combine both models, exterior and crypt, into one. To do this, we load them into CloudCompare and using the merge option, we generate the final joint model.

The texturing of the Crypt in Figure 11 should not mislead us due to the transparency of the texture map (that is, seen from within the niches or inside the terrain) (Cabanes & Girbés, 2023; Franco, 2011).

**Figure 11**. Joint mapped and textured triangle mesh of the Cortina family Pantheon

### *2.2.2. The Morris Family Pantheon*

As the object is small (1.70 meters high), the survey is limited to the use of photogrammetric means, excluding LS. Photoscan or any similar software can be used to obtain the textured mesh.

Later, we applied augmented reality to obtain a model appropriate to the final intention of this work (Figure 12), "The Museum of Silence", to obtain virtual models that allow the Pantheon to be viewed more completely. (Remondino et al., 2008; 2009).


**Figure 12.** Image of Augmented Reality applied to display the Morris Pantheon

With this Figure printed or on a rotating support, we can see the Pantheon from different points of view using a tablet that will give us information about each of the Pantheons that can be studied or exhibited (Figure 13). If we change the image, we can change the display from the outside of the Pantheon to its crypt (Ferdani et al., 2020).

**Figure 13.** Image of the Cemetery of Valencia where a Code is hidden to view the Pantheon.

## 3. Conclusions

We have seen that the objective of obtaining a 3D survey of our Pantheons is achievable with a low-cost methodology.

However, the main objective of incorporating these uprisings into the “Museum of Silence” in order to avoid looting in the General Cemetery of Valencia is not guaranteed.

In April 2016, the Valencia City Council launched two “Contests of Ideas for Rehabilitation in the General Cemetery of Valencia”. They stated: "We will improve and dignify facilities that are the city's heritage through the participation of external people and groups.".

But everything remained as good intentions; in the end, nothing was rehabilitated, the Museum of Silence was not built, and the looting continued.

Proof of this plundering, we have the following example and many more (Figure 14).

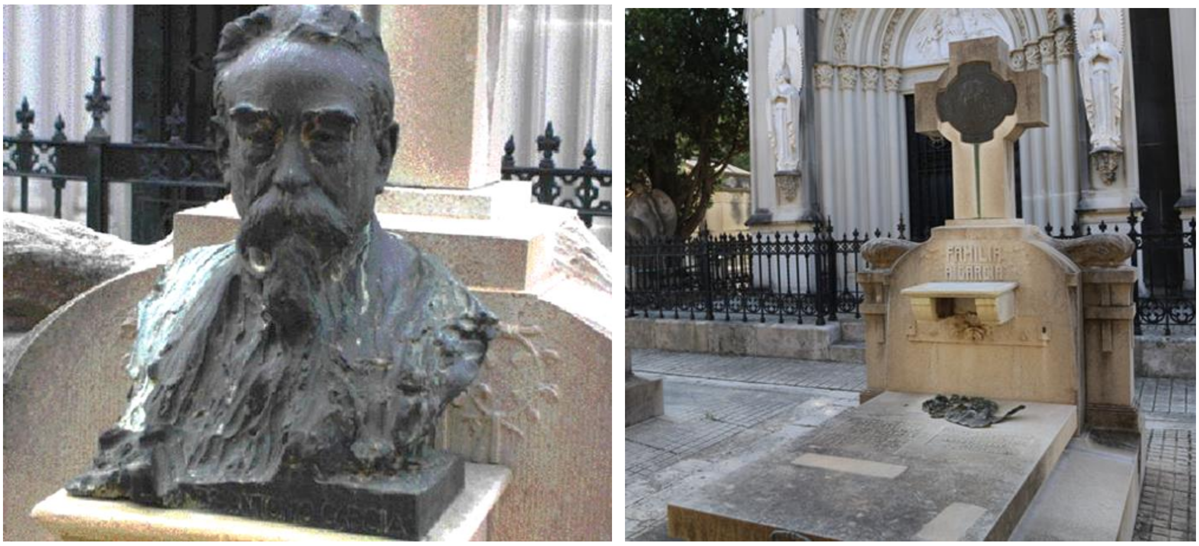

**Figure 14.** Pantheon of Antonio García Peris, before and after.

Result: a looted bronze bust that almost certainly ended up in a foundry and sold by weight.

The problem is the person represented in the bust, “a great character of the time”, Antonio García Peris (1841-1918), was a Valencian photographer who maintained one of the most active studios in the city of Valencia from 1862 until his death, in 1918—Father-in-law of Joaquin Sorolla y Bastida. The bust is by the master sculptor Mariano Benlliure Gil. The intention was that all these sculptures and elements, with great heritage value, would end up inside the Museum, and fibreglass copies would be placed outside. But it was late.

With this Museum of Silence, double value would be achieved:

- Promote Funeral Tourism, giving it artistic value.
- Promote the “Routes of Silence”, tourist tours that take place every 15 days in the General Cemetery.

The looting continues; what we mentioned above is a small sample. We must do something now.

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# The Grand Staircase of the Birago di Borgaro Palace: From Digital Model to physical scale model for the communication of construction aspects

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## *Abstract*

*The combined use of digital and physical models promotes inclusive communication and represents an important medium for presenting heritage to the community, particularly to the tourism sector.*

*The work presented here concerns the Grand Staircase of the Birago di Borgaro Palace in Turin, designed by Filippo Juvarra and built from 1716 onwards. The monumental staircase is located near the main atrium; its development takes place on three right-handed ramps leading to the main floor hall.*

*The contribution focuses on the application of digital technologies for three-dimensional modelling and digital fabrication, aimed at studying and communicating the constructive aspects of architectural heritage.*

*The adopted methodology involves the use of data from previous acquisitions and restitutions (TLS survey by Prof. M.C. López González, two-dimensional drawing by Arch. F. Natta) for the digital modelling of the Grand Staircase in order to retrace the formal ideation process related to the applied construction techniques.*

*Starting from the virtual model, through digital fabrication techniques, a physical model is created on a 1:50 scale, composed of four main blocks obtained using three vertical section planes.*

*The model, in addition to restoring the compositional apparatus of the decorations, aims to make understandable, explicit and readable the construction system used in the design: on the one hand, it restores the overall three-dimensional morphology of the artefact, and on the other, it offers the possibility to be explored revealing the structural composition through the constituent elements such as the ramping barrel vaults, the cross vaults that support the landings and the stiffening arches.*

*The physical model of the Grand Staircase of the Birago di Borgaro Palace is an example of how the physical representation of the built space can become an expression of layered and sedimented information, lending itself to the communication of knowledge even to a non-expert audience.*

**Keywords:** *3D modelling, digital representation, scale model, digital fabrication, 3D printing.*

## 1. Introduction

The architectural heritage represents the cultural expression of an era, and each building, with its structure, decorative details, and constructive peculiarities, narrates a unique story inextricably linked to the historical context in which it was conceived and realised. However, the comprehension of these architectures is not always immediate, especially regarding the technical and constructive aspects that often elude the untrained eye. In this scenario, the combined use of digital and physical models can be a valuable tool for promoting inclusive communication and representing an important medium for presenting architectural heritage to the community, particularly the tourism sector. Through these tools, the constructive elements and challenges faced by architects of the past are brought to light, allowing a broader audience to appreciate the ingenuity of the masters who designed these artefacts.

The contribution focuses on the case study of the Grand Staircase of the Birago di Borgaro Palace in Turin, an architectural masterpiece designed by Filippo Juvarra and constructed starting from 1716. The Grand Staircase is located near the main atrium of the palace and develops through three right-handed ramps leading to the main floor hall (*piano nobile*). The artefact has been assumed to be a paradigmatic case study within the Turin architectural panorama, where a relatively small number of 17th and 18th-century palaces feature a staircase configured as an access structure to the only first floor without continuing to the upper floors.

In the context of Baroque architecture, the Grand Staircase takes a role of great importance, representing a crucial element within the ceremonial of entrance and welcome. It is not a simple vertical connection but rather a primary design nucleus developed with great compositional effort and scenic unity (López González et al., 2022).

The realisation of a detailed digital model of this element has allowed the exploration of its constructive aspects, highlighting not only its remarkable decorative apparatus but especially the system of vaults used in its design (Guillerme, 1987), supporting the three ramps of stairs and landings. Thanks to surveying, drawing, and three-dimensional digital modelling techniques, it has been possible to virtually reconstruct the architectural elements with high accuracy, analysing the employed constructive solutions.

In order to make this geometric and constructive information accessible, a scale model has been created, translating the data elaborated in the digital modelling environment into physical form (Colabella, 2017). The model, obtained through digital fabrication techniques, allows users to appreciate and understand the constructive system of the Grand Staircase, thanks to its division through the introduction of three vertical section planes.

The development of this workflow, from the digital model to the physical scale model, gives rise to an effective communication medium, allowing the explication of an aspect not immediately perceptible in the Grand Staircase of the Birago di Borgaro Palace.

## 2. Previous related works

Among the research and studies dedicated to the Birago di Borgaro Palace, it is necessary to mention the monographic work curated by Elena Gianasso, Albina Malerba, and Gustavo Mola di Nomaglio (2019), as well as the work of Paolo Cornaglia (2000). Regarding the role of the Grand Staircase in Juvarra's architecture, it is significant to mention the essay by Roberto Caterino (2018) and, finally, on the application of geometric-proportional and constructive criteria in the design of Staircases, the article by Cornelie Leopold (2019) and the book by Vincenzo Cirillo (2019).

Regarding the treatise sources, previous studies (López González et al., 2022) have focused on the works of Andrea Palladio (1570), Guarino Guarini (1737) and Bernardo Vittone (1760, 1766), while concerning manuals, the studies have involved the books of Giovanni Curioni (1870) and Gustav Breymann (1884).

The metric survey conducted by Prof. M.C. López González followed interdisciplinary research experiences between representation and constructive history on stereotomic staircases in Spain (López González and Marín Sánchez, 2020; Almagro and Gorbea, 2019; Puche Fontanilles et al., 2017). This approach has allowed for an in-depth study of the geometric, constructive, and structural aspects of monumental Staircases, integrating historical, architectural, and technical knowledge. The previously conducted metric survey represented an indispensable tool for understanding, preserving, and communicating this architectural heritage of high value.

## 3. Aims and objectives of the research

The present contribution explores the potential of digital technologies in three-dimensional modelling and digital fabrication, applying them to the study and communication of the constructive aspects of architectural heritage, with particular reference to the tourism sector. Through the selected case study of the Grand Staircase of the Birago di Borgaro Palace in Turin, this work aims to investigate how the integration of advanced digital tools can represent a valuable ally in the preservation, enhancement, and dissemination of architectural heritage (Spallone et al., 2021).

One of the main objectives was to create a detailed digital model of the Grand Staircase, leveraging the capabilities offered by NURBS (Non-Uniform Rational B-Spline) modelling in the RHINOCEROS 7 workspace. Through this approach, the goal was to obtain an accurate virtual representation of the work, capable of capturing the complex geometries and constructive solutions adopted by the architect Filippo Juvarra in the realisation of this extraordinary artefact.

Furthermore, the digital model represented a nodal point for the exploration and analysis of the technical and structural aspects of the work. Thanks to the functionalities offered by three-dimensional modelling software, it was possible to examine in detail the constituent elements of the Grand Staircase, such as the ramping barrel vaults, the cross vaults of the landings, and the reinforcing arches, in order to fully understand the adopted construction system (Maiezza, 2019).

An additional objective pursued in this work was to translate the digital model into a tangible physical representation, leveraging digital fabrication technologies (Scopigno et al., 2017). Through the use of FDM (Fused Deposition Modelling) 3D printing, a scale model of the work was created, capable of concretely and immediately restoring the constructive and structural aspects previously analysed in the virtual environment.

This step required particular precautions, as the physical model had to be able not only to reproduce the morphology and aesthetics of the artefact but also to clearly and effectively communicate the adopted technical solutions, making them understandable and readable for a heterogeneous audience, especially for non-experts in the field. In this context, one of the fundamental objectives was to fully exploit the potential offered by FDM 3D printing in reproducing complex geometries and architectural details to obtain a high-quality and precise physical model.

The hybridisation of digital and physical tools represents an effective approach to the communication of architectural heritage, and the contribution aims to enrich the scientific research on the role of digital technologies in the conservation and communication of cultural heritage (Neumüller, 2014). By sharing the results obtained and the methodologies adopted, the intent is to stimulate further reflections and research in this field, fostering a fruitful exchange of knowledge.

## 4. Methodological workflow structure

The adopted methodology (Figure 1) involves the use of data from previous acquisitions and restitutions (TLS survey by Prof. M.C. López González, two-dimensional drawing by Arch. F. Natta) for the digital modelling of the Grand Staircase, in order to retrace the formal ideation process related to the applied construction techniques.

Starting from the virtual model, through digital fabrication techniques, a physical model was created on a 1:50 scale, composed of four main blocks obtained using three vertical section planes (Figure 2).

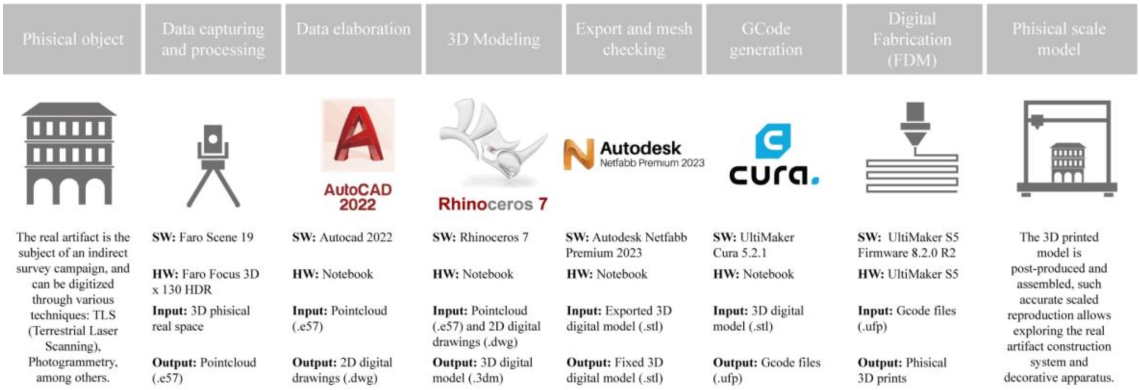



**Figure 1.** Summary table of the process illustrating the main steps of the adopted workflow, for the different phases is specified: the utilised Software (SW), the involved Hardware (HW), the input and the output data. Source: Pupi (2024)

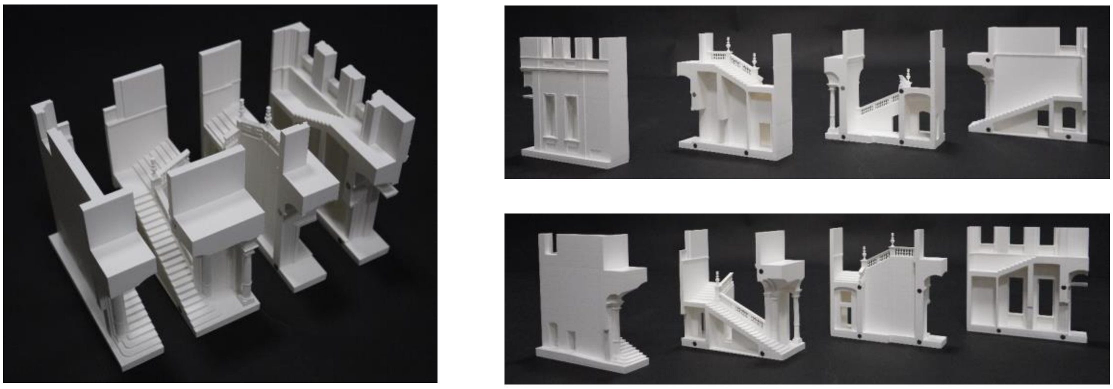


**Figure 2.** Photograph of the model after completion of all workflow steps. Photos were taken at the MOD Lab Arch of the Politecnico di Torino – Department of Architecture and Design. Source: Pupi (2024)

### 4.1. Data alignment in the digital workspace

At first, it was necessary to align the data relating to the atrium and staircase of the Birago di Borgaro Palace within the RHINOCEROS workspace, through which perform the three-dimensional modelling operations:

- The point cloud, previously captured using TLS (Terrestrial Laser Scanning) methodology, was carried out with a Faro Focus 3D x 130 HDR by Prof. M.C. López González (Figure 3). The space was scanned with a high-density resolution (one point every 7.7 and 6.11 mm at a distance of 10 meters) using the scanner's integrated camera (70 megapixels with automatic brightness adaptation). The good overall level of overlapping (21.4%) and the accuracy of the laser scanner led to a satisfactory result: the maximum error in the position of a single point in all scans was 6.7 mm, and the average error was 3.4 mm, values compatible with 1:50 scale graphic restitution. Alignment and registration were performed using Faro Scene version 19 software. It was possible to export the point cloud in *.e57* format to import the data into the RHINOCEROS workspace.
- The vector drawings of plans and sections created by Arch. F. Natta were based on the information derived from the point cloud (Figure 4). Direct survey operations complemented the drawings to complete the knowledge data: a plan was drawn up at the elevation of the underfloor rooms, which was particularly useful for the analysis of the structural and construction system: it consists of a "trumpet" staircase system, with double support of inclined barrel vaults on which the steps are positioned, while very low cross vaults form the intrados of the landings. Between ramps and landings are transverse arches, partly plugged, that stiffen the load-bearing system. The vector drawings, created using AUTODESK AUTOCAD 2022, were imported into the RHINOCEROS workspace in their native *.dwg* format. In this

way, to correctly carry out the three-dimensional modelling, it was particularly useful to subsequently be able to use the profiles of the mouldings and decorative apparatus contained within the drawings.

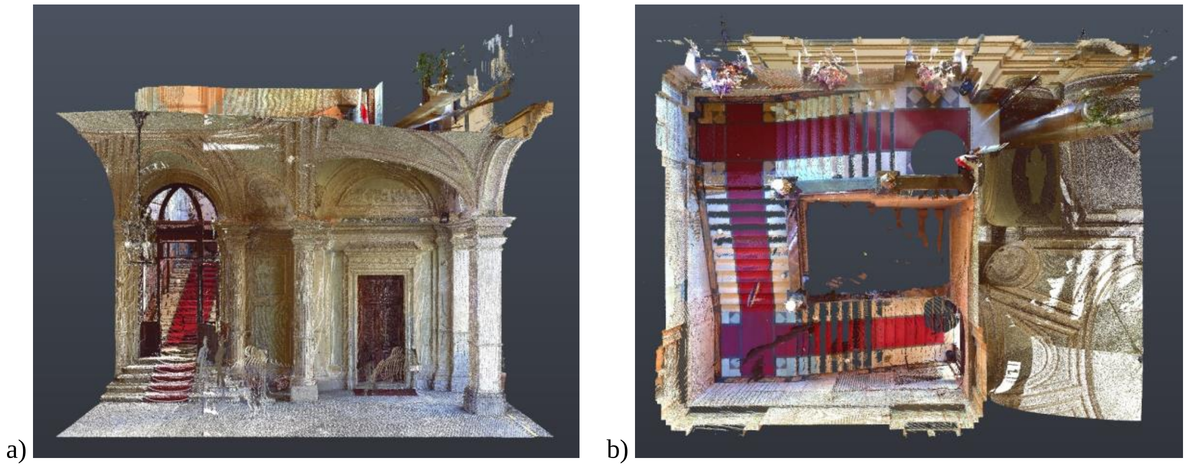


**Figure 3.** Processed and trimmed point cloud: a) Atrium perspective; b) Zenithal perspective. Source: López González (2022)

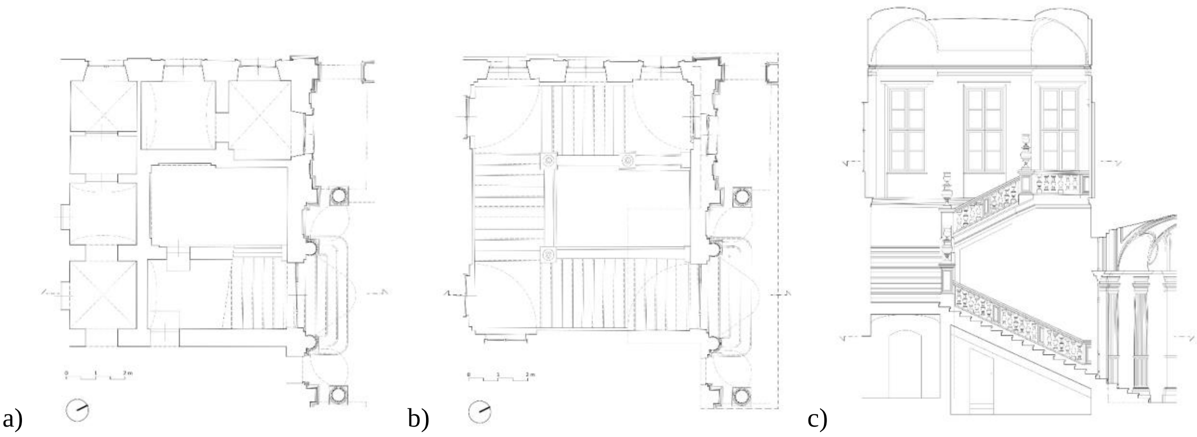


**Figure 4.** CAD drawings: a) Ground-floor plan; b) First-floor plan; c) Section. Source: Natta (2022)

### 4.2. Preliminary identification of the boundaries of three-dimensional modelling

After general considerations about the desired result, the physical limits for three-dimensional modelling were identified. Although the main focus was centred on the three ramps of the Grand Staircase, it was deemed appropriate to slightly expand the identified area to confer readability to the artefact and its contingencies. The digital model included part of the atrium that allows access to the Grand Staircase and part of the rooms on the first floor that are accessible through the Grand Staircase. To use the physical model and with particular reference to its aim, extending the modelling to the vaulted covering system that completes the space hosting the Grand Staircase was not deemed necessary.

### 4.3. Representation scale, digital fabrication tools and level of detail

From a technical point of view, it was necessary to make complementary evaluations to influence multiple aspects of the physical model: the choice of representation scale, digital fabrication tools and material type, and the level of detail of the three-dimensional modelling. Specifically, the use of a 1:50 scale was deemed appropriate (also a coherent solution with the representation scale of the used two-dimensional drawings) in order to obtain a physical model that, on the one hand, would not require an excessive time for the fabrication process, and on the other would be able to provide a satisfactory level of detail. Although involving a partial formal simplification of the artefact, this choice also represented a compromise solution concerning the adopted digital fabrication tools.

Considering the model's geometry, the Cartesian FDM 3D printer Ultimaker 5S available at the MOD Lab Arch of the Politecnico di Torino – Department of Architecture and Design was chosen, capable of combining high detail precision with acceptable execution timing.

### 4.4. Draft early modelling

At this point, it was possible to complete an initial three-dimensional modelling phase in the RHINOCEROS workspace to restore the object of study through a schematic model capable of positioning the raw elements in space to be refined in a more time-consuming phase. For this purpose, the data previously aligned in the digital workspace was used: point cloud and two-dimensional drawings. Given the high complexity of the model, it was preferable first to create an undetailed digital model, which, while on the one hand was able to correctly arrange the dimensions of the constructive elements in space, on the other hand, functioned as a solid starting base through which conduct the subsequent phases of geometry refinement. From this perspective, NURBS (Non-Uniform Rational B-Splines) geometry was used, which was considered optimal in modifiability and adaptability.

### 4.5. Decorative apparatus complete modelling

The subsequent integrative modelling process was based on the profile curves derived from the two-dimensional drawings, making some partial simplifications where the geometry of the artefact was deemed excessively complex to the representation scale adopted for the physical model. It was considered essential to perform the digital modelling with a level of detail compatible with the limitations imposed by the adopted digital fabrication tools – such as the minimum layer height and minimum printable thickness – being aware that high 3D print resolutions inevitably entail a substantial increase in the time required for digital fabrication. In these terms, the choice of RHINOCEROS software was confirmed as an excellent solution, as this software is particularly suitable for constantly checking for parts that may be too thin to be printed (Figure 5). During this highly detailed modelling process, paying particular attention to periodically performing union operations of the so-called polysurfaces was necessary. Since this modelling was intended to function as a digital copy of a physical model made by 3D printing, it is essential to perform "clean" three-dimensional modelling, which is not afflicted by compenetrations of elements but consists of a single shell that can be recognised as representing the boundaries in the subsequent digital fabrication phase. Although, as illustrated in section 3.9, checking the meshes before the 3D printing process is still necessary, this operation can be facilitated in advance during the three-dimensional modelling stage.

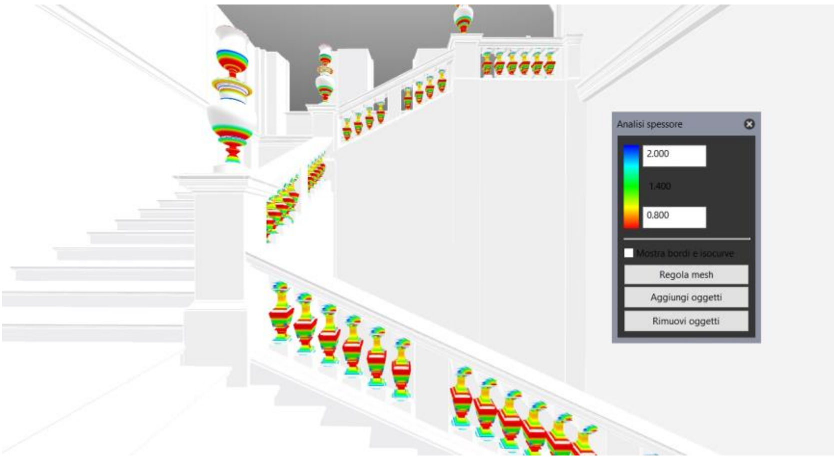
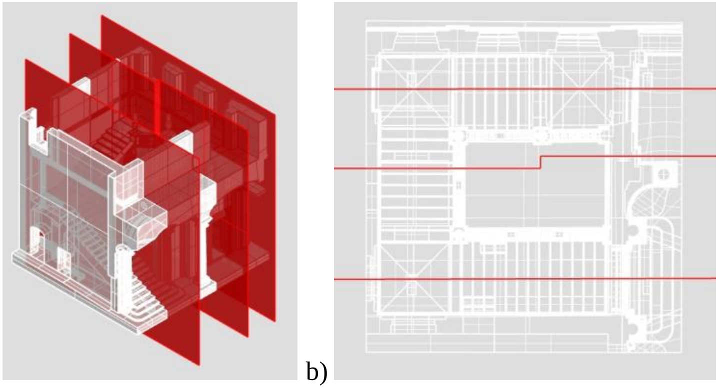



**Figure 5.** Perspective of thin shells thickness analysis in RHINOCEROS workspace. Source: Pupi (2024)

### 4.6. Digital model sectioning

In order to effectively communicate the constructive features of the Grand Staircase, it was chosen to explicate its constructive elements by breaking down the digital model into sub-shells using three vertical section planes (Figure 6). The first and third section planes intersect the first and third ramps of stairs on the axis, and consequently, the ramping barrel vaults with parallel generatrices to the perimeter walls; in this way, it is also possible to section the composite vaults (cross vaults) supporting the three landings along their axes of symmetry, thus intersecting the keystones. The second identified section plane was introduced to make the ramping barrel vault supporting the second ramp of stairs easily readable; in this case, the space is sectioned according to its transverse direction. The development of this section plane also had to provide for a shift in its position so as not to intersect the column present in the atrium. During this process, a further operation of cap the so-called poly-surfaces became necessary, obtaining solid and closed elements that constitute the macro-elements of the model. The described procedure, therefore, gives rise to a model consisting of four main blocks, which, on the one hand, restore the three-dimensional morphology of the Grand Staircase in its entirety, but at the same time, allow them to be separated, revealing its constructive composition (Figure 7).



a) b)

**Figure 6.** Digital model splitting using the three section planes: a) Isometric axonometry; b) Plan. Source: Pupi (2024)

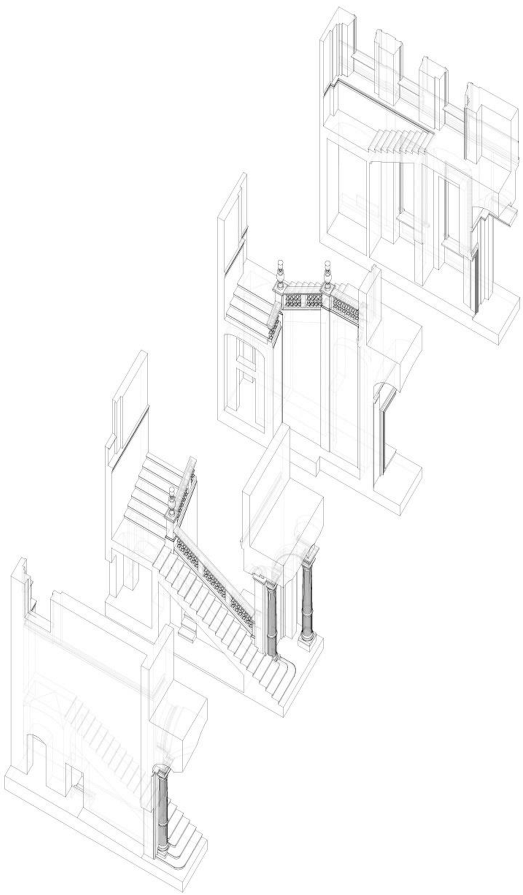


**Figure 7.** Overall, monometric axonometry of the four main blocks composing the model. Source: Pupi (2024)

### 4.7. Digital model assembly and discretisation system

As a final operation, before proceeding with the export of files destined for the digital fabrication, it was necessary to implement an assembly system in the model to make the final physical model easy to handle. From this perspective, the use of a system of cylindrical magnets with a diameter of 7 mm and a thickness of 3 mm has been considered appropriate (Figure 8):

- The chosen size and the force they apply make the assembly quite solid and allow easy disassembly.
- Since they have been embedded in the model shells, they are visually non-impactful.
- After a test on the tolerance to be used in the slot to be implemented in the digital model, they did not require glues but were assembled by a firm interlocking.

Furthermore, to optimise the 3D printing procedure, particularly delicate elements that would constitute a fragility in the printing process were identified (Figure 9). These elements, belonging to the inner shells, were isolated, constituting additional shells, printed separately, and assembled in post-production.

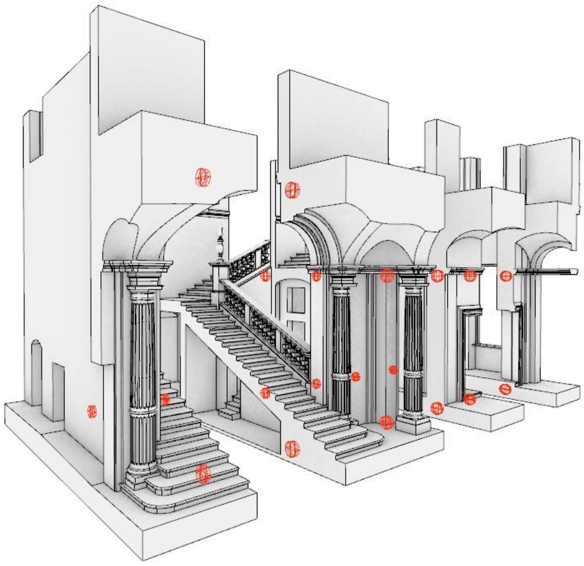


**Figure 8.** Filtered perspective with magnet junctions highlighted in red. Source: Pupi (2024)

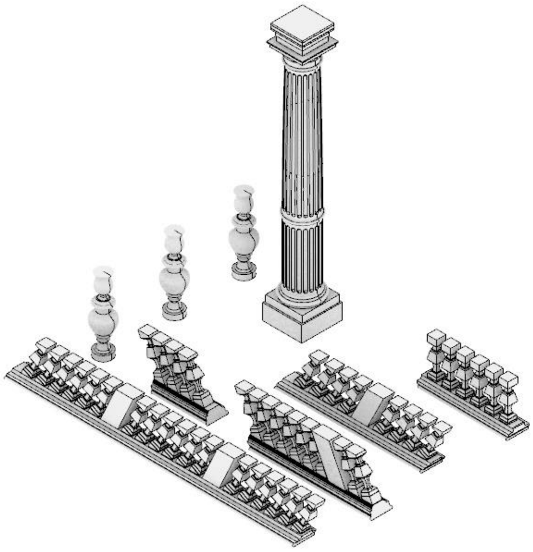


**Figure 9.** Isometric axonometry of isolated and distinctly printed elements. Source: Pupi (2024)

### 4.8. Digital model export, digital fabrication, and postproduction

Before definitively exporting the files, the geometries were transformed from NURBS to Meshes, assigning adequate tolerance parameters during the transformation process to preserve the curvatures of the vaults and other elements with curvilinear profiles (the maximum deviation detected was 0.1 mm). This operation allows for visualising the result of the geometrical transformation; in this sense, it is possible to refine the tolerance parameters to obtain a good balance between the perception of curved elements and the number of polygons in the model. Finally, it was possible to export the shells using the.*stl* format, classifying them accurately. Given the high complexity of the model, a preventive check of the Meshes was carried out to avoid possible errors in the 3D printing process. For this operation, the AUTODESK NETFABB PREMIUM 2023 software was used, which effectively tracked some issues with polygon stitching, which were easily repaired using the Extended Repair function. The fixed files were then imported into the ULTIMAKER CURA 5.2.1 slicing software, representing the last elaboration before the digital fabrication process. After a series of evaluations, it was decided to maintain the vertical orientation of the elements, except for the parapets, which were printed and rotated 180° in the xy plane. Although it was necessary to use supports extensively in the main shells, this choice was strongly influenced by the possibility of restoring with greater precision and accuracy the characters of the decorative apparatus of the Grand Staircase, avoiding sacrificing some details and making the result more aesthetically pleasing. Within the slicer, all the parameters aimed at controlling the printing process were set, for which white PLA material was entirely used, and the main ones are reported below:

- Layer height in the main shells is 0.2 mm.
- Layer height in secondary shells is 0.1 mm.
- Extrusion width is 0.35 mm.
- General print speed is 70 mm/s (with appropriate slowdowns for the shell's perimeters and first layer).
- Infill density is 8% (100% for secondary shells).
- Extrusion temperature is 210°C.
- Maximum support overhang angle is 60°.
- Support density is 15%.

The printing process required about six days, using about 1500 g of white PLA. At the end of the digital fabrication process, during the post-production phase, the physical model got a manual process of support removal, which was removed without great difficulty, thanks to the fact that a parameter for not welding the supports to the main shell was set in the slicer (z-upper support distance of two-layer, z-bottom support distance of one-layer). This operation was followed by assembling the magnets directly fitted into the cavities provided during modelling. Lastly, the secondary shells printed separately were integrated into the physical model using cyanoacrylate glue.

## 5. Achieved results

The communication of the spatial system of the Grand Staircase can take advantage of the continuum between virtual and physical: starting from an accurate NURBS digital modelling carried out in RHINOCEROS, the adopted workflow allowed translating into physical form the information related to the constructive and structural aspects of this architectural masterpiece, offering a dynamic experience for the public who can explore the physical model both in its entirety (Figure 10a) and in its separate sections (Figure 10b).

One of the main objectives of this research was to make the construction system used in the design of the Grand Staircase understandable, explicit and readable. In this sense, the physical model proved to be a highly performant tool, capable of restoring not only the overall three-dimensional morphology of the work but also able to offer the possibility of exploring its structural composition through its constituent elements.

Thanks to the choice of realising the physical model through FDM 3D printing, it was possible to reproduce the Grand Staircase with good fidelity and a good level of accuracy concerning the level of detail assumed during digital modelling, allowing users to appreciate its complex geometry.

a. b.

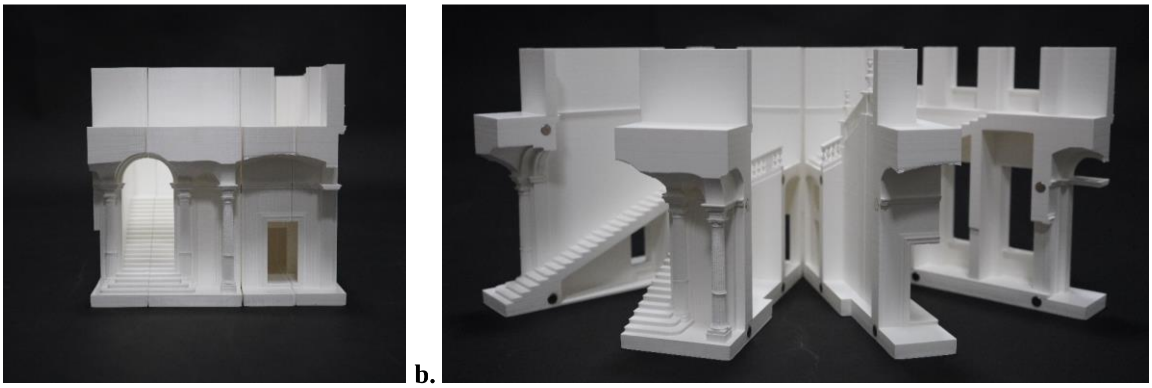


**Figure 10. a.** Whole physical model; **b.** Separate sections of the physical model. Source: Pupi (2024)

A particularly relevant aspect of the physical model is the possibility of appreciating the reinforcing arches, which are fundamental elements to ensure the stability and solidity of the entire structure. These elements, often hidden from view or difficult to understand in two-dimensional representations, have been made explicit and readable in the model, allowing users to note their importance and strategic arrangement within the artefact.

Moreover, the model has made it possible to almost entirely reproduce the decorative apparatus of the Staircase, restoring the ornamental elements that enrich the architectural masterpiece. Thanks to digital fabrication, it was possible to reproduce thin and refined details, such as the moulding system and the conformation of the parapet's abutments, allowing users to appreciate the work of 18th-century artisans.

A fundamental aspect of this research was to make the overall Grand Staircase constructive system accessible to a heterogeneous audience, including those who do not have specific training in the field of architecture. Thanks to the tangible and three-dimensional nature of the physical model, even inexperienced users can intuitively and engagingly explore and understand the staircase's constructive and structural aspects.

An additional value of this project lies in its potential for enhancing and disseminating cultural heritage: the physical model of the Grand Staircase of the Birago di Borgaro Palace can potentially be exhibited in museum contexts or cultural events, becoming a form of knowledge transmission capable of attracting the interest of a broad audience. Furthermore, thanks to its portable and easily replicable nature, the model can be shared and disseminated in various locations, contributing to the promotion and knowledge of this valuable architectural artefact.

## 6. Limitations, application potential, and conclusions

The creation of a scale physical model of the Grand Staircase of the Birago di Borgaro Palace, obtained through FDM 3D printing from a NURBS digital model created in RHINOCEROS, represents a notable achievement in communicating the constructive aspects of this artefact. The contribution analyses how the physical representation of the built space can become an expression of layered and sedimented information, lending itself to the communication of knowledge even to a non-expert audience.

However, it is important to recognise the limits and potentials of this approach in order to further improve its effectiveness in the communication of architectural heritage.

One of the main limitations of using FDM 3D printing to realise the physical model lies in the resolution and precision of the reproduced geometries. Although this additive 3D printing technique offers valuable advantages in terms of flexibility and contained costs, the quality of the printed surfaces and the restitution of architectural details may be inferior to other digital fabrication techniques, such as stereolithography.

FDM 3D printing imposes some limitations on the choice of materials, which can affect some aspects of representation, such as the surface finishes of the original work. This aspect could limit the ability of the physical model to fully communicate the material characteristics and construction choices. From this perspective, an alternative may be represented by subtractive digital manufacturing processes, such as CNC milling (Ronco, 2021).

Despite these limitations, the potential offered by this approach is remarkable and deserves to be further explored. The possibility of translating a highly detailed digital model into a tangible physical representation lends itself to a multidirectional experience through its observation. Furthermore, from a perspective of accessibility and inclusiveness, the realisation of the model could include particular precautions – particularly regarding the more thin and fragile elements – to allow a tactile experience (Spallone et al., 2023).

A further potential of this approach is the possibility of creating physical models at different scales, allowing the exploration of the work from different perspectives and adapting to the potential needs of different exhibition or educational contexts. In the proposed methodology, the representation scale of 1:50 was chosen as a compromise solution between the overall size of the physical model, the level of detail that can be afforded by high-resolution FDM 3D printing technology, and digital fabrication time. This choice, albeit to a minimal extent, involved some simplifications regarding the profiles of some mouldings and some adaptations due to the need to conform slender or thin elements to the requirements of digital fabrication. From this perspective, the fabrication of a physical model on a different scale, such as 1:20 or 1:10, could allow a more in-depth analysis, especially regarding the decorative apparatus of the Grand Staircase.

The combination of the NURBS digital model and the physical model production allows for further layering and sedimentation of information within a single representation. The integration of innovative XR (eXtended Reality) digital technologies could further enrich the users' experience, overlaying additional information onto the physical model or allowing for virtual exploration of the digital model (Spallone et al., 2021):

- The application of AR (Augmented Reality) could use the physical model as a three-dimensional marker and overlay both additional technical information, such as details regarding the employed construction techniques, and additional social information, such as the uses and customs of the era related to the ceremonial of entrance in which the Grand Staircase played a prominent role.
- The application of VR (Virtual Reality) could instead be used for remote fruition of architectural heritage. The digital model could be further elaborated through texture mapping techniques aimed at rendering not only the geometry and morphology of the Grand Staircase but also its highly characterised real perception through frescoes and fine materials. Moreover, complementary annotations and information could also be overlaid during the immersive experience in a completely virtual environment.

In conclusion, through a representative case study, the contribution analyses how combining digital and physical models can become a powerful tool for communicating complex information to a highly heterogeneous audience. The work carried out intends to stimulate research and experimentation perspectives in the field of communication of architectural heritage, and it is essential to continue exploring and refining the techniques used and the consequent methodology employed in order to fully exploit the potential offered by the integration of different types of digital and physical representation.

## 7. Acknowledgements

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# Interactive dissemination of 20th century tourist heritage: Integration of ICT for an immersive experience through interior design in Puerto Rico

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***Abstract***

*Interior design in built cultural heritage has undergone a significant evolution in the late twentieth century, going from being contemplative goods of history to elements that require aesthetic, functional and technological adaptation for their conservation and commercial and institutional use. For its part, contemporary architecture is influenced by the development and integration of digital technologies in its processes, which drives a transformation in this field. While in the field of architectural heritage, the importance of disseminating and promoting these assets is highlighted. The dissemination of the architectural and touristic heritage of the 20th century has become a fundamental aspect of the preservation and promotion of cultural heritage. Today, tourism plays a crucial role in the dissemination of this heritage, being the undisputed protagonist in the dissemination of cultural activities and the reception of the public. It has become an essential tool to make known the architectural, historical and cultural richness of different places, attracting local and foreign visitors. Puerto Rico, an island in the Caribbean with a rich cultural heritage history that has witnessed the emergence of the sun and beach tourism phenomenon, and as a result of this, a participant in the development of the hotel industry of the time, allows us to study its hotel architectural heritage developed in the twentieth century and that certainly contributes to the historical reconstruction of them today. It will be the basis for the development of a proposal for the use of Information and Communication Technologies (ICT) for the dissemination of the architectural heritage of tourism in the twentieth century to society.*

*This research proposes the use of Revit 2024 for the planimetry survey and Twinmotion 2023 software for 3D modelling and historical representation of the Normandie Hotel in Old San Juan. With the purpose of developing a digital historical archive for a possible informative proposal in the Google Arts & Cultue platform, promoting the historical diffusion of the architectural heritage in the visitors of the building and society in general.*

***Keywords****: hotel architecture, interior design, hotel Normandie, architectural heritage, tourist heritage, ICT.*

## 1. Introduction

The present research is framed in the context of previous studies on 20th-century hotel architectural heritage in Puerto Rico and its relationship with interior design, with the objective of exploring how Information and Communication Technologies (ICT) can be effectively implemented in heritage preservation projects in historic hotels in Puerto Rico.

The architectural heritage of 20th-century hotels in Puerto Rico has been the object of interest due to its historical and cultural value. The architecture of these hotels reflects diverse styles and trends of the era, from Art Deco to the Modern Movement, and has witnessed significant moments in the island's history. In addition, the interior design of these hotels has been carefully designed to offer unique experiences to their guests, incorporating elements of the local culture and international influences of the time.

Previous research, such as that conducted by Silva (2015), has analysed the relationship between architectural heritage and interior design, highlighting the importance of considering both aspects in conservation projects. However, the integration of ICT in these projects still represents a little-explored area in the context of hotel heritage in Puerto Rico.

Therefore, this research seeks to fill this research gap by proposing a project that uses ICT as a tool for the preservation and dissemination of the architectural heritage of 20th-century hotels in Puerto Rico. It is intended to develop an interactive digital platform that allows visitors to explore these historic hotels virtually, learn about their history, architecture and interior design, and understand their cultural importance. In addition, we will analyse how these technologies can contribute to the conservation and promotion of these spaces, facilitating their accessibility and dissemination to a wider audience, both locally and internationally.

In summary, this research is part of the continuity of previous studies on the hotel architectural heritage of the twentieth century in Puerto Rico and its interior design. The implementation of ICT as a research project for heritage preservation represents a step forward in the valuation and dissemination of these historic spaces, as well as in the incorporation of technological tools for their conservation and appreciation.

## 2. Aims and objective

The objective of this research is to document and disseminate the architectural-cultural legacy of Puerto Rico nationally and internationally through the use of digital tools (ICT), with the purpose of developing a historical and interactive archive of the Normandie Hotel in Puerto Rico, thus facilitating access to this emblematic building through Information and Communication Technologies (ICT). The main objective of this project is to generate heritage awareness and to bring the population closer to the importance of preserving and valuing the tourism heritage of the 20th century on the island through innovative technological resources. Being the architectural and historical heritage of the twentieth century in Puerto Rico, a goal of dissemination through ICT, thus causing cultural tourism for Puerto Rico from a heritage perspective.

## 3. Methodology

Through the analysis of the use of interior design and its relevance in the hotel architectural heritage of the twentieth century, the collection of historical data has been carried out to identify several case studies. These cases have been selected following specific evaluation criteria for their implementation in Information and Communication Technologies (ICT). In this context, the Normandie Hotel in Puerto Rico has been used as the main case study.

The methodology applied in this research has made it possible to achieve the objectives set, demonstrating the importance of interior design in the promotion of tourism heritage. This research is structured in five clearly defined phases that have facilitated its development. Therefore, this research is based on a scientific process, initially through a bibliographic review that includes academic, historical and tourist sources related to the topic in question. Subsequently, we proceeded to data collection, gathering relevant information on historical buildings, cultural events and the architectural heritage of the island. The selection of case studies is carried out by identifying representative heritage sites of the 20th century in Puerto Rico, following established criteria based on their historical, architectural and tourist relevance. In the analysis and interpretation stage, a comparative study is carried out between the virtual representation and the physical reality of the heritage sites to evaluate the fidelity and usefulness of the virtual tours. In addition, the historical interpretation is deepened to analyse the cultural and touristic impact of the diffusion of 20th-century heritage in Puerto Rico through Information and Communication Technologies (ICT).

These methods and procedures will guide the systematic and rigorous development of research on the tourism heritage of the twentieth century in Puerto Rico, allowing adequate collection, analysis and interpretation of data to achieve the proposed objectives.

## 4. Interior design and hotel architectural heritage of the twentieth-century

In the context of the 20th century, interior design and architectural heritage have played a crucial role in shaping the cultural and aesthetic identity of several emblematic buildings. This period was characterised by a profound evolution in architectural trends and styles, reflecting the social, political and technological changes of the time. Interior design, as an integral part of architecture, has been a determining element in the creation of spaces that not only fulfill practical functions but also convey symbolic and aesthetic meanings. Throughout the twentieth century, different currents and approaches to interior design have developed and left a definitive mark on the architectural heritage, contributing to the diversity and richness of the built legacy of that era.

Interior design, in its different manifestations throughout history, has become a cultural heritage in itself. This is evident in the evolution of styles and trends that have marked the architecture and interior design of the twentieth century, reflecting the social, technological and cultural changes of the time. In this sense, the implementation of an interdisciplinary approach that links architectural heritage and interior design is presented as a key strategy for the preservation and dissemination of the cultural legacy of this historical period. Only through this comprehensive approach will it be possible to guarantee the conservation and enhancement of these heritage assets in a sustainable manner.

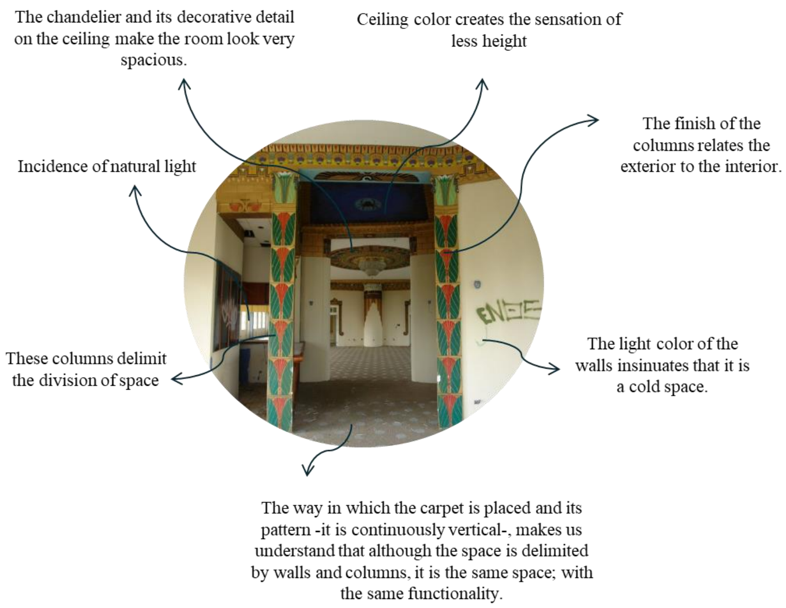


**Figure 1**. Illustration of the Normandie Hotel's Gold Room illustrating how data can be collected through interior design. Source: Interior Design and Heritage Mutual Contributions (Torres Rosario et al., 2021).

Interior design and hotel architectural heritage have become highly relevant topics in the field of architecture and tourism. This is due to the significant evolution in the styles and approaches used in the creation and preservation of emblematic hotels that represent an invaluable architectural legacy.

Due to the configuration and preservation of the architectural heritage of the twentieth century, at the end of the last century, the vision of cultural heritage was reformed, going from being contemplative assets of history to elements that integrate interior design in spaces (Silva, 2015). The analysis of the links between built heritage and interior design has made it possible to determine that the attributes of the building and the conditioning factors of interior design are closely related in the current context. This implies that the conservation of heritage assets should consider not only the architectural aspects but also the integration of interior design as an integral part of the preservation of the spaces (Silva, 2015). Therefore, hotels and historic buildings should not only be restored and preserved in their original architecture but also in their interior design, thus ensuring the authenticity and stylistic coherence of these spaces that encapsulate the history and culture of an era. The integration of the two thus becomes a powerful tool for keeping history alive and promoting appreciation of the cultural legacy in tourism and contemporary architecture; an example of this can be seen in Figure 1, where the Golden Room of the Normandie Hotel is used for data collection.

"*Given the new postures of society, today, it acquires new habits and behaviours, and with it, new needs are presented. This social-cultural transformation involves our past, our history, our origin. Thus, built heritage and societies are immersed in a state of permanence and innovation*" (Silva, 2015). In this sense, the implementation of an interdisciplinary approach that links hotel architectural heritage and interior design is presented as a key strategy for the preservation and dissemination of this cultural legacy. This is reflected in the incorporation of design elements that highlight the functional, aesthetic, historical, and future uses in a way that reflects the social, technological and cultural changes of the time in a respectful way with the properties.

Consequently, the interior design and architectural heritage of 20th-century hotels represent a rich and diverse history in which styles, trends, functionality and experiences converge. These hotels are or were not only places of lodging but also cultural monuments that reflect the creativity, innovation and history of an era. Their preservation and care continue to be fundamental to understanding and valuing the evolution of architecture and design in the context of tourism and hospitality.

## 5. ICT in the hotel architectural heritage of the twentieth century

In the field of 20th-century hotel architectural heritage, the implementation of Information and Communication Technologies (ICT) has revolutionised the way in which this historical legacy is preserved, promoted and disseminated. ICTs have made it possible not only to digitally preserve the architecture and interior design of emblematic hotels of this era but also to create interactive experiences and virtual tours that bring visitors closer to the history and beauty of these spaces. Therefore, the integration of digital tools in the hotel architectural heritage of the twentieth century has opened new possibilities for the enhancement and cultural tourism, facilitating access to historical sites in an innovative and educational way.

Despite advances in the use of ICTs for the preservation and dissemination of cultural heritage, the development of specific tools for the enhancement of heritage buildings and historic urban landscapes has been a little explored area so far. As Agüero (2021)[1] points out, this area represents a challenge that demands solid theoretical support that allows it to advance in its implementation in an effective way. The integration of digital technologies such as 3D modelling, augmented reality and interactive platforms in the field of architectural and urban heritage still presents opportunities for improvement and deepening. It is necessary to generate a conceptual and methodological framework to guide the development of innovative technological solutions capable of highlighting the historical,

[1] "*However, the development of technologies for the enhancement of heritage buildings or historic urban landscapes has been a very little explored area and requires theoretical support that allows further progress for its implementation in this area*" (Agüero, 2021).

cultural and aesthetic value of these heritage assets in a way that is accessible and attractive to the public. Only through this interdisciplinary effort will it be possible to consolidate the use of ICTs as key tools for the preservation and dissemination of the architectural and urban legacy of historical importance[2].

Recently, we are witnessing a remarkable increase in the implementation and use of ICT in the field of cultural heritage. This situation, at the same time, is reinforced by the exponential growth of technologies and cases of applicability in the cultural sector (Ruiz Torres, 2017).

The tools developed by information technologies offer the possibility of actively involving communities from the first steps of any process, not least those related to the protection of cultural heritage. In recent years, the impact of ICT on the cultural sector has grown exponentially. New technologies offer innovative alternatives to create new experiences for a constantly evolving public. Virtual Reality (VR) and Augmented Reality (AR) are positioned as two of the main players in this line that we call 'culture + technology'. Building Information Modelling (BIM) is a collaborative working methodology used in the architecture, engineering and construction industries to create and manage digital representations of the physical and functional characteristics of buildings and other structures as defined (Baraibar et al., 2022), as well as exploring the implication of BIM as a use of collaborative and 3D modelling tools to optimise the design, construction and maintenance of buildings.

In the field of exhibition, the irruption of information and communication technologies offers museums a new opening in the field of interpretation, which can be translated in various ways. In this sense, museums have a significant role to play in the collection of digital images, particularly from different sources, to present and explain the cultural and natural heritage while at the same time having the possibility of communicating with a much wider and more diverse public. On this path, we highlight, as an example, the curricular line defined by Unesco in the museum field, where the main fields of activity of the profession are defined as those represented in the various international committees of ICOM: Specialists in audiovisual media and new technologies.

In this context, new technologies applied to tourism allow better access and a closer approach to these cultural assets, becoming elementary tools for their dissemination (Larrea et al., 2012). Information technologies allow their processing and transmission, mainly through computers, the Internet and telecommunications (Larrea et al., 2012). Advances in virtual reality, for example, enable immersive tours of historical and archaeological sites from anywhere in the world, offering users a unique sensory experience. Likewise, mobile applications and online platforms facilitate access to interactive tourist guides enriched with historical and cultural data, which enhance the understanding and appreciation of these heritage assets. This convergence of technology and tourism not only democratises access to culture but also contributes to the preservation and enhancement of these assets for future generations.

True technological transformation goes beyond simply having new tools, as pointed out by Larrea et al. (2012). It is also about the ability to manage and apply these technologies effectively, which generates diverse territorial realities in the field of cultural tourism. The adoption and appropriate use of Information and Communication Technologies (ICT) can create enriching and sustainable tourism experiences in certain regions, while in others, there may be a digital divide that limits access to these advantages. This phenomenon can be clearly observed in tourism destinations where digital infrastructure and technology training are robust, allowing the creation of interactive applications, virtual tours and immersive experiences for visitors. In contrast, areas with poor connectivity and limited resources may face difficulties in taking full advantage of the opportunities offered by ICT in the field of cultural tourism. Therefore, the real transformation lies not only in the availability of advanced technologies but also in the capacity of communities and destination managers to implement them effectively and equitably, thus ensuring the cultural and tourism development of different territories.

[2] "*Tourism-oriented mobile applications and the implementation of augmented reality for the enhancement of architectural heritage can become a new channel that enables tourism information, development and marketing in a more efficient and innovative way*" (Agüero, 2021).

The integration of ICTs in the field of tourism and heritage becomes an essential means to disseminate the historical, cultural and social value of these works and manifestations, as pointed out by Larrea et al. (2012). These allow a wide and accessible dissemination of information, facilitating awareness and understanding of the importance of these cultural assets. Through mobile applications, online platforms and augmented reality tools, visitors can access narratives enriched with historical and contextual data while exploring monuments, archaeological sites or cultural manifestations. This digital interaction fosters a deeper appreciation of cultural and heritage diversity while promoting preservation and respect for these manifestations that enrich our collective identity.

This topic has been the subject of reflection since the 20th century, and today, cultural heritage is facing a changing and complex context in which precepts on a global scale must be considered. In this scenario, cultural heritage management acquires crucial importance when trying to adapt enhancement initiatives to meet the demands of the macro environment (Lerrea et al., 2012). ICTs are presented as essential tools in this work, allowing a more efficient and dynamic management of heritage. Through geographic information systems, interconnected databases and online platforms, heritage managers can effectively monitor, preserve and promote the cultural assets of a city. These technologies facilitate the identification of areas at risk, the planning of conservation actions and the dissemination of cultural wealth in a more accessible and attractive way for residents and visitors. Thus, the combination of ICT and cultural heritage destinations seeks to adapt to a constantly evolving global environment while enriching and strengthening a city's cultural identity for future generations.

In conclusion, the relationship between ICT and cultural heritage in heritage environments has evolved to become a fundamental pillar in the management and dissemination of our cultural legacy. They offer powerful tools to adapt heritage enhancement initiatives to current demands. The combination of geographic information systems, interconnected databases and online platforms not only enables more efficient heritage management but also enriches the experience of residents and tourists by offering a deeper and more accessible understanding of a city's history and culture. This synergy between ICT and cultural heritage is not only essential for the preservation of our cultural identity but also contributes to the sustainable development of cities, promoting responsible tourism and the appreciation of our cultural diversity.

## 6. Hotel Normandie, Puerto Rico – Case study

The Normandie Hotel, shown in Figure 2, was inaugurated on October 10, 1942, in San Juan, Puerto Rico. It has a rich and fascinating history, and it has been included in the National Register of Historic Places since 1980[3]. It stands out for its design, inspired by the French ocean liner SS Normandie. Between 1939 and 1942, artists from France, Spain, the Dominican Republic and Puerto Rico participated in the hotel's ornamentation, the cost of which was significant. Throughout the years, it has witnessed changes and transformations, from being an emblematic place of tropical nightlife in the 1930s to facing challenges and changes in its structure and use over time. Despite its ups and downs, the Hotel Normandie remains an important symbol of Puerto Rico's architectural and historical heritage, with a presence that evokes nostalgia and timeless beauty in the city of San Juan.

This building is an example of Art Deco on the island, being one of the few luxury hotels of the time; this is rooted in the celebrations of social and political activities that made this building one of great historical and sentimental value for several generations of Puerto Ricans. The forms of the Normandie represent movement, modernism and technology, while its interior was decorated with Egyptian-inspired motifs: lotus flower capitals, murals with Egyptian scenes and friezes with zigzag motifs, all polychrome and adorned with gold leaf details. The main halls were decorated with polychrome plasterwork, tiles, lamps, mahogany furniture, murals, mirrors and all kinds of ornamentation in the Art Deco style. Thanks to the Salón de Oro, Salón de Plata and Salón Victoria, it was eventually compared to a palace (Puerta de Tierra, 2024).

[3] Properties of Puerto Rico National Registry of Historic Places National Park Service U.S. Department of the Interior State Historic Preservation Office Office of the Governor San Juan, Puerto Rico Revised. (2012).

 


**Figure 2.** Exterior of Hotel Normandie 2011. Source: Historical Building Drawing Society of Puerto Rico.

The building has a triangular floor plan with rounded corners, consisting of seven floors organised around an inner courtyard and a basement. The lobby was small and included the restaurant. On the first level, there was a swimming pool -which was eventually covered-, commercial areas, storage rooms, rooms, stairways and elevators in the northeast and southeast corners. The sixth floor contained a ballroom known as the Salón de Oro and a banquet hall known as the Salón de Plata. The same floor contained a dining room with a kitchen and a large hall that was used as a casino. Finally, the seventh floor contained large rooms, a kitchen and a dining room (Puerta de Tierra, 2024).

Throughout the 1960s, the Normandie was closed and abandoned, and by 1976 it was foreclosed. However, it was restored in the early 1990s, and several years later closed its doors again due to damage caused by Hurricane Georges. It was not until 2005 that it reopened its doors after an extensive and costly remodelling. This brought with it the installation of two large aquariums in order to give a touch of the sea to the new Atrium Café; in addition, in all rooms, guests had a work area with a desk and broadband and internet connection (Puerta de Tierra, 2024).

Certainly, the Normandie had many days of glory since its opening, as well as many more of tragedy and eviction. Today, the Normandie remains closed after several attempts to open, and some projects are in the pipeline to give new life to this emblematic building on the island. Given the several reopenings and remodellings to keep the hotel adapted to the new trends of the time during the time of opening, the hotel underwent some significant aesthetic modifications that allowed it to maintain the initial essence in a timeless way. These modifications have allowed us to gather historical and aesthetic data and, of course, to understand the functionality of the spaces beyond their initial configuration.

Within the framework of this research and preservation project of the hotel architectural heritage of the 20th century, the Normandie Hotel in Puerto Rico becomes an emblematic case study. Through the use of tools such as Revit 2024 for 3D modelling and planimetric survey, Softword Twinmotion 2023 for real-time visualisation and simulation, and the creation of a digital historical archive through the Google Arts & Culture platform, we seek not only to document and preserve the history and unique architecture of this hotel but also to disseminate its cultural legacy in an innovative and globally accessible way. This integrated approach of advanced technologies and digital platforms will enable a detailed and immersive representation of the Hotel Normandie, preserving its historical and architectural significance for present and future generations.

Although it is currently closed, this project will make it possible to maintain a digital historical archive of the building and thus provide an effective guide for its future conservation as soon as a rehabilitation and restoration proposal is proposed, focused on maintaining its current use or modifying it for a new use.

## 7. Preliminary results - preservation project (ICT)

The preliminary results of the ongoing research in relation to the heritage preservation project of the Normandie Hotel in Puerto Rico highlight the potential of Information and Communication Technologies (ICT) in the documentation and exhibition of the hotel's architectural heritage of the twentieth century. This study has implemented the use of tools such as Revit 2024, Twinmotion 2023 and the Google Arts & Culture platform in order to develop an interactive digital historical archive that will allow a detailed virtual exploration of the hotel, its architecture and interior design.

Through the collection of relevant information on the Normandie Hotel, the proposal is to develop a historical heritage archive using the Google Arts & Culture platform that will allow it to reach the whole society so that the Hotel can be accessed during a historical tour from its beginnings, its current situation of abandonment and possible rehabilitation of it in the future. Figure 3 shows a graphic proposal of what this proposal would look like if developed under the aforementioned platforms.

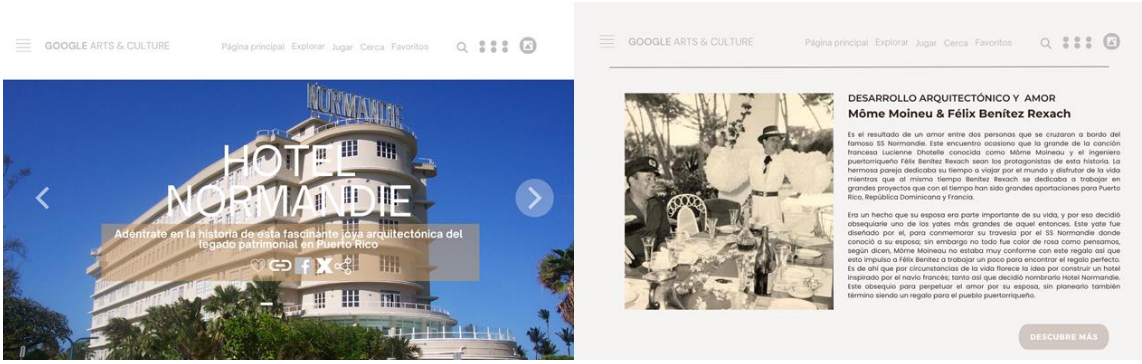


**Figure 3**. Visual proposal of the historical archive of the Normandie Hotel. Own elaboration.

Given the main idea of making a historical tour of the Normandie Hotel to know who its founders were, how it came about and related issues, we proceed to Figure 4, which contains a graphic representation of a timeline that will guide visitors to understand the history of the property and continue this through images of the interiors of the same, revealing the transformations and interior modifications that has experienced the property during its time in operation, as well as the natural modifications that has the mime due to its state of abandonment due to its closure.

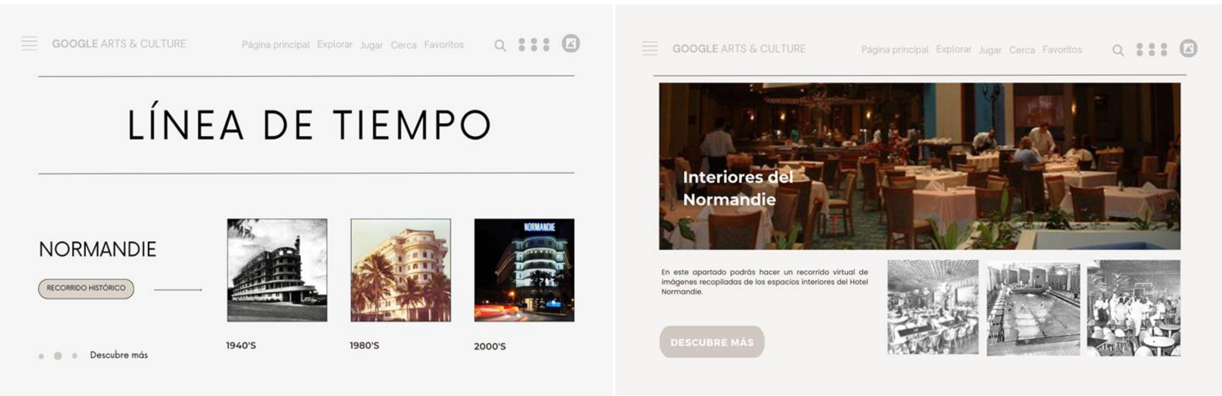


**Figure 4**. Visual proposal, photographic and historical section. Own elaboration.

 

Moving forward in the development of this proposal, Figure 5 shows how two sections have been created to implement the use of software for the collection of planimetric data, the compilation of the initial state of the building and its transformations. This will make it possible to obtain an architectural file and database of the building, as well as to attract the participants to a virtual tour through a 3D representation of the building.

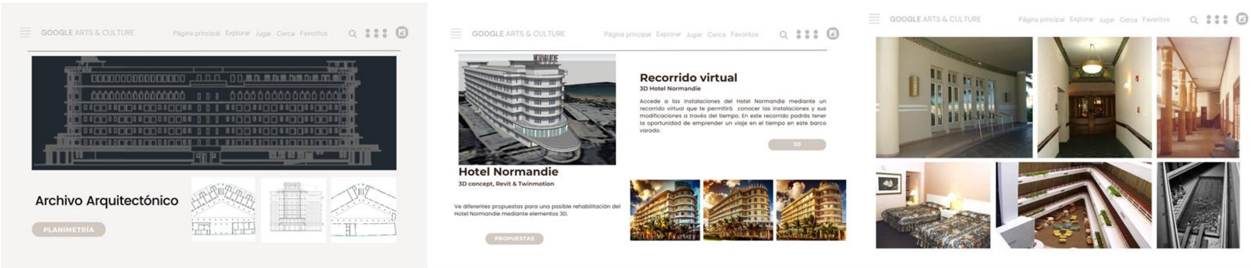


**Figure 5**. Visual proposal, architectural section, use of 3D software and interior data. Own elaboration.

Finally, in Figure 6, we can see three sections related to the exhibition and approach to heritage information such as the technical file related to the National Register of Historic Places to which it belongs since 1980, journalistic information, forums in which the property has been discussed and magazines, posters and other relevant graphic information that allows us to continue to expose its architectural, historical and heritage value. Last but not least, a section is created in which you can see the hotel's location for all those who are in other countries and wish to locate this wonderful property.

This graphic proposal will serve as a guide to meet the objectives set out in this research and thus offer a heritage legacy for all and lasting.


**Figure 6.** Visual proposal, heritage section, historical archives, location and navigation. Own elaboration.

## 8. Conclusions

The potential of ICTs, social networks, and digital tools related to heritage has been at the centre of the studies of many researchers since their origin, mainly related to their possibility of creating a virtual "showcase" or offering parallel or alternative experiences to the heritage property. In these cases, the effects of ICT are considered highly positive in the process of strengthening cultural identity.

The preliminary results of this project have demonstrated the effectiveness and versatility of using BIM software for the collection and reconstruction of heritage properties. Likewise, the integration of Google Arts & Culture would certainly enrich the process of patrimonialisation of 20th-century hotel architecture, specifically the Hotel Normandie in Puerto Rico, by offering exhibition and interactive storytelling functions, allowing users to explore the history, interior design and architectural details in an immersive and educational way.

This innovative approach to her documentation and exhibition of the hotel's architectural heritage has yielded promising results in the valorisation and dissemination of the history and architecture of the Hotel Normandie. In the future, it will allow users to access this emblematic hotel virtually, explore its spaces, learn about its history and appreciate its interior design and modifications from anywhere in the world.

Therefore, these results suggest a great potential for the use of ICT, in particular through Revit 2024, Twinmotion 2023 and Google Arts & Culture tools, in the preservation and promotion of 20th-century hotel architectural heritage, not only for Puerto Rico but also in other similar historical and cultural contexts.

In conclusion, this research focused on 20th-century hotel architectural heritage, interior design and the implementation of Information and Communication Technologies (ICT) for its dissemination, preservation and conservation, specifically in the Hotel Normandie in Puerto Rico, has revealed the relevance and positive impact of the integration of these digital tools in the management of the architectural legacy. The combination of Revit 2024, Twinmotion 2023 and Google Arts & Culture has enabled detailed documentation, a visually appealing presentation and global dissemination of the Hotel Normandie, enriching the experience of virtual visitors and strengthening the cultural identity associated with this emblematic space. These findings underscore the importance of continuing to explore and leverage ICTs as allies in the preservation and valorisation of architectural heritage, not only as technological tools but also as a means to foster appreciation, knowledge and conservation of these architectural treasures for generations to come.

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# Study of visitor flows in heritage streetscapes based on counting people using motion-image sensors. The case of Valencia Cathedral (Spain).

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***Abstract***

*Historical centres are popular places for tourist visits. The public spaces that make up these urban areas are usually characterised by being narrow streets with difficult traffic and where, on occasions, vehicular traffic is restricted in favour of pedestrian traffic. This historic streetscape, together with the concentration of visitors that usually occurs in these areas due to the presence of important heritage assets and cultural attractions, often leads to situations of physical and psychological discomfort for both residents and visitors, and can even lead to episodes of saturation and occasional congestion with the obvious undesirable consequences for the heritage elements, for the recreational experience of visitors and even for personal safety. Knowledge of the visitor carrying capacity limits of a space is very useful information for local managers when planning and managing a tourist destination, especially when it involves historic centres where the cultural attractions are heritage assets of great significance not only architecturally and artistically, but also socially. Visitor carrying capacity studies make it possible to determine the suitability, size and way in which heritage elements and public spaces can accommodate a given number of people. It is therefore an extremely useful predictive tool. However, as these are highly dynamic spaces, it is necessary to have constant and updated information that allows decisions to be taken even in real time.*

*This work is based on the quantitative analysis and behavioural patterns of visitor flows in the surroundings of heritage buildings through the use of motion-image sensors. The methodology followed for this study is based on the use of CPF-SENSORs (model WTK10070) that count people but do not store the image. Subsequently, data processing was carried out to structure the results and obtain reliable, accurate and easy-to-interpret information. The experimental analysis of this methodology has been carried out in the streetscape of the Valencia Cathedral (Spain). The results confirm the validity of the method used and, regarding the case study, it should be pointed out that the preliminary data have made it possible to establish weekly and daily frequentation patterns, as well as peaks of critical frequentation that exceed the visitor carrying capacity of the Cathedral's streetscape coinciding with religious or festive celebrations.*

***Keywords:*** *visitor flow, sensors, visitors accounting system, historic centre, Cathedral of Valencia*

## 1. Introduction

Heritage attracts millions of national and international visitors every year, with cultural tourism constituting 39% of the tourism market (UNTWO, 2018). Moreover, in this segment there has been a growth trend in recent years, focused on urban areas with important historical centres where buildings and public spaces of great heritage value are frequent.

Historic city centres are the preferred places to visit for tourists in a city because they not only contain buildings that give cities a special character and identity, but also the streets, squares and roads through which people pass and where they experience the place (Historic England, 2018). In recent years, due to the high frequentation of these historic public spaces, pedestrianisation has become widespread in many cities in order to provide users (residents, visitors and commuters) with greater comfort (physical, physiological and psychological well-being) and safety.

Many cities could not have imagined what a massive influx of visitors would mean in the short term and having their historic centres under enormous pressure (García Hernández et al. 2017). It should be noted that the vast majority of them were not adequately prepared to receive these volumes of people, nor to cope with the potential impacts on heritage elements, the historic urban landscape and the resident population itself. The often uncontrolled growth of tourist visits to historic centres is, in fact, a critical problem all over the world today. One of the first and most notable and visible manifestations of the lack of development and application of planning and management tools for public use is the high number of people in the public space, causing, at first, problems of punctual congestion and generalized saturation. It should be mentioned that the overcrowding of people, in addition to generating a problem of comfort, can constitute a threat to people's safety. Subsequently and in the medium and long term, more far-reaching social problems are identified (gentrification, touristification, etc.) which have been widely addressed in the scientific literature, and which the World Tourism Organisation (UNTWO, 2004; 2018) and other international institutions such as the European Parliament (Peeters et al., 2018) have been warning about for some time.

Planning and management of the public use of heritage elements and their surroundings is therefore a key element, absolutely necessary to guarantee the sustainability of the preservation of heritage elements, to offer a satisfactory experience to the users of these sites, and also so that heritage can contribute to a sustainable socio-economic dynamization of the place. Addressing these issues requires rigorous scientific analyses that allow, in a first phase, the implementation of practical tools such as visitor carrying capacity, visitor flow management, and the design of mobility patterns, as they have an outstandingly useful predictive character.

Knowing the visitor carrying capacity of public spaces and cultural assets themselves and how to manage it is fundamental and useful information in determining the physical and psychological comfort of visitors, to avoid immediate and cumulative impact on heritage elements and to maintain acceptable levels of social sustainability in tourist districts. Visitor carrying capacity studies are well described in the scientific literature, especially for indoors spaces (e.g. Viñals et al., 2013; 2014; García Hernández et al., 2014; Santos and Pena, 2014). For open cultural spaces, the methods of analysis are more complex; however, there are also numerous studies, especially linked to archaeological sites (e.g. García Hernández et al., 2011; Viñals et al., 2013; Makhadmeh et al., 2020), and also to tourist destinations as a whole (e.g. Costa and Van der Borg, 1988; Canestrelli and Costa, 1991; Camatti et al., 2020; Lopes, 2021). However, there are not so many works that address the calculation of visitor carrying capacity in urban public spaces, although those by García Hernández (2003), Zubiaga et al. (2019), Orozco Carpio et al. (2023) are noteworthy, among others. These studies provide optimal theoretical estimates of space occupancy, but they must then be completed with the application of tools that allow the management of estimated carrying capacity. The use of Geographic Information Systems (GIS) in the estimation and management of visitor carrying capacity has proven to be a fundamental tool in urban recreational environments and especially in natural areas (e.g. Höfer et al., 2014; Jurišic et al., 2023). Among the tools for visitors management, the analysis of the volume of mobility flows and spatial distribution of visitors and mobility patterns, both interrelated, stand out.

The study of the volumes of mobility flows and spatial distribution of visitors has a double component: the first focuses on determining the quantity of people that make up the flow, and the second analyses the typology and characteristics of the spaces through which people pass. In order to address these studies, it is necessary to use people counting systems and, also to know in detail the characteristics of the streetscape. The scientific literature, especially in recent years, offers numerous studies that analyse the different counting systems (Nordback et al., 2016; Erkkonen and Kajala, 2021; Read et al., 2021; Sevtsuk, 2021) that are applied according to the characteristics of the place to be analysed. There is also a wealth of information promoted by private companies. There are also interesting manuals from local authorities on how to manage people flows in public spaces in their cities (e.g. City of Melbourne, 2020; City of Minneapolis, 2020; Transport of London, 2010). These studies serve to solve medium- and long-term urban planning problems that profoundly affect the daily life of urban centres. However, as these are highly dynamic spaces, it is necessary to have constant and updated information that allows decisions to be taken even in real time in order to be able to resolve specific situations of congestion and saturation and even emergencies.

This research focuses on the analysis of analysis of visitor flow count in the streetscape surrounding the Cathedral of Valencia (Spain) through the use of video-cameras. This is the first time that this system has been implemented in the historic centre of the city and that accurate data has been obtained on the people who pass through this public space. A cloud-based platform has been developed to facilitate the collection, processing and management of pedestrian data. The information is collected through the deployment of motion-image sensors (video-cameras) and the data is processed through a series of quantitative indicators, which aim to evaluate the volume of visitors and identify possible risk factors related to the overcrowding of people. This is intended to contribute to the development of the Sustainable Development Goals of the United Nations 2030 Agenda, in particular Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable.

## 2. Methodology

The counting of the people who make up the flows can be addressed by using different procedures. Thus, we have those that are carried out manually, or those that incorporate electronic counters operated by people, and also infrared sensors. Others are RFID (Radio Frequency Identification) systems that allow individualized tracking of people through cards or tags, but require people to carry RFID devices. There are also those based on the analysis of telephone network traffic by determining the density of connected devices in a specific area at a given time. There are also WI-FI or Bluetooth Tracking systems that follow the movement of mobile devices as they connect and disconnect from different mobile phone antennas. In addition, there are 2D and 3D video-cameras that are highly accurate devices well suited for analysing the frequentation of people in the public space (Ashkanani et al., 2015; Salzmann and Fua, 2019; Goto et al., 2024) and have a high reliability of up to 98% of the count (Affluences, 2022). The software of these systems pays special attention to the privacy of the users whose data are analysed, allowing to collect, analyse and visualize data on the concentration of people through a dashboard, obtain analysis at the selected time slot and make predictions based on historical data considering seasonal factors. The choice of one device or another is influenced by the characteristics of the site where the counting is to be done, the needs and volume of information required, as well as the resources and capacity of the personal equipment.

The experimental site for this methodological study of visitor flows in urban heritage environments based on counting people using motion-image sensors has been the streetscape surrounding Valencia Cathedral, in particular Miguelete street and Barchilla street (Figure 1).

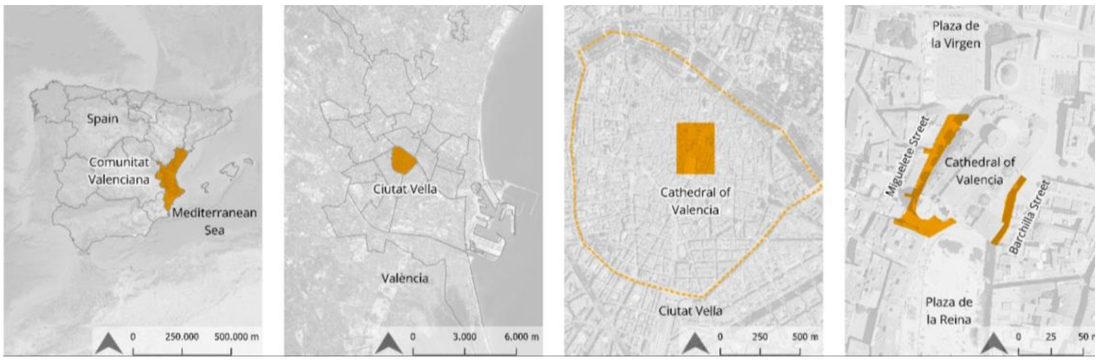


**Figure 1.** Location map of the study area.

These public spaces are characterized by high pedestrian traffic, especially visitors, and by the scarce presence of static activities (there are no shops, restaurants or cafés). It is worth mentioning the existence of benches to sit on one of the sides of Miguelete street.

The choice of these streets to install the motion-image sensors was conditioned by their geographical location, flanking the Cathedral, and by their physical characteristics, as they were linear urban spaces where access to the Cathedral was compulsory. The streets were between 5-8 m wide and allowed a good angle of view for the cameras (Figure 2) on the movements of the people on the chosen imaginary counting line.

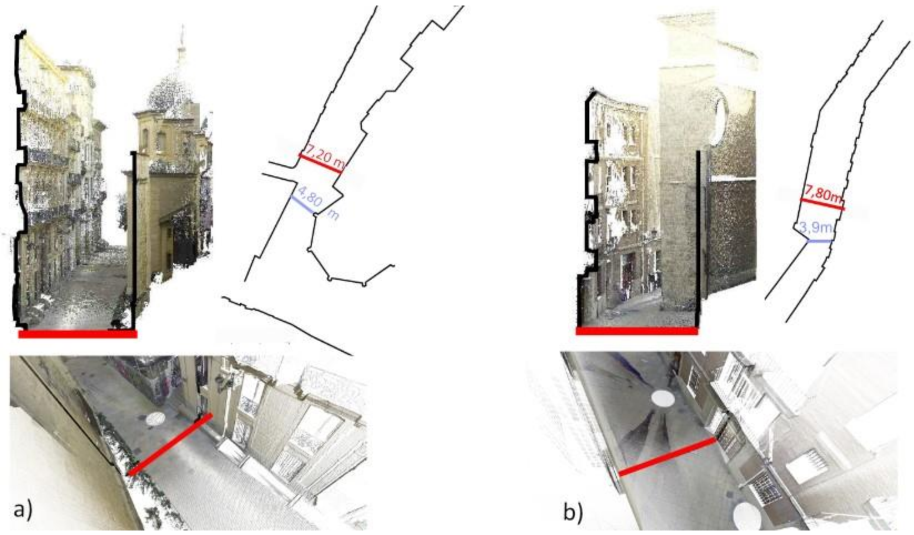


**Figure 2.** a) Top. Section, ground plan, count line (in red) and minimum width of Miguelete Street. Bottom. Camera view angle. b) Top. Section, plan, count line (in red) and minimum width of Barchilla Street. Bottom. Angle of view of the camera.

On the other hand, the installation possibilities of the sensor were good. Thus, they were attached to the walls (at a high height) and roofs of the Cathedral, which were stable and protected surfaces, thus avoiding undesired movements and remaining out of reach of acts of vandalism or theft, while offering the necessary height to obtain a viewing angle that covered the width of the street and thus obtain a suitable image to be analysed by the software (Figures 3 and 4). As it is a heritage building, a non-invasive support system was designed to avoid making fixings and perforations on the envelope. The central unit with the PC and the 4G USB modem with SIM were also located in a protected and discreet place, with a permanent 220V power supply. This station performs the storage and analysis of images and sends them wirelessly to avoid the distribution of wiring in the building.

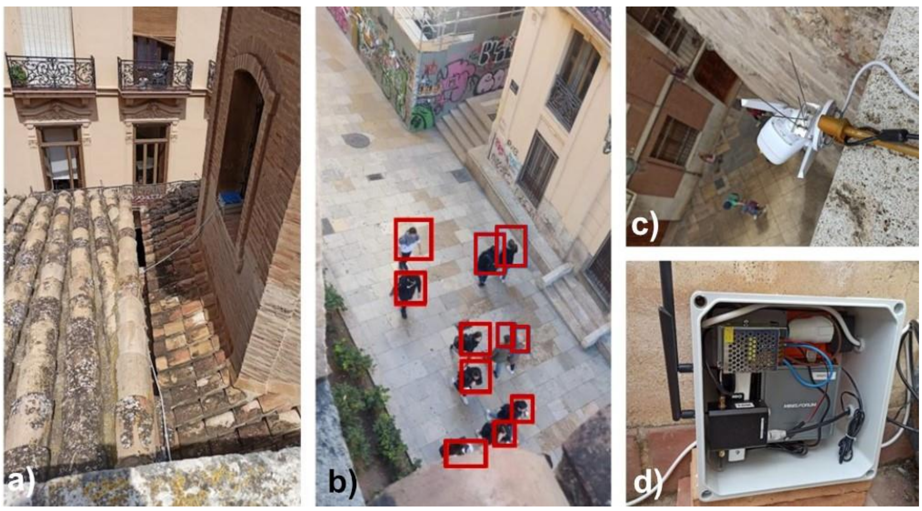


**Figure 3.** a) Location of the Miguelete Street camera on the roof of the Cathedral. b)Motion-image capture and people counting. c) Camera placed on a clamp fixed to the parapet. d) Central unit with the Mini PC, power supply and modem.

 

The chosen motion-image sensors were 2D video-cameras with people recognition software that provide accurate data and can track people's movements in detail, providing information continuously and remotely while respecting people's privacy, as the images can be analysed with the software in real time, but the data stored and sent to the servers are purely numerical. This, in turn, has avoided saturating the memory of the central unit, allowing smooth data collection over long periods of time.

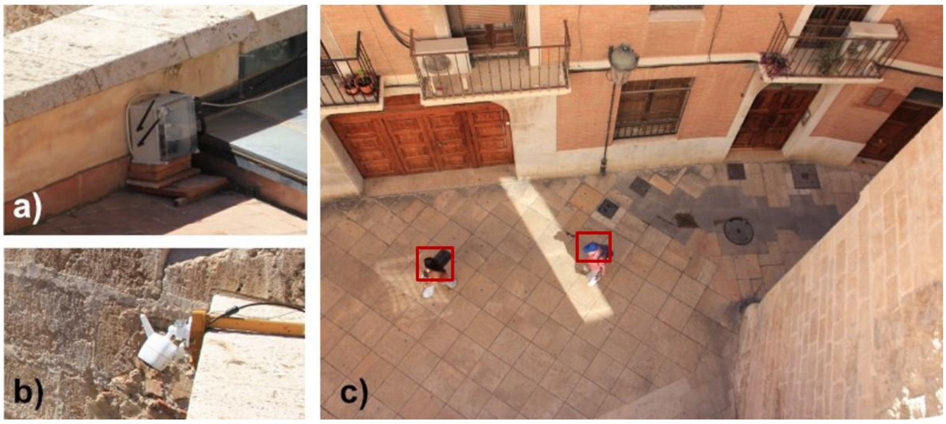


**Figure 4** a) Location of the central unit with the Mini PC, power supply and Barchilla Street modem. b) Motion-image capture and counting. c) Camera location.

The cameras used were CPF-SENSOR (model WTK10070) from Witeklab, whose characteristics are shown in Figure 5.

| | |
|---|---|
| **Features** | Wired or wireless networks: Allows connection to the network via the wired Internet or via radio via WI-FI. |
| | Tracking: Real-time tracking of people, with high clarity, resolution and filtering people and other objects. |
| | C2K QHD: 2560 x 1440 sharp definition image recording. |
| | Night vision: High vision capability even at night. |
| | Motion detection: The calculation system reports movement in the vision box, differentiating between different types of movement of different elements. |
| | Secure storage: Store up to 256GB of 2K QHD video locally on a microSD card, providing convenient access to video footage. |
| | Mini PC: Central system with detection and calculation process algorithm, with HD graphics card. |
| **Specifications** | Protection: IP68 security camera. |
| | Placement: For both indoors and outdoors. Optimum heights between 3 and 10 m. |
| | Detection angle: For person counting, an azimuthal angle between 20° and 40° is recommended. |
| | Lens system: 1 f:3.18 mm lens |
| | Image sensor: There is 1 optical sensor per camera: 25.4 / 3 mm (1/3") with night vision capability. |
| | Night vision distance: 30 m. |
| | Led type: 850 nm wavelength IR. |
| | Video: Maximum resolution 2160 x 1440 pixels. |
| | Total megapixels: 4 MP. |
| | Supported video format: H.264. |
| | Frame rate: 15 pps |
| | Radio connection: WI-FI 802.11b/g Wi-Fi 4 (802.11n) with speed of 150 Mbp. |
| | Power supply: AC: 100-240 Vac, at 50/60Hz. With DC output voltage of 9Vdc at 0.6 A. |
| | Environmental conditions: It operates between -20°C and +45°C and a relative humidity between 10 and 90%. |

**Figure 5.** Technical data sheet and specifications of the devices used in the study.

The data collected by the cameras are sent to a server in the cloud where they can be accessed, in numerical or graphical form, at any time from any device with an internet connection (Figure 6). After that, the data provided by the cameras has been processed using Excel spreadsheets (version v2019). This allows us to obtain the results of the counts quantitatively and graphically every 10 seconds. In this study, time ranges have been established by hours, which allows us to extend to days, weeks, months and years in order to better understand the pattern of frequentation of this space and thus facilitate decision-making and make the management of public services more efficient. This system would also allow the establishment of alerts that are automatically activated when critical levels of frequentation are registered employing specific monitoring software.

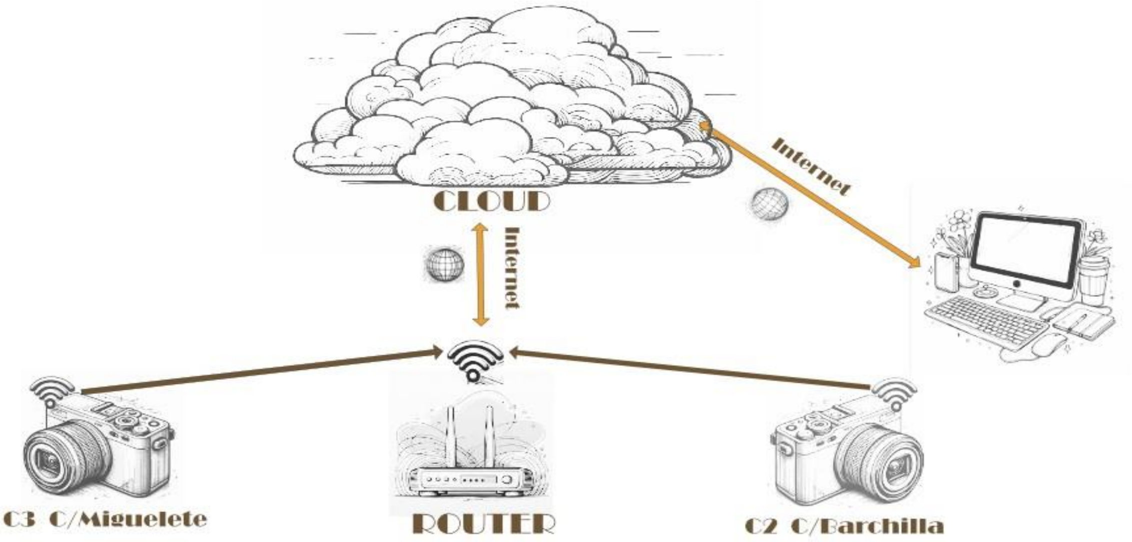


**Figure 6.** Diagram of connections and information flow between devices.

For the evaluation of the levels of flow density in the analysed area, the values established by Transport for London (2010) have been taken as a reference. These values are the result of counting the number of people who cross one metre of free width on the street (imaginary line) per minute (ppmm) on foot. Thus, this institution establishes the following standards:

- A. Comfortable human inflow level: < 3 ppmm / 3-5 ppmm / 6-8 ppmm
- B. Minimum recommended comfort level: 9-11 ppmm / 12-14 ppmm / 15-17 ppmm
- C. Signinicant level of discomfort: 18-20 ppmm / 21-23 ppmm / 24-26 ppmm
- D and E. Extreme discomfort levels: 27-35 ppmm / >35 ppmm

Thus, the standard comfort level for a flow of people would be around 9-11 ppmm (Level B). Above this figure (12-14 ppmm and 15-17 ppmm), people may feel uncomfortable and consider avoiding the area. At level C there is great discomfort as people feel that their intimate-personal space is invaded, which according to Hall (1959) is between 45 cm to 120 cm. In these circumstances, movement in both directions is difficult. Levels D and E correspond to situations in which the speed of pedestrian traffic is very slow and people can hardly move (Level D) and may even block two-way traffic (Level E).

In addition, daily information on visitors to the interior of the Cathedral has been made available in order to carry out a comparative analysis of the influx between the interior of the building and its immediate surroundings. It has also been possible to assess the saturation of the space thanks to previous studies to establish the visitor carrying capacity in the Miguelete Street (Orozco Carpio et al., 2023).

## 3. Results and Discussion

The data obtained from the motion-image sensors for this study cover six months. The sequence started in September 2023 and has been extended until May 2024. During the first two months, work was carried out to adjust the sensors, modify data acquisition schedules, and control data and image storage, which prevented continuous data recording. Therefore, with the existing data, it is not possible to offer annual or monthly data to make an interannual comparative study or to compare the same months of different years. However, it has been possible to carry out an analysis of pedestrian weekly traffic volumes and their hourly distribution on a daily basis. This has made it possible to draw conclusions regarding pedestrian traffic trends, flow density levels and the detection of extraordinary situations.

### 3.1. Pedestrian frequentation volumes on a weekly and daily basis

The first result detected by the analysis is that there are notable differences in volume between Miguelete Street and Barchilla Street, with the former regularly experiencing almost four times as many people as the latter. It should be noted that, in the counts, all the people who cross the counting line are registered, and that often the same person can be registered twice if he/she is walking in both ways (going and coming back).

The weekly volume of people passing through the Miguelete Street ranges from a minimum of 329,068 (22-28 January 2024) to a maximum of 764,785 people (6-12 May), with the latter number coinciding with the festivity of the Virgen de los Desamparados, which is celebrated in this street.

Regarding daily flows, the volume ranges from a minimum of 15,289 persons (Monday 1 April 2024) to a maximum of 215,289 persons (Tuesday 19 March 2024). The minimum volume curiously occurred on a local Easter holiday, which was not a national holiday, nor was it an international holiday. The 19$^{th}$ March, which recorded the highest number of visitors, coincided with St. Joseph's Day, a public holiday in the city of Valencia.

### 3.2. Weekly distribution of pedestrian flows

In terms of the days of the week with the highest number of visitors, there is a significant difference between working days and weekends. Thus, it can be seen that the busiest days are Sundays, Saturdays and Fridays (in that order) as opposed to working days (figure 7).

Another noteworthy fact is the higher number of visitors on Thursdays, due to the celebration of the regular session of the Water Court of the Plain of Valencia (Tribunal de las Aguas) in Miguelete Street, next to the Cathedral's Apostles' Gate. This event, included in the Intangible Heritage of Humanity List (UNESCO, 2009), takes place at 12.00 every Thursday of the year and attracts the attention of numerous visitors during this time slot.

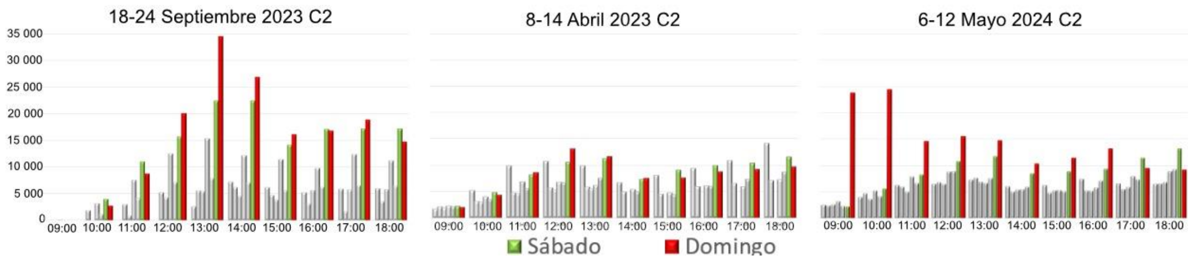


**Figure 7.** Graphic representation of the busiest days of the week (Sunday, Saturday) in the area around Valencia Cathedral at different weeks of the year.

### 3.3. Hourly distribution of the pedestrian flows

The time slots of the day with the highest volumes of people are 11:00-12:00, 12:00-13:00 and 18:00-19:00, with the critical time being 12:00-13:00. Thus, in these time slots, volumes of up to 25,711 people have been recorded (19 March 2024), 15,502 (12 May 2024), both coinciding with local festivities; but a large influx of 34,547 (Sunday 24 September 2023) and 15,392 (Thursday 21 September 2023) has also been detected, which did not coincide with events or festivities. The midday slot (14:00-16:00) suffers a notable drop, which is maintained with low volumes until 18:00 hours, when an upturn is observed coinciding with the start of free visiting hours at the Cathedral. No differences were detected between working days and public holidays. In the evenings, a significant flow has also been observed, especially at weekends, being remarkable until at least 24:00.

### 3.4. Pedestrian Flow Density Levels

Regarding the levels of pedestrian flow density in the area analysed, and following the values established by Transport for London (2010), Figure 8 shows the different levels detected in Miguelete and Barchilla Streets. To establish the Pedestrian Flow Comfort Levels in the case of the streets analysed, the results of the video-camera counts were divided between the established time range for data collection (1 minute) and the width of the imaginary line (7.2 m imaginary line and 4.8 m width/minute in Miguelete Street and 7.8 m imaginary line and 3.9 m width/minute in Barchilla Street).

The results show that on normal days, Miguelete Street occasionally reaches C levels of considerable discomfort with slow pedestrian traffic, especially between 11:00-13:00, with occasional congestion.

From a pedestrian flow density of level B at 10 ppmm, the visitor carrying capacity established for the Miguelete Street by Orozco Carpio et al. (2023), in which the Street can accommodate between 278 people with a proxemics distance of 1.2 m, or 3 groups of 15 people plus 40 people distributed with an interpersonal proxemics distance of 3.5 m, begins to be exceeded. At the same time, it is possible to notice how in the most critical areas of the Street, where the width of the Street reaches up to 4.8 m, the flow of people far exceeds the number of people that should pass if a personal proxemics distance of 1.2 m and the separation distance that should be maintained in relation to the walls are taken into account.

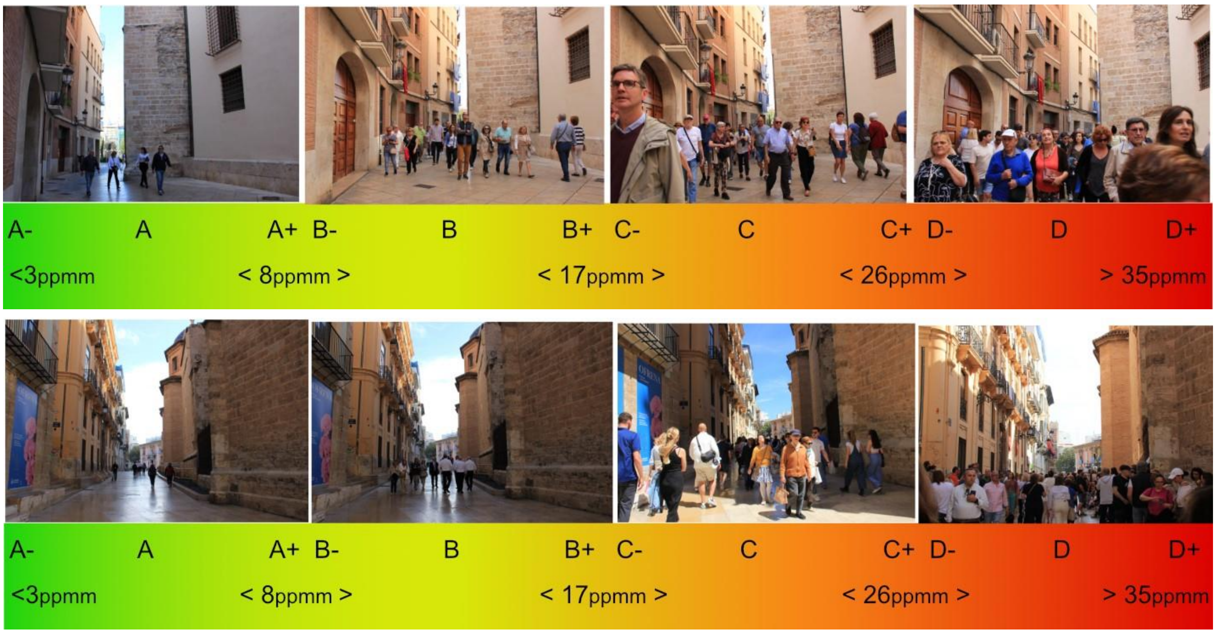


**Figure 8.** Pedestrian Flow Density Levels in Barchilla Street (top) and Miguelete Street (bottom).

On days of maximum pedestrian flow, such as 19 March 2024, this flow density reached levels of discomfort D, with the physical space becoming saturated as this situation occurred during various periods of the day. The effects of this situation are the blockage of movement in both ways, constituting a major safety risk for people and for the integrity of the Cathedral's skin.

## 4. Conclusions

As final reflections on this work, some key ideas can be noted which have to do, firstly, with the evaluation of the methodology and the study procedure developed. It should also be pointed out that, above all, this work has opened up many opportunities that will allow us to deepen this procedure for analysing the management of historic centres in the near future thanks to technological developments related to visitor management systems.

In this way, and in relation to the methodology used, it can be said that, for a first approximation to the knowledge of the situation of visitor flows in the historic centre of Valencia, it has been adequate in its procedure, being simple to use, affordable and with a great wealth of information. In the development and processing of the information, opportunities have been detected for more detailed analyses of the pedestrian flows and, among other utilities, the possibility of obtaining other types of data from the use of more sophisticated cameras and software specifically designed for, for example, obtaining pedestrian information in both ways of circulation, and predictive analyses from the incorporation of Artificial Intelligence (AI) into the analysis, have also been identified. In this respect, it is important to stress the need for efficient management of the large volume of existing people counting data, not only for processing, but also for proper visualization to be useful to managers and the general public.

It is also noteworthy that the collection and processing of real-time data from motion-image sensors combined with the use of GIS for monitoring and distribution of visitor flows in urban space has enabled the establishment of a protocol for the establishment of early warning of people overcrowding of the urban physical space by combining the parameters established in the study of visitor carrying capacity and levels of visitor flow density. This tool will be of great use to cultural and tourism managers and public administrations in general, and also to address issues of safety and security of people in the public realm.

With regard to the results obtained on the spatial and temporal distribution of visitor flows in the urban environment of the Cathedral, it can be said that they show clear behavioural trends, despite the fact that we do not yet have a complete annual sequence of data recording. Thus, the results show that the transit of people mainly takes place along Miguelete Street as opposed to Barchilla Street. Weekly figures for the number of people passing through always exceed 330,000 people, and this volume is more than doubled in weeks coinciding with local or religious festivities, when the local population goes to this public space to celebrate these events. The busiest days of the week are Sundays and Saturdays. There were also busy days with more than 200,000 people, such as Saint Joseph's Day (19 March 2024), the city's local holiday. The most frequented time slot is from 11:00 to 13:00. With in relation to the density of flows, it should be noted that, occasionally, at some points in Miguelete Street, level C of discomfort is reached, especially in the busiest time slots, thus noting situations of occasional congestion.

As future lines of work, in addition to those mentioned above, this team intends to work on combining the results of visitor flows with other existing sources of data on the urban environment (motorized traffic, meteorological data on temperatures, humidity, winds, rainfall, sunshine, etc.) and also with those relating to the interior of the Cathedral (volume of visitors, environmental data - temperature, humidity, $CO_2$). Likewise, another future line of work is to generate the bases for the coordination of those interventions programmed in the historic building in HBIM, allowing the "critical path" method to be applied with greater confidence, since in this way the intervention tasks in the historic building can be appropriately sequenced in harmony with the dynamics of the public use of the surroundings. Finally, it should be noted that these visitor flow data, with the support of the GIS, also make it possible to design and manage evacuation and emergency plans for the historic centre.

For all the above reasons, the results of this work are considered to have taken a step beyond the traditional ways of conserving and managing heritage and public use together, focusing the future towards more sustainable and effcicient modes of operation.

## 5. Funding

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# Analysis of tourism development indicators and their relationship with communication at cultural heritage sites

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***Abstract***

*Destinations are devoted to ruling them under sustainable development principles given by institutions such as UNWTO, UICN or ICOMOS. In this aim, strategic communication appears to reinforce them and bolster sustainable tourism development within the cultural tourism sphere. Nevertheless, in the field of communication, it is not always clear what is interesting to present to boost tourism development. In this sense, this study evaluates the opportunities for cultural heritage conservation, preservation, and promotion by analysing tourism development indicators and their relationship with communication. The methodology involves an in-depth exploration of cultural heritage interpretation and communication to achieve this aim, identifying good practices in communicating sustainability. The findings reveal promising avenues for utilising cultural heritage as a primary sightseeing vehicle for sustainable development using strategic communication. The implications of this study extend to fostering a symbiotic relationship among cultural tourism sites, Destination Management Organizations (DMOs), local communities and stakeholders to encourage visitor perception of cultural heritage for sustainability, thereby contributing to a more harmonious and sustainable tourism ecosystem.*

***Keywords:*** *strategic communication, sustainability dimensions, cultural tourism, sustainable development, heritage preservation, heritage interpretation.*

## 1. Introduction

The global tourism sector is developing dynamically, and the turnover of funds in this area is increasing yearly. While tourism was considered the central sphere that suffered after the Covid-19 pandemic at the same time, it has been showing a significant recovery rate after the pandemic period, reaching 88% of the recovery rate of international tourist numbers (direct GDP share of the Global market evaluated at 3% in 2023 as well as in 2019). It is supposed to be a total recovery in 2024 (United Nations World Tourism Organization - UNWTO, 2024). However, tourism is considered a significant potential source of profit; it causes serious problems such as overcrowding, cultural appropriation, and the loss of authenticity, among others (Hamú et al., 2004). Tourism brings money and jobs to cities and regions, but it can also damage residents' day-to-day lives and the area's culture and heritage. Under this scenario, sustainable tourism development at cultural sites offers a new perspective, as it places cultural heritage and local communities at the centre of decision-making processes (EU Commission[1]). That means it involves local communities and other stakeholders in the decision-making processes as a key to ensuring the benefit of both cultural heritage and the local population. In this context, sustainable cultural tourism aims to provide good conservation practices and authentic interpretation that supports the local economy production by tourist services enhancement, contributes to poverty reduction by creating job places, makes aware of environmental conservation and encourages cultural diversity by presenting a variety of traditions of destination (Brooks, 2011).

Cultural heritage tourism is one of the suitable types of tourism where visitors intend to support the preservation of the local cultural heritage and the economy with high spending (Richards, 2001). Cultural tourism is a vital catalyst for regional development, yet it necessitates meticulous oversight to mitigate adverse effects (Girard, 2008). However, the sustainability of cultural tourism is a complex issue, requiring a balance between economic benefits and the preservation of natural and cultural heritage (Murzyn-Kupisz, 2012; Hong Van, 2020). Rakitovac & Urošević (2017) and Hong Van (2020) both stressed the significance of cultural heritage for well-being and the quality of the local community by increasing new job places, raising visitor perceptions and improving the image of the destination, making it more attractive for regional investment leading destination to well-being. Still, other issues regarding the preservation of cultural heritage require a look at carrying capacity limitation, climate change damage to heritage and conservation of original heritage conditions for future generations.

The multisectoral tourism sector involves many stakeholders, such as public authorities, tourism businesses, local communities, NGOs, academic and research staff, and media organisations. Communication takes an essential role in sustainable tourism development, acting as the means of connecting tourism stakeholders based on sustainability principles. Principles for the implementation of efficient communication must be filled by the next: a) integration of the idea of sustainability anywhere, not just as a goal but as an ongoing process; b) clear and understandable communication (explanation through storytelling) showing different channels (ads or websites) of tourist companies and being a vehicle for knowing all Sustainable Development Goals (SDGs) established by the United Nations Agenda 2030[2]. It is crucial to consider that sustainability is not just environmental and climate protection. Still, it is a social and economic issue to avoid stereotypes and to provide a comprehensive view of the progress made and prospects in the relationship between communicational tools and sustainable tourism. Tourism activity at this destination belongs to the service sector and is customer-oriented. Therefore, the effectiveness of

[1] European Commission, Culture and Creativity: Sustainable cultural tourism, https://culture.ec.europa.eu/cultural-heritage/cultural-heritage-in-eu-policies/sustainable-cultural-tourism)

[2] Commission Communication, 'Agenda for a sustainable and competitive European tourism, Brussels, 19.10.2007- https://eur-lex.europa.eu/EN/legal-content/summary/agenda-for-a-sustainable-and-competitive-europeantourism.html#:~:text=This%20Communication%20is%20the%20official,and%20environmental%20and%20cultural%20protection.

communications that link the government, the producer of tourism services (tour operator) and the consumer (tourist) is crucial.

In this context, the importance of communication and interpretation in enriching the tourist experience and safeguarding the cultural significance of heritage sites has arisen recently (Köhler, 2020). Enhancing and marketing historical and cultural tourism sites represent pivotal priorities within the tourism sector. In this sense, Hana et al. (2023) stressed the importance of proficient communication strategies and engaging stakeholders in advancing sustainable tourism, as it was done at Kupang City, where the lack of promotional activities was considered the main reason for low interest in tourism and supposed relevant actions by the side each of participant. This viewpoint is reinforced by Musthofa (2021), who underscores the significance of digital technology in fostering the growth of cultural tourism, particularly in augmenting promotional and marketing communication for sustainable tourism development in cultural heritage sites.

At the same time, lack of communication leads to failure, and it can be approved in case the most problematic province of Cambodia in Angkor was accepted by 'The Angkor World Heritage Area Tourism Management Plan, 2012–2020' (United Nations for Education, Science and Cultural Organization - UNESCO, n.d.) based on the community opinions to minimise the damage. According to Bramwell & Lane (2000), communication also includes "how people use messages to generate meanings within and across various contexts, cultures, channels, and media".

For all these reasons, communication is presented as a powerful tool to support sustainable tourism development in a destination, although it must be used in an orderly and strategic way (Teruel, 2016). The first step is understanding the interpretation international organisations and other researchers gave to tourism sustainability indicators. Once analysed, the aim will be to address communication to support the sustainable management of destinations. To this end, this work has focused on studying tourism sustainability indicators. Identify and extract those that can serve to publicise the good practices a destination is doing regarding sustainability.

Moreover, regarding the role of cultural sites, communication includes heritage interpretation, which is a crucial factor in strategic communication for sustainable tourism development (Tatarusanu, 2018). Linking cultural heritage with cultural tourism development can help achieve sustainable tourism by considering economic, environmental, and socio-cultural aspects (Hong Van, 2020). Furthermore, heritage can contribute to and stimulate development in the modern world, with tourism being a significant factor in building public awareness and support for heritage conservation (Brooks, 2011). However, there needs to be more interpretation purposes, as most of them are intended to present historical value to heritage through interpretation.

After this introduction, this article will consider the importance of strategic communication for sustainable development in the cultural heritage sites based on good practices of different destinations to identify the conceptual framework of sustainability of heritage sites and how they can communicate through them using various strategic communication means.

### 1.1. Sustainable communication at cultural tourism development: A theoretical approach

Several studies have investigated the establishment of criteria for sustainable tourism applied to cultural tourism and heritage communication aspects from different points of view. First, the contributions given by Ngamsomsuke et al. (2011) highlighted the architectural character and urban design as pivotal indicators of cultural tourism sustainable development. They supposed sustainable cultural heritage tourism indicators are divided into four groups: economic activities, social support, management of cultural heritage sites, and the surrounding environment of cultural heritage sites. In total, they presented 20 relevant indicators highlighting the importance of social and management dimensions, which were considered the most communication-related. In this sense, Social Support indicators regard tourist satisfaction, tourist attitude towards culture, public awareness, and public prints. On the other hand, the management of cultural heritage sites includes indicators that consider attraction promotion activities, knowledge and beliefs from the visit, advanced information and communication technologies (ICT), and principal site narration.

Lozano-Oyola et al. (2012) introduced an indicator system for sustainable tourism in cultural destinations, stressing the necessity for practical guidance in interpreting and integrating the collected data. Jelinčić (2021) introduced a framework for evaluating the influence of cultural and creative industries on heritage and tourism, giving attention to stakeholders' involvement process. Nocca (2017) emphasised the significance of empirical evidence in illustrating the role of cultural heritage in sustainable development, especially concerning climate change awareness raising and the tourism sector's economic growth.

ICOMOS[3] considered the contribution of cultural heritage in the promotion of SDGs: 11, 8, 12, 4, and 16, remarking on its role in responsible consumption through, role in awareness raising and knowledge sharing, it's contribution as the way of local business support and employment, and raising the sense of pride through belonging and cultural identity, moreover, understanding of culture is the key to peace and tolerance in the multicultural universe.

UNESCO World Heritage and Sustainable Program[4] highlights cultural heritage tourism promotion through the following objectives where communication plays a pivotal role in each step:

- Interpretation means of heritage (integration of sustainable tourism principles)
- Sustainable tourism policy (advocating strategies, policy, framework and tools)
- Stakeholders awareness raising and capacity building (involvement of stakeholders in preservation of cultural heritage)
- Fostering the local community's sense of pride (by involvement and local community empowerment)
- Responsible tourism promotion (provide stakeholders with tools and capacity for managing cultural heritage responsibly)
- Raising visitor understanding and awareness (promoting quality services)

Sustainable communication for cultural heritage tourism development is crucial to bond objectives, principles, and steps in establishing management plans and sustainability activities. Further, after identifying the role and importance of communication in sustainability, the following points are made regarding the communication establishment's effectiveness and practical approach.

### 1.2. Strategic communication applied to sustainable tourism development

In the context of sustainability communication, there are complicated cases between economic growth objectives and sustainability principles, replacing them with economic benefits and drawbacks in sending messages about sustainability activities for awareness raising (Jones et al., 2017). By properly establishing effective strategic communication using visitor awareness-raising purposes in cultural tourism, there can be a significant positive change in many tourist perceptions, encouraging them to learn more about traditions (Wang, 2022). At the same time, there can be drawbacks in communicators' competency and lack of sustainability content in the communication process, intending communication not participatory but just announcing final reports, leading to the sense of absence of all sustainability activities even if they exist in the sites (Hamú et al., 2004). However, communication serves as the supporting instrument in sustainable tourism development (Galvin et al., 2012); it has a direct and indirect role in the organisation process of each other instruments such as sustainability indicators, economics (fee and taxes, job, etc.), management (legislation, policy, etc.) and voluntary instruments (guidelines, certification, etc) and others (capacity building, infrastructure improvement, etc).

[3] ICOMOS - International Council on Monuments and Sites online source "Arts and Culture - https://artsandculture.google.com/story/ewVBpE8qiz0gUQ

[4] Official web site of UNESCO World Heritage Convention organization - https://whc.unesco.org/uploads/activities/documents/activity-669-7.pdf

## 2. Methodology

The methodology employed in this study was qualitative and comprised three steps to identify the relevance between sustainable tourism development and its application to cultural tourism. To achieve this aim, a case study technique of good sustainability practises of cultural heritage sites and identify communicational means used for sustainability practises enhancement based on general research questions “What are sustainability actions in heritage sites?” and “How heritage sites communicate sustainability through various means”.

Firstly, a comprehensive literature review was conducted to identify the main aspects of sustainability within cultural heritage. This involved synthesising existing knowledge and practices related to sustainable tourism development and cultural heritage preservation and promotion. This first step was a clue to create the theoretical framework and this study's introduction to strategic communication’s role in tourism.

Secondly, content analyses of the most relevant sustainability indicators in cultural heritage sites based on the works of several authors allowed the identification of essential fields of action where sustainability could be interpreted through cultural heritage. Moreover, the documents' revision of good primarily practises of sustainable development at eight heritage sites completed this second step, presented in the subsection “Results”.

Finally, to better understand the sustainability communication of cultural heritage sites, case studies were used to identify sustainable development practices at cultural heritage destinations by finding links with the sustainability indicators. The sources used to afford this third step were:

- World Heritage Manuals*: Managing Tourism at World Heritage Sites* (Pedersen, 2002)
- The good practices of protected areas strategic communication approaches presented by Hamú et al. (2004).
- ICOMOS guidelines (Brooks, 2011) and the *ICOMOS charter for the interpretation and presentation of cultural heritage sites* (ICOMOS, 2008)
- *Practical, profitable, protected. A starter guide to developing sustainable tourism in protected areas* (Galvin et al., 2012)
- The *World Heritage Sustainable Tourism Online Toolkit* (UNESCO, n.d.)[5]

## 3. Results

First, based on a literature review on sustainability principles and activities, the key findings were presented as the framework of strategic communication, which related the fundamental sustainable tourism indicators with the practices endorsed by local communities and stakeholders through the communication means to ensure the messages (Figure 1).

[5] Official web site of UNESCO World Heritage Convention organization - https://whc.unesco.org/en/sustainabletourismtoolkit

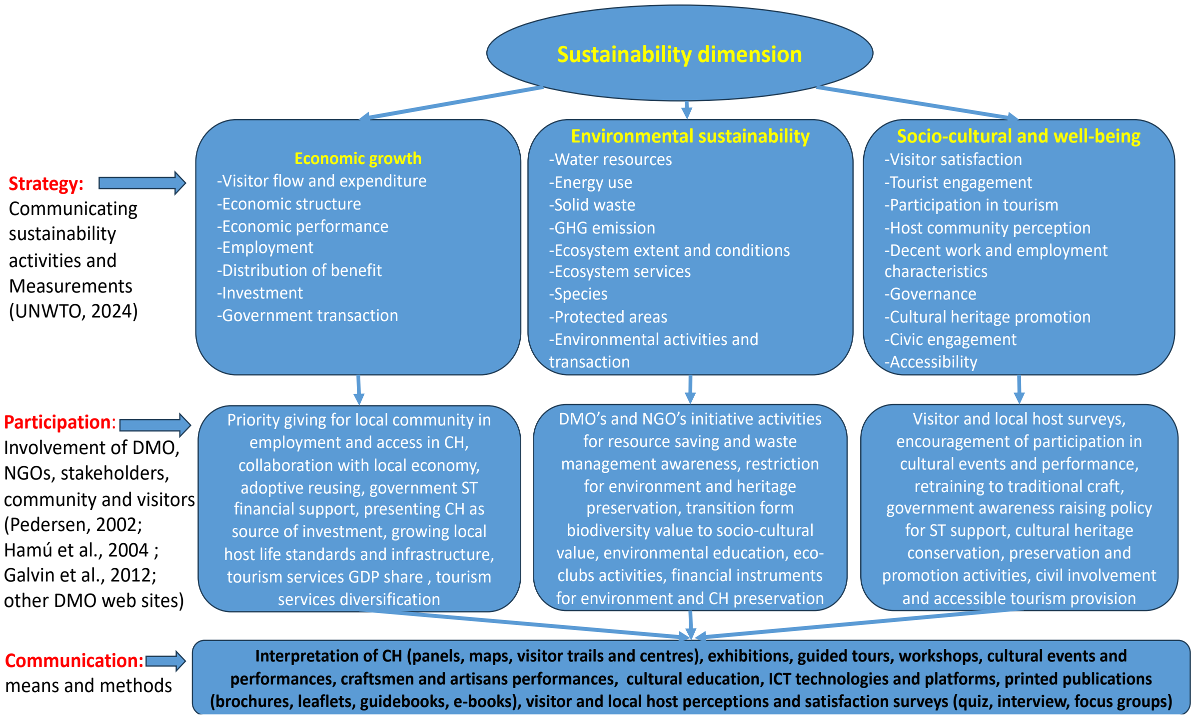


**Figure 1.** Communicating sustainability applied to cultural heritage sites

This first approach to the issues and indicators (in case) is contained in Table 1.

**Table 1.** Issues and indicators of sustainable tourism development

| Authors | Sustainable tourism issues/indicator's themes |
|---|---|
| Durovic & Lovrentjev (2014) | **-Social:** Socio-cultural effects of tourism on host Community, Local public safety, Conservation of cultural heritage, Social carrying capacity of the destination, Safeguarding cultural identity of local Community, Quality of life in general;<br>**-Economic:** Economic benefits of cultural tourism for the host community and destination, Sustaining tourist satisfaction, Cultural facilities, Institutional regulation, Seasonality of tourism activity, Tourism related transport, Cultural routes;<br>**-Environmental:** Protection of the natural ecosystem, Energy Management, Water availability and management, Wastewater treatment, Waste management, Atmospheric pollution, Management of the visual impact of facilities and infrastructure, Intensity of use, Environmental management; |
| Agyeiwaah et al. (2017) | **-Economic:** Revenues and profitability, Employment, Visitor satisfaction, Tourists arrivals, volume and numbers;<br>**-Social:** Residents involvement, participation and awareness, Congestion and overcrowding, Community satisfaction;<br>**-Environmental**: Water quality and management, Solid waste discharge and management, Recycling rate, Air/atmospheric quality;<br>**-Cultural:** Retention of local customs and language, Maintenance of cultural sites, Actions and events taken to promote indigenous culture; |
| Jelinčić (2021) | **-Heritage vibrancy:** Heritage attractions, Heritage participation and attractiveness;<br>**-Creative economy:** Creative and knowledge-based jobs, Heritage innovation, Internationalization of heritage;<br>**-Enabling environment:** Human capital and heritage education, Quality management of heritage;<br>**-Heritage preservation and protection**<br>**-Enhancement:** Research, Preservation, Preservation;<br>**-Heritage revival and livability:** Revival, Livability<br>**-Financial, environmental and** |

 

| | |
|---|---|
| | **socio-cultural sustainability of cultural heritage:** Financial sustainability, Environmental sustainability, Socio-cultural sustainability;<br>**-Heritage products/services enhancement.**<br>Heritage marketing improvement: Distribution, Pricing/sales, Branding, Promotion<br>- **Heritage interpretation enhancement:** Interpretive media, Visitor satisfaction, Heritage awareness and education;<br>**- Enhanced human resources:**<br>Management: Employees, Volunteers;<br>-**Visitor management improvement:** Tools, Visitor number and satisfaction;<br>**-Local community**: Access, Participation |
| Trišić et al. (2023) | **-Institutional Aspects:** Trained guides and community representatives, Local brands, The manager's directions for visitor activities, Information about the history of the reserve;<br>**-Dimension of Ecology:** The protection of the environment, the service provides facilities, services, and events that benefit tourists and the local community, Facilities for tourists exist that do not harm the environment;<br>**-Economic Dimension:** Residents in the destination gain from tourism, tourism industry boosts the regional economy, an increase in tourism in tourism keeps locals employed, Visitors can purchase local goods, and The costs of domestic goods are supported by tourists;<br>**-Socio-cultural Aspects:** Crafts and household items, the residents and guests interchange, Tourists are curiosity about regional customs and traditions, Tourists attend local cultural venues and events, Historical sites pique the interest of visitors; |
| Kadir & Chew (2024) | **-Cultural value:** The uniqueness of the way of life, wisdom, and knowledge, Continuation of traditional cultures, Cultural beauty, Continuation of the way of life, wisdom, and knowledge, A searchable historical culture, Local commitment, strengthened to maintain cultural identity, Cultural conservation groups network;<br>**-Physical potential and activity:** Accessibility: Ease of access, Accessibility: Access route signs, Safety and security, Safety and security: The frequency of the dangers of external factors such as crime, epidemics, etc. The frequency of the dangers of natural disasters in the past year, Diversity of tourism activities |
| UNWTO (2024) | **-Economic:** Visitor flow, tourism expenditure, economic structure, economic performance, employment, distribution of benefit, investment, government transaction<br>**-Environmental**: Water resources, energy use, Solid waste, GHG emission, Ecosystem extent and condition, Ecosystem services, Species, Protected areas, Environmental activities and transactions;<br>**-Social:** Visitor satisfaction, Visitor engagement; Participation in tourism, Host community perceptions, Employment characteristics, Decent work, Governance, Civic engagement, Accessibility |

Source: Own elaboration from Durovic & Lovrentjev (2014), Agyeiwaah et al. (2017), Jelinčić (2021), Trišić et al. (2023), Kadir & Chew (2024), and UNWTO (2024)

The above mentioned authors and institutions remarked on the significant role of cultural heritage in Sustainable Tourism development, where culture is considered one of the dimensions and key points of sustainable tourism development. Most were oriented to general tourism sustainability indicators following the main pillars such as economic, environmental and socio-cultural sustainability. At the same time, Kadir & Chew (2024) and Jelinčić (2021) focused on exact indicators relating to cultural tourism development, remarking on its cultural and physical value through technical conditions and accessibility of heritage. According to the authors, visitor flow, visitor expenditure, stakeholders' involvement, employment, tourism services, and infrastructure are the main points of economic sustainability. The socio-cultural dimension includes visitors' satisfaction, local community perception and participation, civic involvement and cultural heritage preservation and its role in local community well-being. Overall, it is clear from the authors' works that economic and socio-cultural indicators are more relevant to built heritage, and there is more opportunity to reflect through communication than environmental indicators, which have an indirect influence on cultural heritage development.

Secondly, this research continued with the analysis of good practices taken by governments and institutions at 8 heritage sites to highlight the importance of communication for raising awareness and inspiring people to develop goals. Table 2 matches sustainable indicators with the actions they did and communicates the institution or enterprise responsible at each heritage site.

**Table 2.** Good practices cases for sustainable cultural heritage development

| Heritage site | Sustainable indicators | Actions | Promotor |
|---|---|---|---|
| Angor, Cambodia | -Decent work and employment<br>-Governance | Cooperation of local stakeholders<br>Tourism industry stakeholder workshop and community, Monks and NGO workshop for tourism management plan (TMP) | Royal government, Destination management organisation (DMO), Non-Governmental Organizations (NGOs) |
| George Town and Meleka | -Adoptive reuse for tourism services | -Reused places were intended for cultural heritage interpretation based on Outstanding Universal Value (OUV) | Local stakeholders |
| Vigan, Philippines | -Local community perception (sense of pride)<br>-Decent work<br>-Using local building materials | -Education for value raising (brochures, e-books, films, newsletters, postage stamps, children's books, tourist web opportunities, and table books)<br>-Retraining of locals for craft and city guide services<br>-Using local materials for street signs | DMO with international Spanish professionals |
| Avebury, UK | -Local community perception (sense of pride) | -Involvement of local community in preparing promotional materials by interview docs and sharing their private photo archive of place (leaflets, maps and others) | DMO and NGOs |
| Roros, Norway | -Heritage conservation<br>-Local economic support | -Involvement of young people against vandalism by education<br>-supporting collaboration of local food economy and hotel, restaurants service | DMO, schools and stakeholders |
| Wadded Sea, Denmark | -Heritage interpretation | -low-cost social media and involvement of local hosts for storytelling through education | Schools |
| Cornwall and West Devon, UK | -Heritage interpretation | -using world heritage status in interpretation and information facilities by value-adding strategy | Stakeholders |
| Wadi Al-Hitan's | -Heritage preservation | -restriction on visit using awareness raising for heritage preservation | Stakeholders |

Source: Own elaboration from https://whc.unesco.org/en/sustainabletourismtoolkit/

## 4. Conclusions

Strategic communication in sustainable tourism is an ambitiously organised practical activities system based on the purpose of supporting sustainability indicators through awareness raising, community involvement, and collaboration for general goals. Communication must be strategic (must have achievable objectives) and must be based on a two-way method (Galvin et al., 2012). Communicating sustainability strategically means knowing how sustainability indicators can be transmitted through tourism types. That is, the sustainable practices taking place in a destination must be well identified and measured, if done, to make communication efficient. Moreover, Strategic communication for sustainable tourism development requires more integration between the public and private sectors and visitors. Using communication strategically with high efficiency provides proper information and stimulates consumers for day-to-day actions and decision-making. The lack of integration and promotion activities between stakeholders and other tourism participants can decrease the attitude towards the preservation of cultural heritage due to the low interest of the local host and government (Hana et al., 2023).

The research findings present general and special indicators systems for assessing sustainable tourism development in destinations with cultural heritage, focusing on utilising cultural heritage for sustainability and sending a message of sustainability through heritage communication means and ways.

Establishing efficient strategic communication within a destination can enable cultural heritage sites to convey sustainability principles effectively. Cultural heritage interpretation, local community and tourist perception analysis, education of tourism services, and improvement of other communication methods such as social media, web websites, and applications can foster the awareness-raising process. Moreover, It can be channelled through cultural heritage, which is vital in raising awareness among local communities and tourists and fostering mutually beneficial relationships. This entails engaging tourists with local traditions and involving the community in tourism activities.

While the primary aim of sustainable tourism is to preserve and pass on cultural heritage to future generations, collaborative efforts in cultural heritage management can benefit Destination management organisations by reducing economic burdens associated with heritage preservation. This, in turn, frees up budgetary resources for other heritage sites within the destination, with tourism serving as a significant driver for local economic growth.

These findings hold value for further research endeavours, serving as fundamental variables for measuring sustainability in cultural heritage sites. Based on the findings, it is helpful to identify sustainable cultural tourism measures and investigate them through these measures to determine whether heritage sites endorse sustainability or not.

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# Analysis of tourist flows and the comfort of guided tours in the Seu-Cathedral district of Valencia using participant observation and digital itinerary monitoring tools

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***Abstract***

*One of the challenges facing tourist destinations is to increase knowledge about aspects such as security concerning its implementation, measurement and evaluation to ensure the comfort of the visit. Tourist groups, both spontaneous and organised, that pass through the historic centre of a city are a permanent and fundamental element in the development of the tourist experience.*

*However, it is necessary to know the routes taken by the guided groups to avoid concentrations of visitors that could impede mobility and hinder the daily lives of other residents. To obtain more information about this tourist activity, this study focuses on the study of the group's situations of insecurity and discomfort during the tour. The methodology consisted of participant observation on the routes usually followed by these guided groups applied to the Seu-Cathedral neighbourhood in Valencia. The Geo Tracker GPS tool was also used to monitor the route and detect the number of encounters and places of congestion. The results point to the need to plan the safety aspects of the visits, especially traffic and transit obstacles, the identification of congestion situations and the holding of periodic events, as well as the study of shaded areas and the incorporation of outdoor furniture to increase the number of visitors.*

***Keywords:*** *tourist flows, guided tours, digital tools, mobility, streetscape, GPS*

## 1. Introduction

As highlighted by the World Economic Forum (2024), tourism destinations must strive to increase their competitiveness and improve the quality of their services. This includes controlling the number of visitors, which is not always easy in open spaces, to ensure the safety of visitors and residents. However, despite the importance of safety and knowing that many tourist destinations, to a greater or lesser extent, have been affected by risks and are aware of the concentration of visitors, the study of visitor comfort is an aspect that is scarcely dealt with by the scientific community.

In this sense, the activity generated by guided tours in city centres is essential to the local economy. It brings people closer to heritage while generating undesirable situations without planning. However, these guided tours awaken the interest of other visitors to get to know the destinations and are an attractive way to better understand the past and present idiosyncrasies of these destinations. Through guided tours, visitors can understand a historic centre's past and present and imagine its magnitude through history. It can be seen how the increase in the number of visitors to a city means an increase in the number of service companies dedicated to these activities, especially group guiding companies such as free tours, which have proliferated in many cities in the last ten years (Gutiérrez & Roldán, 2020).

In any case, once the visitor is at the destination, efforts should be made to optimise the space they occupy by considering tourists and residents, who are the guarantors of a destination's identity (Wallingre, 2014). However, to offer a quality experience, focusing on developing cities that serve tourists and residents is necessary. This fact leads us to reflect on visitor flows and the comfort of guided tours from two points of view; on the one hand, it is clear that the increase in these activities caused by tourism promotion policies carried out by destinations requires visitor management where flow control or carrying capacity tools are implemented to avoid undesirable situations. On the other hand, the visitor's comfort must be ensured to guarantee the quality of the experience, and it is here where aspects of physical and psychological comfort and safety come into play. The responsibility for tourism management lies with local governments, which provide the appropriate conditions and infrastructure to ensure that the visit is satisfactory and safe. In the case of tourist group guides, the coexistence with other people (residents), as well as the overcrowding that historic centres are suffering, makes it necessary to establish control measures to ensure the comfort of the tourists and the low social impact of the visit (Dominguez & Crespi, 2021). Faced with problems that have overwhelmed the cities, specific initiatives have recently been implemented, such as controlling the number of tourists in groups. A maximum of 20 visitors per group has been established in Valencia and Bilbao. However, it is necessary to know the routes taken by the guided groups to avoid concentrations of visitors that could impede mobility and hinder the daily lives of other residents.

On the other hand, concern for visitor comfort is related to the analysis of safety, the adequacy of facilities and equipment, connectivity and accessibility (Ruiz-Sancho et al., 2021). Thus, health and cleanliness conditions are essential for visitors on a guided walking tour. They are one of the determining factors considered before arrival at the destination. Likewise, other factors that may cause risk during the visit are related to the transit of different means of transport (trams, bicycles, buses, etc.), which are included in the safety analysis.

Other aspects to consider are visitors' physical and physiological requirements during the guided tour. According to Viñals et al. (2014), physical-physiological factors influence visitor satisfaction, including bioclimatic and safety factors. Bioclimatic factors are essential in outdoor activities. In this sense, it should be borne in mind that historic centres have particular characteristics, both in terms of safety and visitor comfort, as they conform to significant urban planning patterns which give them their identity and respond to their planning adjusted to the means of centuries ago when they were built, but which were not designed to be visited. For this reason, exposure to the sun is an aspect that conditions the visit, even if we are in a Mediterranean climate.

For all these reasons and with the intent to obtain more information about this tourist activity and the observation of the flows, this work focuses on the study of the safety and comfort situations of the group during the tour. The methodology consisted of participant observation on the routes usually followed by these guided groups applied to the Seu-Cathedral neighbourhood of Valencia (Figure 1). The Geo Tracker GPS tool was also used to monitor the route and detect the number of encounters and places of congestion. In this way, the innovation presented by this study lies in the integrated vision of the analysis of the essential components of visitor comfort and, therefore, of the tourist experience.

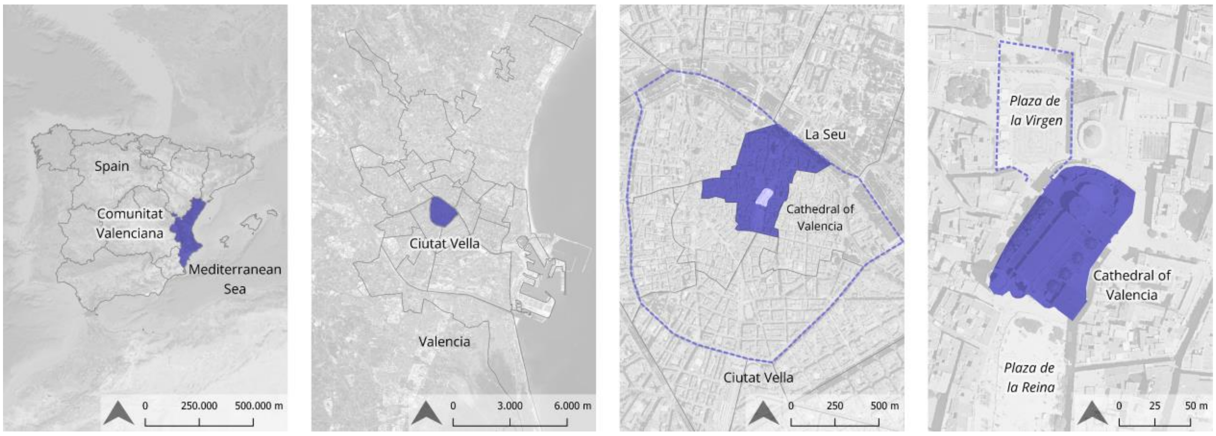


**Figure 1.** Location of *La Seu* neighbourhood and the Cathedral of Valencia. Source: Own elaboration

The structure of this article is as follows: after this extended introduction, the methodology and results are presented to conclude with the main findings obtained, which warn of the need to plan the safety aspects of visits, especially traffic and transit obstacles, the identification of congestion situations and the holding of periodic events, as well as the study of shaded areas or the incorporation of outdoor furniture to increase the comfort of both visitors and tour guides.

## 2. Methodology

The qualitative methodology began by identifying the companies that regularly offer guided tours around the cathedral. We identified and contacted by email or telephone nine tourist service companies that provide interpretative tours in the La Seu neighbourhood. The fieldwork was carried out from April to June 2023. The tour started in the *Plaza de la Mare de Déu* or *Plaza de la Virgen* at 10:00 am. Generally, these companies coincide in this place, in front of the basilica, which we will call the Meeting Point. All texts, figures and tables will be included within the margins of the template.

In addition, a methodological sheet was drawn up for the collection of information, which included the following aspects:

- General data: size and profile of the group
- Itinerary and points of interest, number of stops and duration of the tour
- Entrance to monuments or visit outside (Streetscape)
- Encounters between tourist and non-tourist groups (school or educational groups) - Safety aspects of the tour
- Safety aspects of the visit (traffic, situations of congestion or danger, places of exposure to the sun, pedestrian crossings, possibility of taking a seat at some point, restaurants or cafés, public toilets, universal accessibility, among others.
- Use of technological devices (audio guides, use of loudspeakers, QR codes for the guided tour).
- The guide controls bookings (this speeds up the group's reception and facilitates booking). It also incorporates an element of psychological comfort of pre-booking compared to free tours and other guided tour participants.

## 3. Results

The results obtained from the participant observation are shown below and distributed according to the different aspects defined in the methodological sheet.

Firstly, in relation to the profile of the demand, it was observed that the groups are heterogeneous in terms of age and gender, as well as nationality. The majority were middle-aged tourists, and only two groups corresponded to senior citizens between 60 and 75 years of age. Random guided groups are the most common, i.e. those tourists who decide to visit the city on a guided tour but do not belong to any tourist package or cruise. Also, within these homogeneous groups was a group of school visits by children and teenagers. The gender distribution is similar. The group size is identical in all cases, averaging 20-25 people.

The guide controls bookings at the meeting point, which facilitates the group's reception and booking. Most guides used an app on their mobile phones to control those visitors who had booked in advance. This element of group control provides security for the visitors who make the booking, although in the case of free tours, which are not usually booked in advance, a situation of discomfort arises due to other visitors joining the tour along the route.

About the points of interest (POI), they attended to the pattern of an angular visit that starts at the Plaza de la Virgen, which was established as the meeting point. The Turia fountain is usually a meeting point, the centre of the square and the access stairs to the Basilica of the Virgin. Once here, the group continues to the Valencia Cathedral. On some tours, the guide briefly explains at the meeting point and invites the group to enter the Basilica of the Virgin, as it is easy to pass through the main altar and out onto the Plaza de la Almoina. A second option is to pass directly through the right side of the Basilica to reach the Cathedral. This route is used when entering the Cathedral of Valencia to visit the interior of the Cathedral. This visit is usually brief (maximum 20 minutes), and it includes seeing the high altar, walking through the ambulatory, and finishing in the Chapel of the Holy Chalice. It should be noted that, in general, guided tours do not allow time to contemplate the interior of the Cathedral on their own. Audio guides provided by the Cathedral are used for the autonomous visit.

The visit continues through the Taperia neighbourhood to the *Lonja de la Seda*. The entrance to this building is at the back, although it is skirted to contemplate and explain its main façade, placing the group in the middle of the *Plaza de los Santos Juanes*. Once at the back of the building, you can enter directly into the famous column room or the garden. In this case, most of the tour started with a visit to the garden to give an initial explanation and access to the interior. One aspect to note here is that the group's visibility was lost. This stop lasted 20 minutes. After the visit to the *Lonja de la Seda*, the group moved to the outside of the square, where the guide introduced the buildings that make up the Central Market, leaving the group free time to visit the market on their own, enjoy the cafeteria, fast food and souvenir shops, among others. The visit to the interior of the Central Market cannot be done in groups to avoid crowding and distorting the market's own commercial activity and that of the residents. Figure 2 shows the coincidences in the route followed by these guided tours.

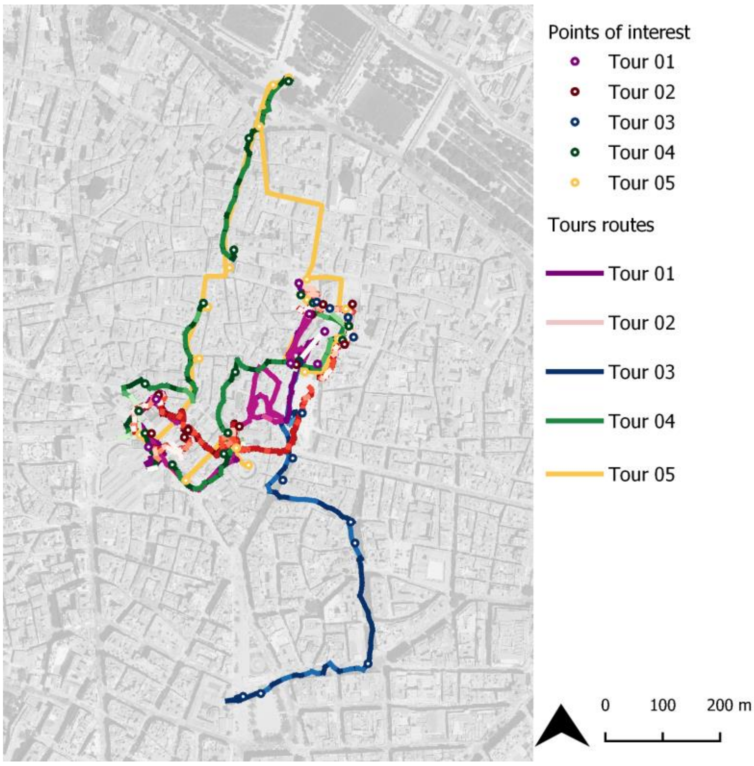


**Figure 2.** Guided tour routes and points of interest. Source: Own elaboration from Geo Tracker GPS

The meetings with other groups occurred in the most traffic squares, such as the *Plaza de la Virgen* and the *Plaza del Mercado*. Figure 3 shows the five models of itinerary followed by the groups. In the former, more than ten groups were starting the visits. Inside the Cathedral were two groups with guides; the rest were individual visitors. The encounters with different groups on bicycles were highlighted as discomfort. This hinders the normal dynamics of the city.

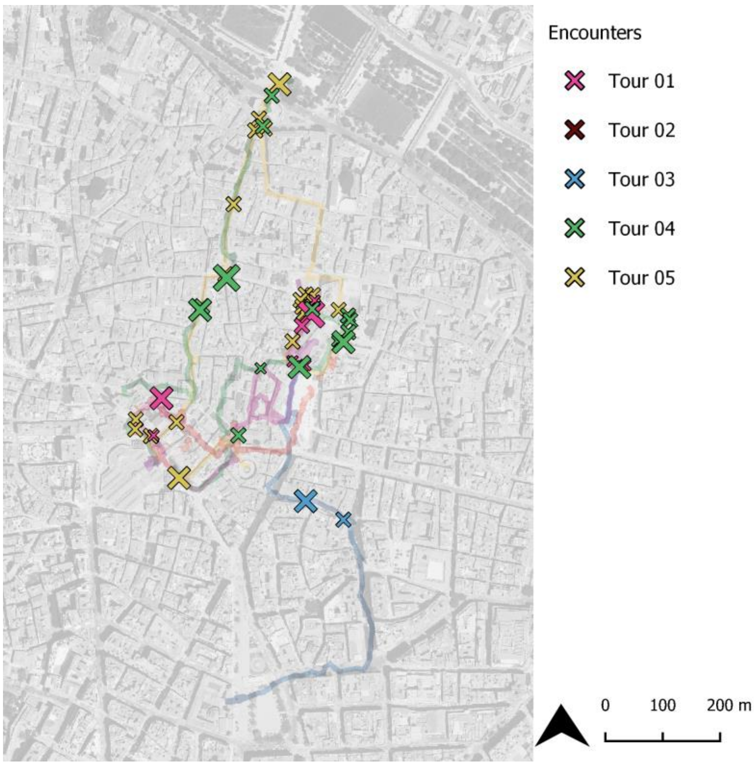


**Figure 3.** Itinerary and encounters for the five itineraries of the visitor flows. Source: Own elaboration from Geo Tracker GPS

Concerning the safety aspects of the visit, it was observed that, in general, the streets in the La Seu district of Valencia are safe. Road traffic speed is restricted to vehicles for delivering goods and residents. Therefore, even though most visits occur outdoors, there are no significant safety problems in vehicle traffic situations. The Central Market Square would be the most congested with traffic due to the distribution of goods. In addition, the guides know the areas well and try to lead the group through traffic-free streets. However, other aspects of physical comfort for the visitor still need to be resolved. There are very few areas to protect oneself from the sun, which is a problem for the normal development of the visit, considering that many of the explanations take place at times of the day when it is hot. There is no possibility to protect oneself. Visitors find very few shadows in the buildings or trees.

During the visit, there is also a need for more seating and rest facilities (Figure 4). This aspect is of the utmost importance, especially when visiting with children or elderly people. Throughout the tour, only two places to take a seat were identified, in the Plaza de los Santos Juanes and the Plaza de la Reina, although this point is not usually used as the visit starts in the adjacent square and is therefore not necessary. Finally, they also recorded where people sat, not necessarily on benches.  People sat, not necessarily on benches, but they also counted bollards, floors or bleachers.

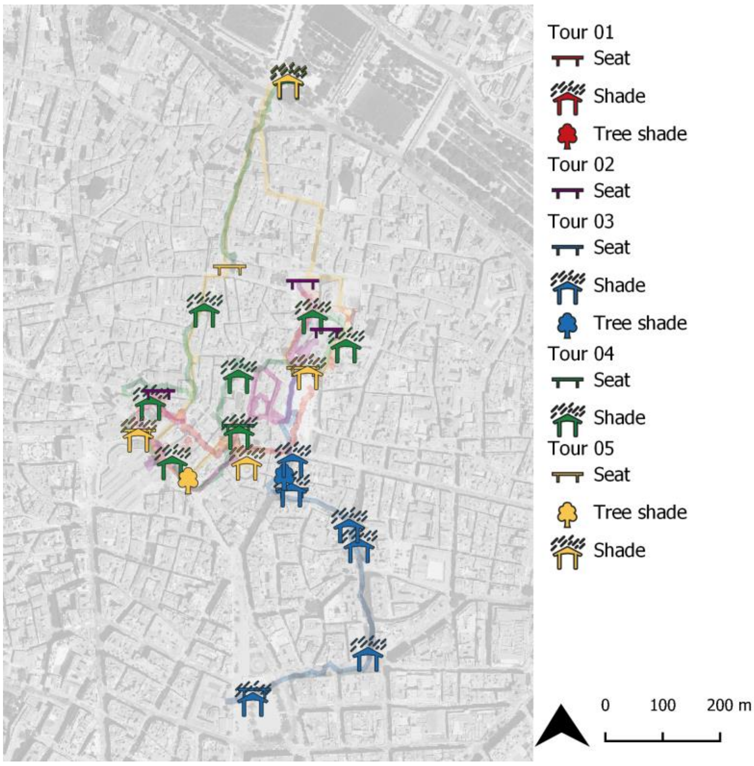


**Figure 4.** Urban facilities at the five visitor flows. Source: Own elaboration from Geo Tracker GPS

The offer of cafeterias and restaurants along the entire route, especially at those points of interest along the itinerary where visitors spend more time, increases the comfort of the visit. Another aspect linked to comfort is the use of closed audio circuits between the guide and the visitors, which minimises the volume of the explanations in such a way as to keep the group under control while avoiding unnecessary noise pollution.

The results warn of the need to plan the safety aspects of the visits, especially traffic and traffic obstacles, the identification of congestion situations and the holding of periodic events, as well as the study of shaded areas or the incorporation of outdoor furniture to increase the comfort of both visitors and tour guides.

## 4. Conclusions

The conclusions of this work respond to the objective of obtaining more information about the group guiding activity from the visitor's perspective and the compatibility of the residents' daily lives. The methodology allowed this research to be carried out, and the results were oriented towards analysis. Secondly, the study of the situations of safety and comfort of the group during the tour makes it possible to affirm that to prevent groups of such a large size from disturbing the historic centre, and some streets should be avoided, offering such large groups a route adapted to their size. The entrance to some monuments causes them to flood the room, which disturbs the regular transit of spontaneous and organised visitors. The visit should be better planned so that the narrowest and busiest streets are avoided to make the group comfortable and, at the same time, not disturb the residents' daily activity.

Among the proposals that could be implemented is limiting the size of the group, which is already a recent initiative being carried out in some cities in Spain, and Valencia appears to be a pioneer in this sense. In this way, the acoustic comfort of the place is better controlled, massive concentrations of visitors are avoided, and the tourist experience is improved. Regarding the physical comfort of visitors, it is noted that there are no shaded areas, nor is there any urban furniture that allows visitors to sit down during the tour, which, as mentioned above, lasts two hours. Visits during the very hot months in Valencia are being rescheduled to take place in the early hours of the morning and in the afternoon-evening to avoid exposure to the sun, given the lack of shaded areas throughout the tour. It should be noted that the planning of the visit includes free time to allow the group to use the services of cafés and traditional shops, which contributes to boosting the local economy.

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# Analysis of the online public opinion on the web platform Tripadvisor on Spain's industrial mining heritage by structuring the data for sentiment analysis

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***Abstract***

*This study examines visitors' perceptions of industrial mining heritage in Spain, a sector of significant cultural and economic value that has led to the establishment of museums and mining parks, which have been transformed into tourism products. Using text mining and natural language processing techniques, Tripadvisor's online reviews of nine industrial mining heritage resources distributed across different autonomous communities in Spain were analysed. The primary objective was to investigate how visitors describe and evaluate their experiences at these sites. The results indicated a generally positive perception, with visitors frequently citing terms such as "interesting," "recommendable," and "spectacular." However, critical points were also identified, particularly in relation to the duration and physical demands of the visits. This study highlights the educational and aesthetic importance of these sites, recognising their value in teaching the history of industrial mining and in offering cultural tourism.*

***Keywords:*** *mining park, Tripadvisor, sentiment analysis, text mining, NLP, qualitative research.*

## 1. Introduction

The legacy of mining in Spain constitutes a relevant tangible testimony, where the recognition of historical, cultural and sentimental values stand out (Cañizares, 2016), through which they become a pillar for the understanding of the industrial and social history of Spain.

The vestiges of the industrial mining heritage not only have histories of development and exploitation of resources but have also constituted the economic base of numerous territories, which have been part of the prosperity of the mining towns (Cañizares, 2011). Likewise, these sites have a unique landscape and ecology that offers a wide spectrum of study and enjoyment; however, they are currently becoming spaces of environmental awareness by way of reinvigoration in the field of tourism (Cole, 2004).

The interest in this type of industrial heritage has been demonstrated in intervention and revaluation initiatives since the end of the last century and the beginning of the present (Pérez & Verde, 2010), generating museums and interpretation centres that invite reflection on the facts or implications (Jelen, 2018). Nowadays, these opinions or reflections are shared on digital platforms such as social networks or opinion web platforms (Google and Tripadvisor), allowing us to analyse public perceptions towards industrial mining heritage.

This study explores visitors' perceptions of this type of heritage through sentiment analysis of online reviews issued on Tripadvisor, applying text mining and natural language processing techniques to examine how visitors describe and evaluate their experience. The data for this analysis comes from the Tripadvisor web platform, considered a benchmark in the cultural tourism sector (Taecharungroj & Mathayomchan, 2019) and influential in tourists' decision-making (Banerjee & Chua, 2016).

Through data collection and structuring, this study focuses on nine industrial mining heritage sites distributed in the autonomous communities of Asturias, Castilla-La Mancha, Catalonia, Extremadura and Murcia. The web scraping method was used to obtain reviews and then subjected to preprocessing to ensure relevance and accuracy in sentiment analysis. This research aims not only to reveal the general impression of visitors but also to identify specific aspects that generate interest or dissatisfaction. In this way, it seeks to provide information for the development of strategies to improve the tourist experience and, consequently, the socio-cultural value of these historical spaces.

## 2. Data collection and research methodology

Through sentiment analysis of online reviews, it is possible to interpret how visitors describe and reflect on their experiences on web opinion platforms (Gao & Yu, 2024), the results of which can be relevant in understanding users' interests and detecting trends, which can be relevant in developing strategic plans (Dang et al., 2020). For example, authors such as Sánchez-Vargas et al. (2022) evaluated the titles of online reviews published on Tripadvisor about 3- and 4-star hotels in the city of Cáceres (Extremadura); on the other hand, authors such as Seok et al. (2020) analysed graffiti tours, detecting the value of sustainable tourism, through the online reviews of users of social networks, applying text mining and sentiment analysis of opinions, and finally, authors such as Cheng & Jin (2019) conducted a research study on the attributes that influence the experiences of Airbnb users through online reviews.

For the development of the sentiment analysis, data collection and structuring were carried out, following the objective of applying a methodology that ensures that the data set is well-organised, relevant, and optimised for the study, as shown in Figure 1.

The elements of the industrial mining heritage in Spain were obtained from the database of the International Committee for the Conservation of the Industrial Heritage (TICCIH). Their presence on the Tripadvisor web platform was confirmed, which is considered one of the most relevant tools in the decision-making process of visitors (Ali et al., 2021). As shown in Table 1, nine elements were considered and distributed in different autonomous communities.

 

As a first step, the web scraping process was carried out using the Octoparse software, as an initial part of the data collection necessary for the initial experiments in sentiment analysis (Barbado et al., 2019). The data extraction was performed for Tripadvisor Spanish reviews, whose percentage rate in the detection of fake reviews has been 3.6%, preventing 67.1% of the simulated reviews from being admitted to the platform (Tripadvisor, 2021). Research by authors such as Reyes-Menendez et al. (2019), Glazer et al. (2020), and Tufail et al. (2022), establishes parameters for the detection of fake reviews, avoiding the extremism of ratings, which can be an indicator of distrust among users. These guidelines have been considered in this study. In total, 10,160 sentences were processed, corresponding to 4,540 online reviews, whose files have been extracted in CSV format.

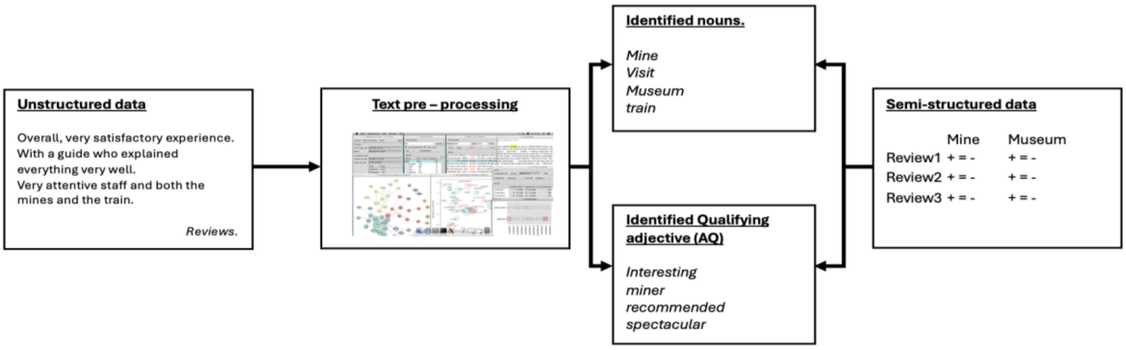


**Figure 1.** The methodology applied in the data structuring process. Source: Own elaboration.

**Table 1.** List of industrial mining heritage resources analysed in this study.

| Name of the Resource | Province |
|---|---|
| Museum of Mining and Industry | Asturias |
| La Jayona Mine Natural Monument | Badajoz |
| The Salt Mountain Cultural Park | Barcelona |
| Arnao Mine Museum | Castrillón |
| Almadén Mining Park | Ciudad Real |
| Rio Tinto Mining Park | Huelva |
| Interpretation Centre of the Mining Village of Bustiello | Mieres |
| La Unión Mining Park | Murcia |
| Bellmunt del Priorat Museum of Mines | Tarragona |

The extraction of raw data is a source of unstructured data that has been treated through the pre-processing phase, which can refer to the manipulation or elimination of data that, prior to its use, can guarantee or improve the performance of the analysis (Choudhary et al., 2022) through the process of cleaning and transforming the data into a structured format (Pandey et al., 2020).

In this process, punctuation marks in the text and icons that did not contribute meaning and were irrelevant at this stage were omitted. Similarly, common and intranscendent empty words were eliminated, which were obtained by means of a list of stop-words[1]. For this study, the open-source software KH Coder 3 was used for the procedure, quantitative analysis, and text mining for the language (Blasco-Gil et al., 2020; Higuchi, 2017).

## 3. Material field of work: heritage resources

As mentioned above, the working methodology was applied to nine heritage products belonging to the industrial mining heritage modality. Among the numerous mining elements existing in the country, those with the greatest tourist relevance or the greatest number of visitors were selected, with the aim of covering the entire national territory.

[1] The list of empty words omitted in the pre-processing section of the data has been obtained from the github. Retrieved 10 April 2024, from https://github.com/Alir3z4/stop-words/blob/master/spanish.txt

### 3.1. Bellmunt del Priorat Mines Museum (Tarragona)

Within the Priorat region (Tarragona), dedicated to the agricultural activity of vineyards and olive groves, its mining wealth, exploited since ancient times, also stands out. The Priorat mines, dedicated to the exploitation of galena, were active from 1920 to 1960, characterising the landscape and the economy of the mining town that arose nearby. The galena was transformed into lead ingots, and the sulphur was used, combined with oxygen, to produce sulphuric acid, which was in great demand and useful in the chemical industry. In order to save costs, the process was carried out in pits so that mining activity underwent an evolution in terms of extraction and transformation techniques, from the most traditional (auger and chopper) to the use of pneumatic hammers. The installations had their own electricity production plant.

The existence of its own cinema or brass band in a town of just over 1,000 inhabitants is an example of the considerable standard of living that the town has achieved, which changed drastically when the mine was closed. In 2002, the museum was opened to the public, whose visit includes the interpretation centre and access to the Eugenia mine, the largest and deepest, in which part of its galleries were fitted out and made into a museum, making them suitable for visits. The import centre, in addition to the technical aspects, pays attention to the social aspects and the memory of the people and their workers. One aspect to highlight is that the museum, owned and initiated by the municipality, was integrated into the system of the Museum of Science and Technology of Catalonia, made up of more than twenty visitable industrial spaces that do not repeat contents and benefit from a common design and promotion (Font, 2003).

### 3.2. The Salt Mountain Cultural Park (Cardona)

The existence of a mountain made entirely of mineral salt is not something common in geology, and the one in Cardona (Barcelona) has been exploited since prehistoric times, although the beginning of the exploitation of potassium salts by the company Unión Española de Explosivos Riotinto intensified the activity, although the working conditions were very hard. The abandonment of the exploitation led to the start of visits in 1997, but the creation of the Mining Park in 2007 allowed for a more profitable tour, which includes the possibility of guided and dramatised visits. The current management has proved to be very beneficial, and in 2022, 66,000 people visited the mine, a significant increase from previous years[2].

### 3.3. Museum of Mining and Industry of Asturias (MUMI)

The closure of the coal mines, first for economic reasons and then for environmental reasons, has put many towns in the north of Spain, whose main activity was mining, in a difficult situation. To alleviate the social and economic effects of this measure, several projects were undertaken. One of them was the creation of the MUMI, which, with significant institutional support, erected an emblematic circular building in front of which a large recovered derrick was installed. It was inaugurated in 1994, although a train ride to the San Vicente well was added later. The museum's collection is notable for its quantity and quality of machinery, as evidenced by Figure 2. Additionally, the museum's didactic approach to its museographic project is noteworthy, with a particular focus on the various mining professions and the social aspects of the workers' movement.

The visit includes the (simulated) descent into a mine, which has been reproduced by means of a tunnel excavated ex novo, and whose scenography manages to transmit the sensations experienced in a real mine. Its location, relatively close to Oviedo, and its good communications explain its success: an average of 66,000 visitors a year, compared to other less-promoted authentic mining museums[3].

[2] Parque Cultural de la Montaña de sal de Cardona. (n.d.). Retrieved 17 April 2024, from https://patrimoni.gencat.cat/es/coleccion/parque-cultural-de-la-montana-de-sal-de-cardona

[3] Museo de la Minería y de la Industria de Asturias (n.d.). Retrieved 17 April 2024, from http://www.mumi.es/es/mumi/tren_minero.html

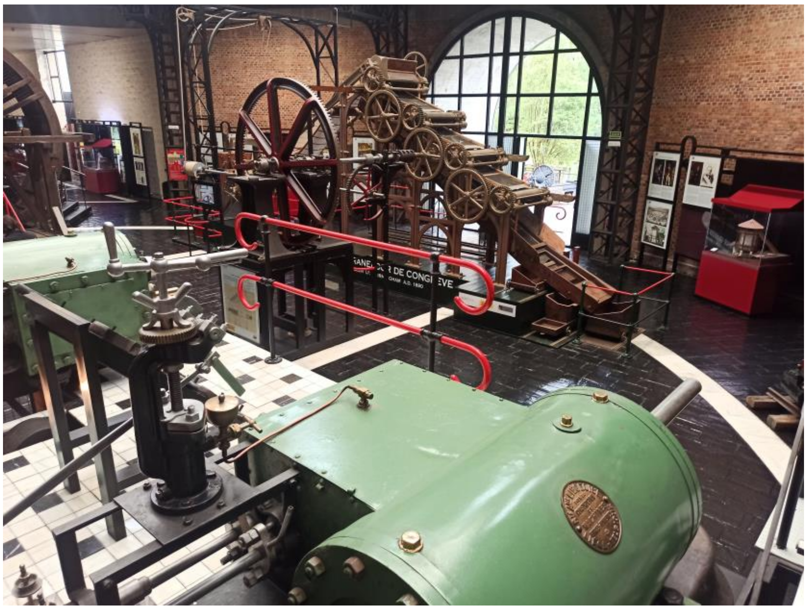

**Figure 2**. Details of the exhibits at the Museum of Mining and Industry of Asturias. Author: F. Rodríguez

### 3.4. Arnao Mine Museum (Castrillón, Asturias)

In contrast to the previous example, the Arnao Mine Museum offers the seal of authenticity and uniqueness: the coal seam, although there were previous extractions, was massively exploited in the 19th century, and in fact, the castle that can be seen is the original one, dated 1856. It has the particularity that the vein runs under the sea, so a vertical shaft of 80 m was dug and then a horizontal gallery of 250 m. It can be considered the cradle of the Industrial Revolution in Asturias, as it was the first mine to use a blood-traction railway or to employ women, for example. The flooding of the gallery in 1915 led to its closure, but this allowed the mine to remain intact. Visitors have the option of joining a guide who accompanies them in the original cage to a depth of 20 metres, the only accessible point not flooded by the sea. However, this museum, which is less well equipped with exhibition material but characterised by authenticity, receives barely 10,000 visitors a year[4].

### 3.5. Interpretation Centre of the Mining Village of Bustiello (Mieres, Asturias)

Bustiello complements all of the above, as it focuses on the human aspect: it is a village built by the Marquis of Comillas for the engineers and workers of his mining companies, equipped with services and very well cared for in terms of aesthetics. It is an example of the bourgeois paternalism that was widespread at the time and which implied the assumption of Catholic principles. Visits are always guided and start at the interpretation centre installed in the engineer's house. The complex, also exceptional in its type, has been declared an Asset of Cultural Interest and receives just over 1,000 visitors each year[5].

### 3.6. Almadén Mining Park (Ciudad Real)

The municipality of Almadén is the second largest accumulation of cinnabar in the world, exploited since the Roman period but which began a period of splendour in the 16th century when mercury - obtained by distilling the mineral - was demanded for the process of amalgamating silver in the mines of Potosí and others. In this way, the initial settlement became a prosperous mining town, which in the 18th century was exemplary in many ways: the construction of a bullring to subsidise a mining hospital, the later location of the School of Mines, and the

[4] Mina de Arnao (n.d.) Retrieved 17 April 2024, from https://asturias.com/mina-de-arnao/

[5] Centro de Interpretación Poblado Minero de Bustiello (n.d.). Retrieved 17 April 2024, from https://www.turismoasturias.es/descubre/cultura/museos-y-espacios-culturales/otros-espacios/centro-de-interpretacion-poblado-minero-de-bustiello

gloomy side, provided by the existence of the prison for forced labourers which supplied the workforce. The mining installations are inland, with kilometres of galleries and baritels for the extraction of ore and people through vertical shafts, mining fences and shaft furnaces for distillation.

In 2003, a European environmental directive brought production to a halt after more than 2000 years, and almost immediately, steps were taken to make the enormous mining heritage accessible to the public. The inscription of the mines on the UNESCO World Heritage List in 2012 was a clear endorsement of the interest in the project. The public visit includes access to an exhibition area, a guided tour of the galleries and a trip outside by mine train. There is no doubt that the opening of the Mining Park provides a unique experience for the visitor and has contributed to the socio-economic recovery of an area that needs to overcome the absence of effective communication routes and which would require greater promotion.

### 3.7. La Jayona Mine Natural Monument (Fuente del Arco, Badajoz)

Located in the municipality of Fuente del Arco in the province of Badajoz, very close to Andalusia, iron ores such as haematite, oligist, goethite and limonite began to be mined between 1900 and 1901, initially in an unscientific manner and, from 1905, by means of an overhead cable that transported the ore to the town's railway station, from where a railway line transported it to Peñarroya (Córdoba), which took over all production. Between 400 and 500 miners of both genders and different ages worked the deposit following the veins for two decades until it became unprofitable.

Mining usually has a negative impact on the environment. However, in this case, the paradox of nature, of its own accord, recolonised the space with vegetation and animal species. Some species, such as different types of bats, even made the galleries their usual habitat. The recognition of its natural values came in 1997, with its declaration as a natural monument, which generated a growing flow of visitors that it became advisable to control. At present, the area houses a visitor reception centre, an interpretation centre, various itineraries for the public to follow and the possibility of exploring the galleries on 11 different levels, where large openings allow visitors to contemplate the colourful landscape. The complex receives about 20,000 visitors per year and about 220,000 in the first two decades of its opening (VV.AA., 2018). Two guided tours are offered daily, which are managed by the local council.

### 3.8. Riotinto Mining Park (Huelva)

As is often the case with areas that have been privileged by nature and geology in the form of mineralogical wealth, the Andévalo area of Huelva has been exploited uninterruptedly since Roman times. This presence has been attested to in the form of a rich archaeological mining heritage, including the water extraction wheel, which, now restored, can be seen in the Huelva Museum. However, the sale by the State to the Riotinto Lmtd. Company in 1873 marked a turning point in the intensification of copper ore mining, the introduction of new techniques and the opening of the impressive Corta Atalaya open-cast mine. The Spanish state took them back in 1954, and since then, profitability has fluctuated depending on the world's copper price. Although iron pyrites (gossan) did not cease to be mined, the resumption of copper mining began in 2015. In 1985, the Riotinto Foundation was created as a non-profit charitable and educational institution with the aim of recovering and maintaining the immense industrial and documentary mining heritage and contributing to the social and economic reactivation of the region.

Through a progressive and lengthy process, the mining museum (located in the former company hospital), visits to Corta Atalaya and the Peña del Hierro indoor gallery, Victorian house no. 21 in the Buenavista district as an ethnographic museum and part of the mining railway line were opened to the public, including the restoration and commissioning of the oldest steam locomotive in Spain. At the same time, it is worth highlighting the careful marketing work, which has included the creation of a brand, the design of a logo and the choice of an identifying colour palette, the reactivation of social networks, direct marketing with tour operators and educational centres, which has resulted in a total of 96,935 visitors in the past year of 2022.

As a paradigm of success and an example of good practice in the recovery of natural and cultural heritage, the project has received numerous awards and distinctions, including the Tripadvisor Certificate of Excellence in 2015 (Narbona & Delgado, 2018).

### 3.9. La Unión Mining Park (Murcia)

The municipality of La Unión treasures a great diversity and wealth of minerals (galena, blende, pyrite, gypsum, etc.) that have been exploited since ancient times. In its current configuration as a mining museum, it offers a visit to the exhibition area, a touristic train ride that allows visitors to contemplate the mineral washing and roasting areas and access to the Agrupa Vicenta mine, which is located at a depth of 80 metres. There is less to visit, but it follows a recovery plan for industrial assets of 50 elements, and in fact, the museum is currently closed for refurbishment[6].

## 4. Analysis of visitor perceptions

The first result, as shown in Table 2, corresponds to word frequency, an important tool for understanding the reiteration of terms and their context. This type of processing shows the frequency of words, determining relationships between them and establishing coding rules (Higuchi, 2017). In this case, adjectives related to the experience of visitors to the industrial mining heritage of Spain have been extracted, and, in this way, the terms with the highest frequency have been analysed. It should be specified that the words have been extracted in Spanish, making it necessary to translate them into English for the purposes of this study.

**Table 2.** Frequency of words in relation to Spain's industrial mining heritage

| Words | Frequency | Words | Frequency | Words | Frequency |
|---|---|---|---|---|---|
| Interesting | 767 | Best | 202 | Beautiful | 109 |
| Miner | 610 | Impressive | 181 | Didactic | 108 |
| Recommended | 472 | Hard | 168 | Roman | 107 |
| Spectacular | 253 | Great | 153 | Major | 105 |
| Small | 252 | Curious | 147 | Kind | 103 |
| Old | 250 | Long | 136 | Only | 95 |
| Pleasant | 232 | Different | 135 | Excellent | 94 |
| Unique | 227 | Medium | 133 | Touristic | 93 |
| Beautiful | 208 | Pleasant | 123 | Amazing | 91 |
| Complete | 208 | Short | 115 | English | 91 |

The predominance of the words "interesting" (767), "recommendable" (472) and "spectacular" (253) show a generally positive perception of industrial mining heritage among visitors. Likewise, the words "old" (250), "pleasant" (232), "complete" (208) and "beautiful" (208) reflect an appreciation of the symbolic and aesthetic value of this type of heritage. On the other hand, the terms "didactic" (108) and "English" (91) indicate the high degree of specification of the educational experiences that take place in these spaces, as well as the quality of the explanations in English for non-Spanish-speaking visitors.

Words such as "curious" (147), "different" (135) and "unique" (227) demonstrate the different appreciation of mining and diverse industrial heritage in terms of comparison with other types of heritage or tourism resources. Finally, the terms "hard" (168) and "long" (136) indicate physically challenging experiences for visitors, and also criticisms of the length of visits or tours. Figure 3 shows a word cloud with the word frequency results.

Figure 4 shows the result of the structural characteristics of the network formed by the co-occurrence of words. Using the network graph of word co-occurrences, we can detect the association of terms with patterns of similar appearances that are directly linked with network lines (Higuchi, 2017). The result, based on the top 100, shows us a graph of 39 nodes (N), 60 edges (E) and a density of 0.81 (D). The correlation coefficient between the nodes was also considered, which indicates the strength of the association between the terms, represented by the thickness and intensity of the edges.

[6] Parque Minero de La Unión (n.d.). Retrieved 17 April 2024, from https://www.ayto-launion.org/turismo/parque-minero-de-la-union/


**Figure 3.** Word cloud refers to the frequency of terms for industrial mining heritage. Source: Own elaboration.

The highest coefficient corresponds to 0.4, which, in relation to the high-frequency level, is located in the central part of the graph, in relation to the term "mine", which appears as a central node, as a consequence of the context studied, but has a strong link with the words "visitor", "history", "museum", and "miner", showing an association in the perception of the visitors, on the quality of the experience with the personnel linked to the industrial mining heritage and a recognition of the historical value of the mines. In this cluster of words, there is also a connection between the words "guide", "explanation", "recommendable", and "enjoyable", indicating a level of positive satisfaction with the guided tours and the informative quality of the visits.

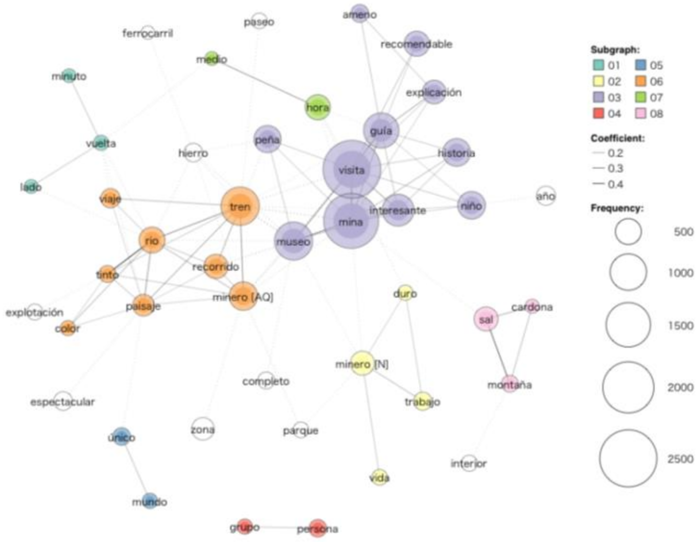


**Figure 4.** Word co-occurrence network associated with Spanish industrial mining heritage. Source: Own elaboration.

Another node with a high-frequency density corresponds to the term "train", which is associated with the terms "miner” (adjective), "journey", "trip", and "river", alluding to the Riotinto Mining Museum in the province of Huelva, whose terms form part of the museum experience, where the visitor can take a train ride and enjoy the scenic views. In addition, the words "river", "landscape", and "colour" are associated with the appreciation of the natural environment, highlighting the peculiarity of the river's reddish colour as a result of the dissolution of minerals.

A theme has been found around the word "miner" (noun), which is connected to the terms "life", "work", and "hard", demonstrating empathy and connection between the visitor and the historical conditions of the miners, calling for discussion of those situations and the risk posed by such work. The theme of "work" and "hard", demonstrates empathy and connection between the visitor and the historical conditions of mine workers, calling for discussion of those situations and the risk involved in such work.

Similarly, a connection has been found between the terms "mountain", "salt", and "Cardona" in an allusion to the Salt Mountain Cultural Park, province of Barcelona, one of the areas with great acceptance and reception in the online reviews of Tripadvisor, and through which, the experience in relation to the visit to the geological formations of salt is highlighted. Finally, the words "unique" and "world" in the reviews demonstrate the visitors' perception of this type of industrial heritage, emphasizing the exceptional value and uniqueness of industrial mining heritage in Spain.

Figure 5 shows the result through the word correspondence network graph. Through the correspondence analysis graph of the extracted words, a two-dimensional scatter plot is produced, which is used to explore the types of words that possess a similar appearance pattern (Higuchi, 2017).

These terms are distributed between Dimension 1 and Dimension 2, representing the two main sources of variability between the terms. As far as Dimension 1 is concerned, it contrasts aspects related to the visual characteristics of the mining environment, with terms such as "landscape", "river", and "color", alluding to the Riotinto Mining Museum, one of the elements with the highest number of online reviews and good acceptance on the Tripadvisor web platform. These terms suggest an experience based on the aesthetic appreciation of the place, creating an emotional connection with the environment. However, in the same dimension, aspects more related to the direct experience stand out in relation to the words "museum", "visit", and "guide".

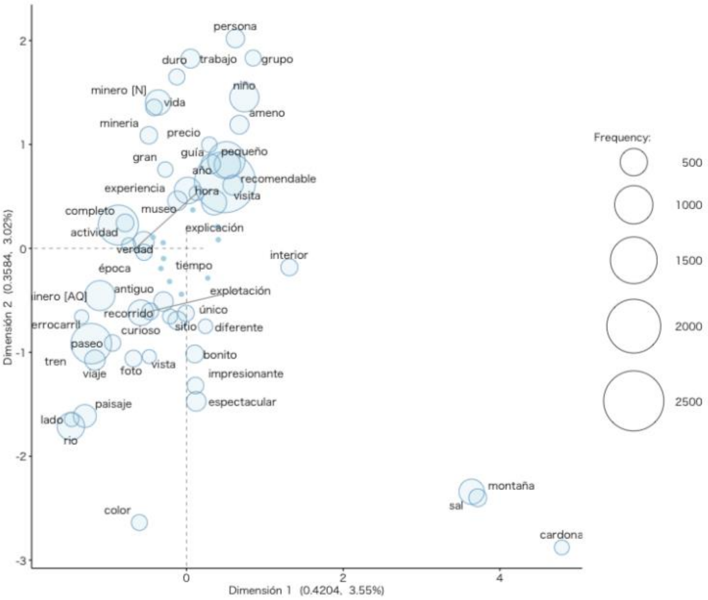


**Figure 5.** Correspondence graph of words associated with Spain's industrial mining heritage.
Source: Own elaboration.

Terms such as "history" and "experience" demonstrate the intangible (historical) or conceptual aspects that are often central to the symbolic value of this type of industrial mining heritage. Therefore, these terms demonstrate that Dimension 1 is related to the visual perception of the landscape environment of industrial mining resources as well as the museum experience. With regard to Dimension 2, these terms represent the polarity of the experiences described in the online reviews. At one extreme are the terms with positive connotations, which are associated with emotions, reactions, and appreciations towards the industrial mining landscape, with the words "impressive", "spectacular", "beautiful", and "curious" standing out. These terms reflect an emotionally favourable perception of the visits, which are described as unique experiences. On the contrary, the terms associated with the most challenging, critical aspects and points of improvement in the visitors' experience are located; however, negative terms are not prevalent, which shows a generally positive perception.

In addition, terms such as "old", "trip", "excursion", "walk", and "tour" demonstrate the activity-based experiences and the logistical factor in these resources, reflecting the relevance of the infrastructure and easy access to the mining sites analysed. Such terms in Dimension 2 demonstrate the emotionality of the experience and the physical description of the industrial mining heritage environment.

## 5. Conclusions

The study of Spain's industrial mining heritage through online reviews on Tripadvisor has provided relevant information on how visitors experience and value these sites of historical and cultural importance. The methodology used revealed a generally positive appreciation of industrial mining heritage, with adjectives such as "interesting", "recommendable", and "spectacular" standing out.

The frequency of words and the network of co-occurrences highlight the educational elements, the quality of the guides and the landscape impression, details that show a positive tourist experience towards industrial mining heritage. In addition, the study shows several mentions that highlight the uniqueness of this heritage and the historical narratives that manifest the potential of these sites that can be used to create authentic and enriching tourist experiences. However, areas for improvement have also been highlighted, as indicated by the terms "hard" and "long", alluding to the duration and physical intensity of some tourist routes, which should be taken into account in order to improve the experiences offered.

The recognition of the revaluation of the industrial mining heritage is highlighted by the inclusion of interactive and educational elements, as well as adequate promotion and access to information in several languages, elements that have been highlighted as an important part of the positioning of this type of heritage in the cultural tourism offer in Spain.

Finally, the studied elements of the industrial mining heritage, as reflected in the visitors' reviews, are seen as dynamic spaces for learning and appreciation, fostering a deeper understanding of Spain's industrial history, as well as living spaces, generating an integral local development.

Two possible lines of future research are suggested. The first would focus on how online reviews from web platforms such as Tripadvisor or Google influence visitors' decisions when planning visits to industrial mining heritage sites and how managers can use this information to attract a non-captive audience. Similarly, studies could be developed to monitor visitor perceptions and experiences at these sites over time to inform improvements or changes to exhibits.

Another point, based on the information obtained, is to investigate the sustainability practices implemented at industrial mining heritage sites and how these practices attract environmentally conscious visitors through web-based opinion platforms.

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# Interpretation of the Lost Architectural Heritage of Guadalajara (Spain) - Its Dissemination and Tourist Promotion

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## Abstract

*Architectural Heritage is part of the Cultural Heritage inherited from the past, which is why its conservation and recovery is important, but so is knowledge of the lost heritage, of those manifestations of which traces or remains remain, forming part of what is the Archaeological Heritage, and even also that of which only descriptions or references remain collected in documentary sources.*

*Regarding the Lost Heritage, although excavations and discoveries are essential as a source of information, other research methods are essential, such as the study of documentary sources, especially graphics, to advance in its knowledge, to know its past, its historical evolution, architectural and urban planning and, consequently, recover its memory.*

*This work aims to advance the knowledge of the disappeared Heritage of the historic city of Guadalajara using documentary sources, mainly graphic ones, to get to know its configuration, precise location and original dimensions, as well as understand the current urban layout, which is a consequence of the spaces in which they were located and often originated. Subsequently, by understanding that they are a public good that should be enjoyed by all of society, transfer the results obtained.*

*It is proposed, for the buildings studied and the road layouts on which they were located, to be able to georeference them, which would allow them to be replanned "in situ", leaving permanent witnesses, which would allow for a better understanding, understanding of the remains that may have been preserved and current urban plots.*

*After that, through the integration of Information and Communications Technologies (ICT), an App was developed, using QR codes, to store the relative information of the buildings, transmitting it from the same place where its traces have materialised.*

**Keywords:** *lost heritage, Guadalajara, transfer, tourism management.*

## 1. Introduction

The purpose of the project object of this communication is the recovery of the memory of the Missing Architectural Heritage together with the urban fabric for which they were conceived or that which resulted as a consequence of their construction, to be transferred in the most direct way possible both to the civil society as well as different interest groups.

This work is proposed for the historic centre of the city of Guadalajara because it is a town that, despite its rich historical and architectural past, is probably one of the Spanish cities that has suffered the most from this type of loss, although it could be developed, in greater or to a lesser extent, in any other population.

### 1.1. Background

As occurs in other cities in the region, there is an almost exact correspondence of what the city of Guadalajara has been until the mid-20th century with what is currently its Historic Center, which has become a consequence of the development that arose from of that moment, in one of its neighborhoods.

Due to this correspondence of centuries, despite the fact that wars, confiscations, religious persecutions, questionable modernisations and even lack of sensitivity have left its architectural heritage very decimated, most of its most notable buildings, still numerous, continue to be found there and Its urban fabric, despite appearing very transformed, continues to distinguish it from other areas or other cities, that is, it continues, at least partially, maintaining its identity features.

Guadalajara was walled since Muslim times. It was triangular in shape and was wedged between two ravines that flowed into the Henares River, where a bridge from the Caliphate era, which is still preserved, crossed it. In the narrowest part between the ravines was the Alcázar (Cuadrado, 2001; Navarro Palazón, 2008), also of caliphal origin, later a Royal residence. Already in the 15th century, despite the existence of free spaces inside the fence, due to the need for new areas in which to locate the population that, due to their activities, had no place within it, a series of suburbs of not much extension.

The interior of the city itself was made up of small buildings located in a labyrinth of small streets. The main ones were those that started from the city gates, which joined together, forming the backbones of the urban fabric. The secondary streets were determined by the spaces between the different buildings. The narrowness of these streets meant that arches and passageways were frequent. The squares were formed by the small widenings that occurred at the meetings between the different streets, so, as was the case in other cities, the largest square, necessary for holding fairs and markets, was outside the wall.

Only in the Renaissance was some urban reform carried out to create larger spaces, as occurred at the initiative of Cardinal Mendoza with the Plaza Mayor demolishing the hermitage of Santo Domingo, the one also created by him between his palace and the Church of Santa María, or the one located in front of the Infantado Palace between it and the Montesclaros Palace.

Also, from this moment on, the defensive doors were replaced by others with more direct access and, in some cases, of a more monumental nature.

The oldest surviving graphic representation of the city of Guadalajara is the one made by Anton Van den Wyngaerde in 1565, commissioned by Philip II (Figure 1). On this date, when Guadalajara reached a population that would not be exceeded until well into the 20th century, the city was still limited to the medieval walled area and a few suburbs.

The representation that Pier Marie Baldi left us of the city in 1668 (Figure 2) shows us the changes it experienced in the following century. In this view, we can see that the image of the city has changed with respect to Anton Van den Wyngaerde's view due to the appearance of new architectural styles with larger buildings and important transformations of the existing ones, however, the city continues to be limited to its Medieval perimeter and the extension of the suburbs that emerged outside its limits remain minimal.

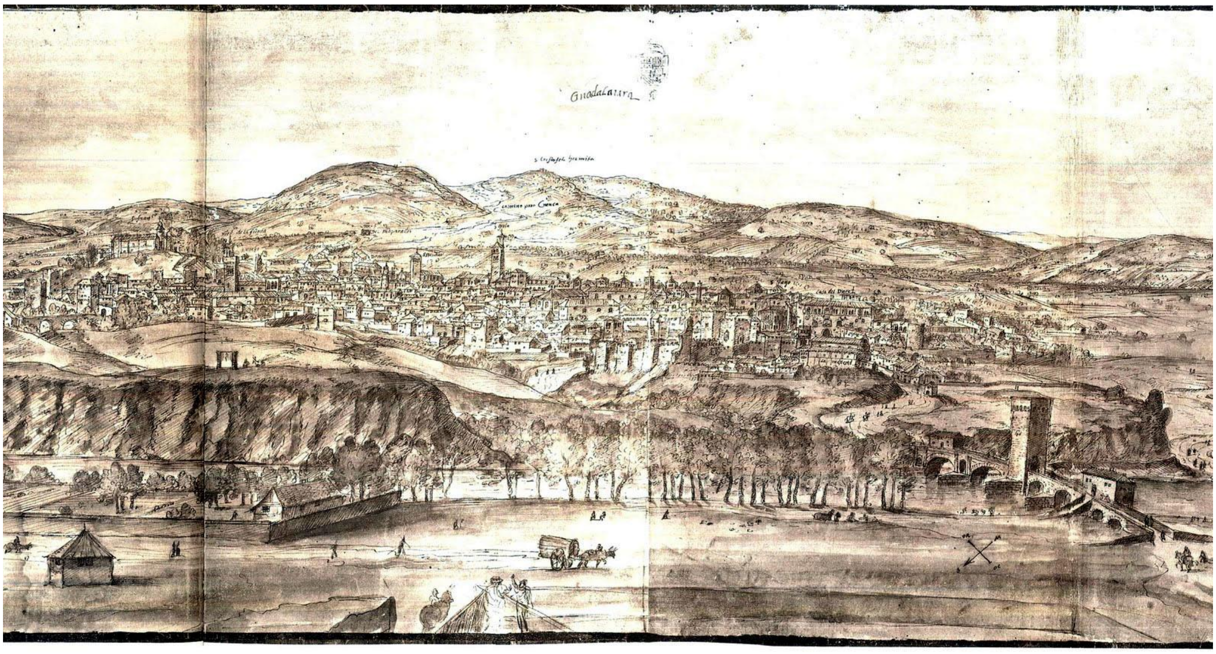

**Figure 1.** Guadalajara 1565. Source: Anton Van Den Wyngaerde (1565)

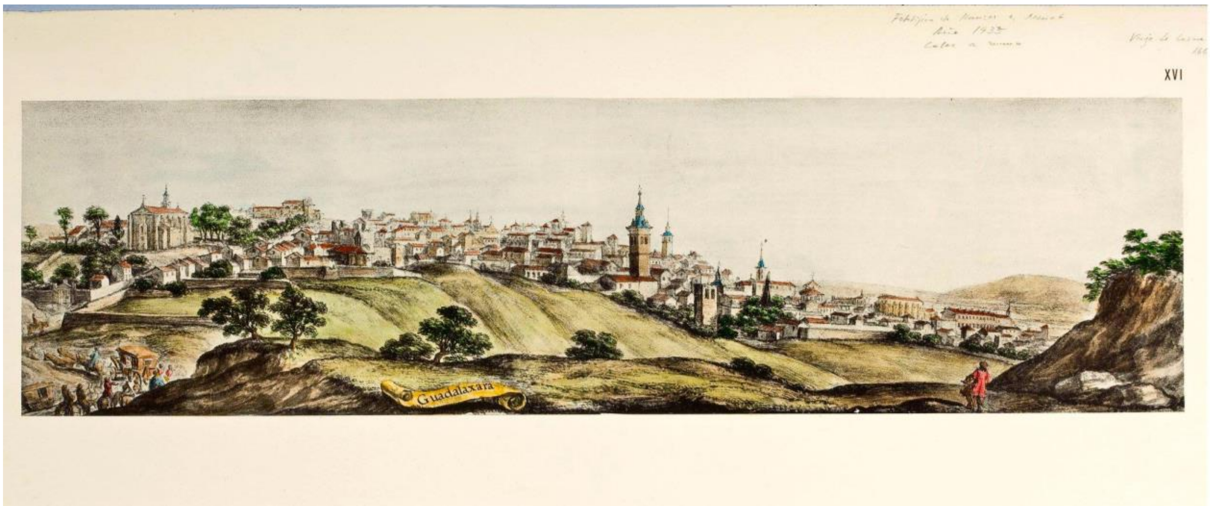


**Figure 2.** Guadalajara 1668. Pier Marie Baldi (1668)

### 1.2. Evolution of the city

The urban evolution of Guadalajara, like that of any other city, is determined by the functions that have been developed there (García Ballesteros, 1978).

The city of Guadalajara is heir to the Islamic population known by the name of "Wad-l-hiyara", which comes from the Arabic words *wadi* and *hiyara*, river or valley of stones and which is where it derives the current name, and *Medinat-al-Faray* or city of *Alfaray* or *Faradj*, a character who in the 9th century was lord of the land of Guadalajara. The Islamic city was born with a clear defensive function, and its military importance comes from its relevant position in the Middle Mark.

After the Castilian reconquest during the reign of Alfonso VI, the Muslim fortress was transformed into a Christian royal palace, which attracted numerous nobility, and the mosques into churches. With the settlement of the Mendoza family in the city, the influence of the city increased, exercising all the functions of the capital. From this moment, and also due to its influence, it served as a residence for a large nobility, which determined the adaptation of the hamlet for this function, which in turn led to the development of other functions.

Already in the 15th century, Guadalajara stood out for the large space dedicated to religious buildings. To its ten medieval parish temples, we had to add four convents of San Francisco and other religious buildings.

The 16th century marks the moment of greatest splendour of the city, mainly serving as the residence of the nobility, six new convents were founded. In the 17th century, the transfer of the nobility to Madrid marked the beginning of the city's decline. Despite this, four other new convents were founded in the city, making it a convent city.

In the 18th century, the War of Succession contributed to the decline of the city. The founding of the Cloth Factory was an attempt to revitalise the city. Also, in this century, with the division of Spain into thirty-one municipalities, the city of Guadalajara was chosen as the capital of one of them.

In the 19th century, the War of Independence caused the closure of the Royal Factory and destroyed a large part of its buildings. With the new administrative division of Spain, Guadalajara was established as the provincial capital (Figure 3).


**Figure 3.** Guadalajara 1860. Francisco Coello

Starting this century, Guadalajara experienced an important transformation that sought its modernisation, a new image of a city more in line with its status as a provincial capital, which at the same time favoured its development. All this was possible and, to a large extent, a consequence of the decrease in the religious function, which allowed the implementation of important interior reforms in the city, which led to a massive loss of what was a very important architectural heritage. If the architectural losses were important, so were the urban planning actions of interior reforms carried out simultaneously. These heritage losses and transformations suffered in the urban layout make it currently difficult to understand the evolution of the city (Trallero, 2018).

Despite the important modifications carried out during the 19th century, in the first half of the 20th century, it continued to largely maintain its character until the approval of the first General Urban Planning Plan. With this plan, without further justification than a poorly understood “modernity” or excessive interests, many of its still existing historic buildings continued to be demolished, which has not stopped happening despite the successive declarations of intentions of the various subsequent Planning documents.

## 2. Objectives

The Architectural Heritage forms an important part of the Cultural Heritage inherited from the past, a Heritage in which the Urban Heritage is also decisive.

This Heritage has been created over the centuries. However, its concept is relatively new since it emerged in the 19th century, motivated by its recognition as a manifestation of the culture and art of a certain era. With the birth of this new concept, concern also arises for its conservation and recovery and even the knowledge of the Lost Heritage of which we have traces or remains that form part of what is the Archaeological Heritage and, in some cases, only references. or descriptions collected from documentary sources.

Research on vestiges that bear witness to other eras is essential. To achieve this, although excavations and discoveries are essential as a source of information, other research methods are essential, such as the study of documentary sources, especially graphics, since this study will allow us to continue advancing in the knowledge of the lost Heritage, to know its past and its historical, architectural and urban development, and consequently, recover its memory.

The purpose of this Project is to obtain new results and advance the knowledge of the missing Heritage of the historic city of Guadalajara using mainly graphic documentary sources (Figure 4) and, with this, get to know its configuration, precise location and original dimensions, as well as be able to understand the current urban layout, starting from the layout in which the studied buildings were located, or created, and, after that, transferring said results because it is understood that they are a public good that should be enjoyed by the entire society.

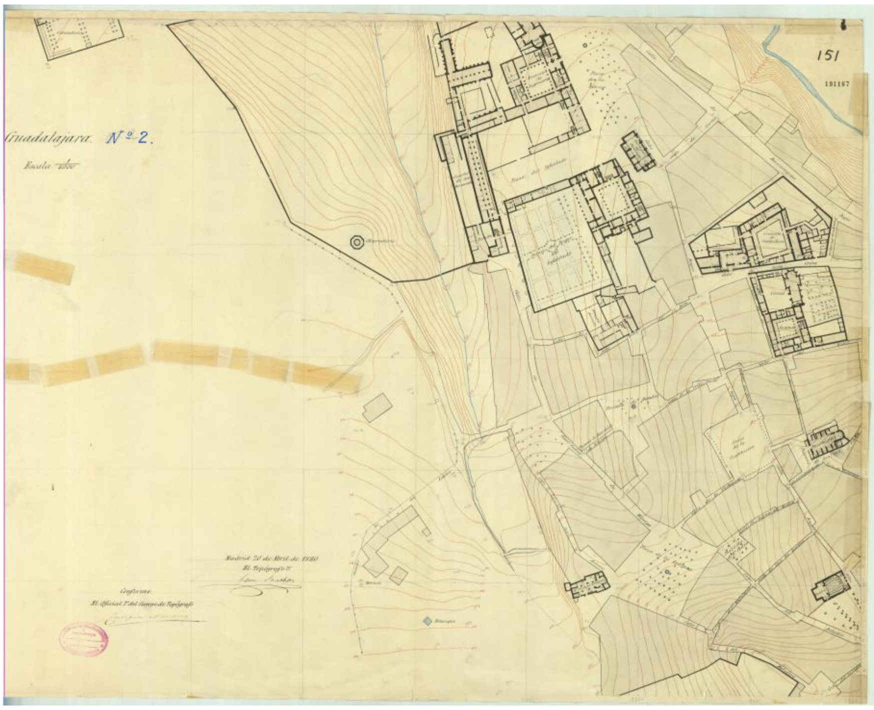


**Figure 4.** Guadalajara 1880. Source: Instituto Geográfico y Estadístico

It has already been noted how the heritage losses served to undertake important transformations in the city's road layout since the 19th century. For this reason, part of the missing buildings were in what are currently public spaces.

In this work, it is proposed to georeference the buildings studied and the road layouts on which they were located, which would allow their rethinking "in situ", leaving permanent witnesses and if an agreement is reached with the Guadalajara City Council, their layout through more or less treatments. less superficial pavements. This will allow us to better understand the buildings studied, the preserved remains and the urban fabrics in which they were located, with layouts that were often originated by them.

The integration of Information and Communications Technologies (ICT) is also intended develop an App that, through the use of QR codes, stores the relative information of the buildings accessible from the same place where their traces have materialised.

Therefore, the transfer of the advances achieved in the knowledge of the disappeared heritage of the historic centre of Guadalajara to society has been established as a priority line, transferring the benefits of ICTs to citizens.

The “in situ” materialisation of the results obtained and the transfer of the rest of the information obtained thanks to the QR codes will allow both civil society and the different interest groups to understand “in situ” some preserved remains, such as the apse of the old church of San Gil (Trallero, 2015a).or the remains of the Medieval Gate of Bejanque (Trallero, 2001), also mutilated buildings, such as the Conventual de la Piedad Temple (Prentice, 1970; Trallero, 2020) (Figure 5), and buildings that have completely disappeared (or perhaps not so much) such as the old parish temples of Santiago (Gamir Gordo, 2014; Trallero, 2015b; Trallero, 2015c) or San Esteban (Sánchez Mariño, 1994), as well as the current layouts of public spaces (Trallero & Trallero, 2024), streets modified after demolitions or squares that emerged of old parish cemeteries (Cuadrado, 2006) or the layout of the medieval wall. To do this, as has already been pointed out, since they are public spaces most of the time, an agreement will be established with the City Council.

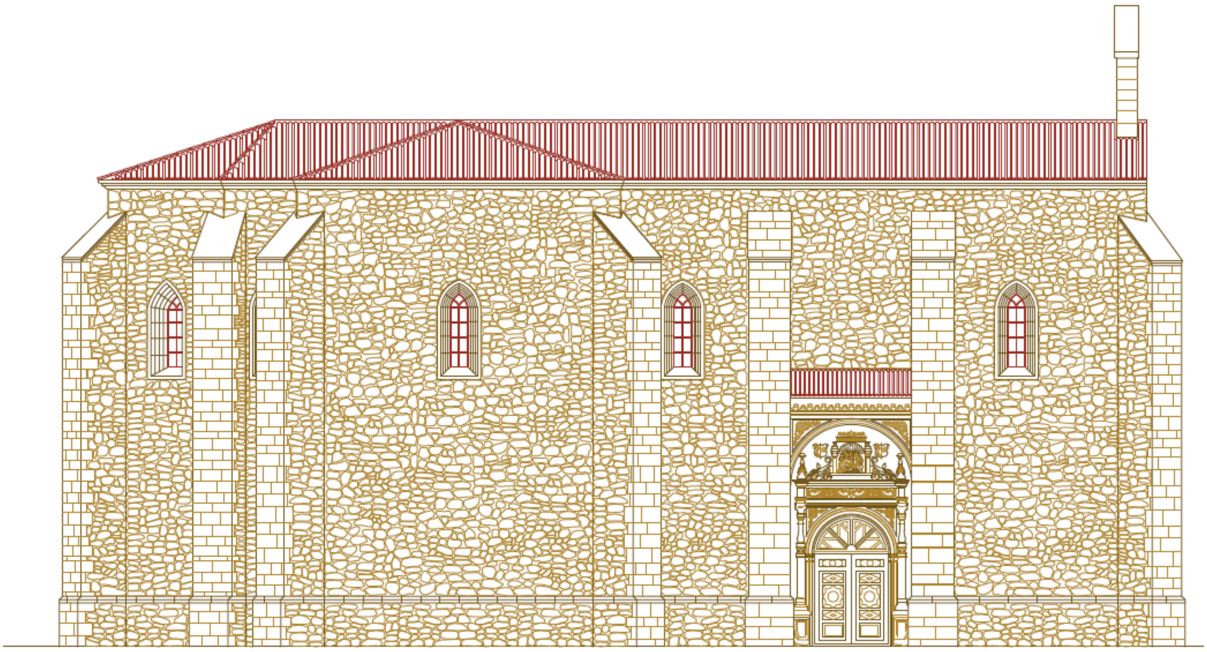

**Figure 5.** Restitution of the facade of the Church of La Piedad. Drawing: Mireya Ibarra Pérez

## 3. Methodology and Work Plan

### 3.1. Investigation of missing buildings and road layouts

Starting from documentary sources, its original layout and volume will be studied and determined to the extent possible. To do this, fundamentally, information will be collected in the Municipal Archive of Guadalajara (AMG), the Provincial Historical Archive of Guadalajara (AHPG), the General Administration Archive (AGA), the General Military Archive (AGM), the Archive of Castilla La Mancha (ACM), the Historical Cadastre, the historical planimetric minutes of the National Geographic Institute, the Center of Photography and the Historical Image of Guadalajara (CEFIHGU) with its different collections, information from Museums such as the Guadalajara and the National of Sculpture of Valladolid, Libraries, as well as the works of authors such as Núñez de Castro (1993), Catalina (1911) or Layna (1941, 1943). The information contained in newspaper archives and private collections of graphic documentation is also important.

### 3.2. Georeferencing of elements

In the office, using the information from the map legend, where it exists, with respect to the geodetic reference system, they must calculate the cartographic transformation parameters that allow the current location of the buildings in the current geodetic reference system, ETRS89 and UTM30 projection. Cartographic minutes that do not have SGR or that are flat will be georeferenced and adapted to the Earth's curvature through the use of common points and the geodetic applications program, PAG of the IGN, for the change of datum transformation.

### 3.3. Location of elements in their true magnitude and position in the city

Once the coordinates that delimit each of the buildings in the official SGR are known, using GPS technology and the use of topography equipment, supported by the geodetic network of the Guadalajara City Council, we will proceed to the physical delimitation on the ground of each building. The most appropriate signalling method will be analysed on a case-by-case basis.

### 3.4. 3D modeling of elements

At the same time that the coordinates that delimit each of the elements are calculated, the investigation, based on images, drawings, and descriptions, will begin the analysis for the reproduction of the vertical walls. For the extrusion of elements, a single program, yet to be determined, will be used for all buildings. Initially, the use of SketchUp, 3DMax, Blender, CATIA and SolidWorks will be assessed.

### 3.5. Web and QR dissemination

A web page will be able to collect all the progress of the project, where you will have access to 3D virtual models, a historical plan with georeferenced constructions, texts, speeches, historical photographs and all the relevant documentation that is generated. The QR codes that can be seen on site, in each place in the city, will redirect to the appropriate place on this website to expand the information.

### 3.6. Virtual and augmented reality

The 3D models generated for each building will be transformed into the appropriate format that allows visualisation through augmented reality first, representing the façade of the building, and if sufficient information is available, internal modelling of the building will also be carried out. Some buildings allow an immersive visit using 3D glasses, such as Oculus Rift or Samsung VR.

## 4. Results and Conclusions

### 4.1. Expected scientific-technical contributions

First, a recovery of the city's heritage that was considered lost, a critical and rigorous vision, with the perspective that time gives, of how the historical vicissitudes and the different urban planning decisions of the last hundred years have modified and conditioned the landscape of the city.

In the technological field, the aim is to model historical buildings in 3D, which will require the computer development of new architectural elements and textures that represent those that were used then. Themodelled elements will be incorporated into virtual reality and augmented reality programs, which allow passers-by an immersive visit.

### 4.2. Impact of the project on social development

The project, although proposed for the historic city of Guadalajara, can be exported to other towns. The first impact will be to be able to discover through the direct transfer of the results what the architectural and urban development of the city has been, something that is currently difficult to understand for a large part of society. It will boost tourism in the city of Guadalajara, but since it is tourism in addition to cultural and technological, not only the areas where there are currently visitable elements will benefit, but the entire city. Guided tours can be created through the different architectural elements that are recovered by specialists in the history and heritage of the city.

### 4.3. Impact of the project on cultural heritage

The main objective of the project is the recovery of the cultural heritage of the city of Guadalajara and making it available to citizens. Unlike other projects where the dissemination of results is carried out through activities that we can classify as specific, such as exhibitions, conferences, or publications,whose scope is limited to a small number of people located in interest groups; in this project, other more innovative methods will be used that we could classify in the broadest sense, as immersive, so that it will be impossible for any citizen or visitor to walk around the city without observing the results obtained.

To do this, two lines of research will be worked on. The first is through physical signage on the pavement, where the space occupied by the architectural elements under investigation will be delimited. The observer will be able to walk through the interior of the building and, through information panels, see the appearance presented, its history, and more. These panels will have QR codes that redirect to a web space for the dissemination of the project and where images, videos and narrated texts of the project can be seen. On the other hand, 3D modelling techniques and integration with augmented reality will be used, in this way, the viewer will be able to see the reality of the territory captured with their own phone, the building in three dimensions, with its true magnitude and position. It is intended to return to Guadalajara, making the entire society participate in it, its lost heritage wealth.

### 4.4. Possibilities for technological transfers

First of all, it must be emphasised that the project itself, although proposed for the historic city of Guadalajara, is transferable to another town. In addition, new avenues of research, such as 3D modelling and virtual and augmented reality laboratories, which methods can be extracted that will allow the application to current buildings and their integration with BIM models.

### 4.5. Avoid new losses of architectural heritage

Finally, we would like to point out that heritage losses may also be reduced, such as those that are a consequence of actions in buildings that currently do not have protection (or even with it) but that may have house remains or important parts of unknown buildings, or that are believed to be completely lost, of remains altered by actions on infrastructure or unjustified modifications to the urban fabric.

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# True-to-life modelling of Auteur architecture of the 20th century. From BIM modelling to webGIS fruition

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***Abstract***

*This study explores the concept behind the modelling and digital fruition of 20th-century auteur architecture, with a specific focus on the Santa María Micaela residential complex designed by Santiago Artal Ríos in Valencia (ES). The research uses BIM techniques to create a detailed digital representation of this architectural landmark, facilitating the integration of different historical data sources and providing a comprehensive understanding of the building's original design intent, construction methods and subsequent modifications.*

*The Santa María Micaela residential complex serves as a case study to explore the potential of H-BIM in architectural heritage conservation. The 3D model of the complex was created after an in-depth data collection study, which involved archival research and an accurate on-site survey.*

*In addition, the study extends the utility of BIM models by integrating them with webGIS. This integration enhances accessibility and interaction, allowing a wider audience to engage with the digital model. Allowing the users to navigate the model, retrieve detailed information about various elements, and analyse the architectural and historical context of the complex.*

*The results highlight the value of combining BIM with webGIS technologies in the preservation and dissemination of architectural heritage, helping to preserve the physical and intangible aspects of historic buildings but also facilitating access to heritage information.*

*This study aims to be a preliminary approach that explains how contemporary digital tools can breathe new life into 20th-century architecture, ensuring that its legacy will endure for future generations, contributing to the wider discourse on digital heritage conservation and advocating the adoption of advanced modelling and visualisation techniques in the conservation of modern architectural icons.*

***Keywords:*** *digital twin, BIM, webGIS, auteur architecture.*

## 1. Introduction

This study investigates the use of Building Information Modelling (BIM) and Geographic Information Systems (GIS) in the digital representation and preservation of 20th-century auteur architecture, with specific attention on the Modern architecture complex recognised in the DO.CO.MO.MO Ibérico catalogue in the register of *"La vivienda moderna" (*Figure 1) and specifically focuses attention on the Santa María Micaela residential complex designed by Santiago Artal Ríos in 1958 and constructed in 1961 in Valencia, Spain. This complex exemplifies how these architectural styles aimed not only at building new flats but also at creating communal spaces without compromising on design and aesthetics. The design approach is a masterful combination of Vitruvian principles, i.e. *firmitas* (strength), *utilitas* (utility), and *venustas* (beauty), which are now widely recognised and appreciated globally.

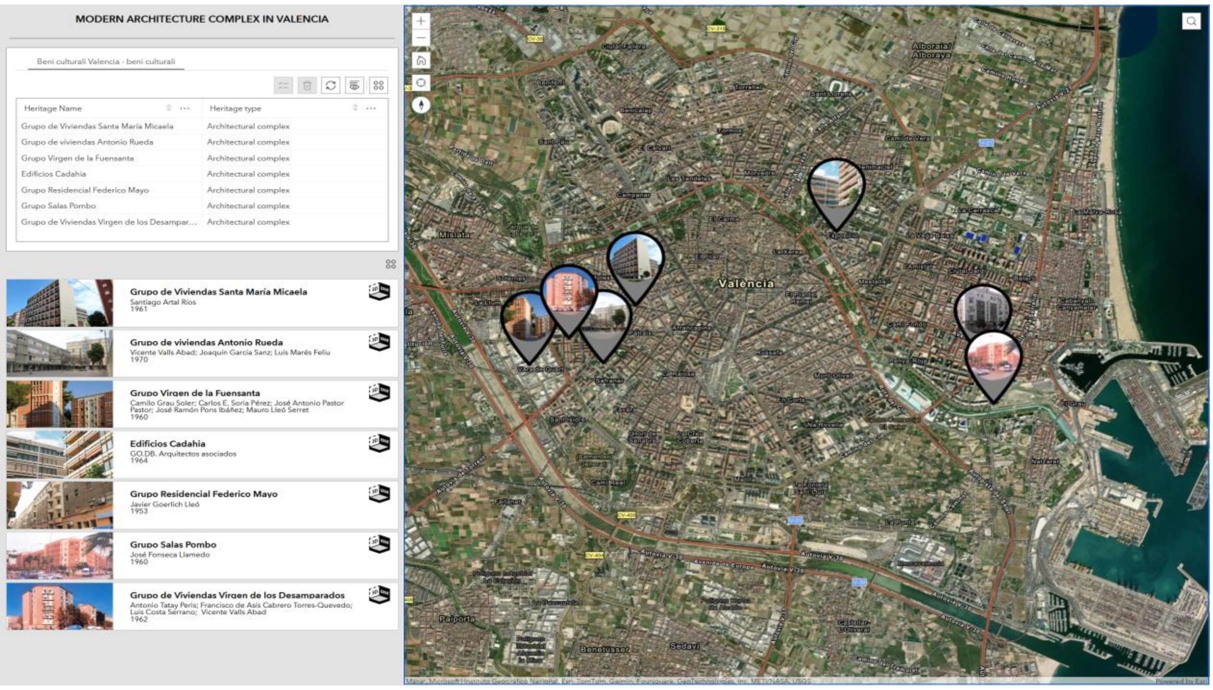


**Figure 1.** First web interface - identification and presentation of architectural complexes. Source: Angileri (2024)

These buildings were all constructed in the period between the 1950s until the end of the 1960s. Modern proposals are the result of rational approaches determined by the functionality of the space, the solar cycle, concerns about ventilation, hygiene and comfort, and the minimisation of technical elements in new buildings. At that time, however, there were no current calculation tools and aids, only certain approximations obtained through basic calculations, which, based on certain constants such as orientations, provided data on which elements to use and how to use them. Small diagrams were drawn on the then-famous graph paper, leading to coherent proposals with a certain design and construction logic.

The building that is the case study of this work takes part in the *"Plan de Mutualidades Laborales"* developed during the Franco regime; their magnitude and very short execution time were already boasted in the regime's own propaganda and is currently recognised, which exhibits the best architecture of the Spanish modern movement usually characterised for their sensitive attention to collective needs, a programmatic methodology, a technical efficiency and a critical assimilation of modernity. The case of collective housing is where this architectural style was most applied, modifying the style that had been established up to that time and opting for it in the creation of new buildings. In this way, they opted for the modulation of the façade, the liberation of the ground floor to create spaces for social recreation with vegetation and the use of materials such as reinforced concrete, which give it an exemplary character in Valencian architecture.

The Santa María Micaela building is the first project in Valencia Santiago Ríos (Pozo, 2004). The complex is located on the corner of Pérez Galdós and Santa María Micaela streets, where is also located the main access in a site that belongs to the extension of the Valencia General Plan of 1946 with a buildable depth of 46 metres. It is organised in three buildings with 138 dwellings. The architect offered a solution for widening a closed block, in which he introduced a coherent alternative of occupation based on the grouping of three blocks around a free area for the use of the community and carefully treated in all its details, with ponds and walkways. As a critique of the traditional planning of the city, the fragmentation of buildings is perfectly articulated to favour orientations and views, centralisation of common services and housing density with non-speculative use of the land.

The strict compositional geometry is subtly challenged by the diverse nature of the materials and by a chromatic animation with neoplastic roots: red panels under the windows, yellow brick closures and blue tiles for the terraces.

The use of BIM in the conservation and restoration of heritage buildings offers several important advantages for architects and heritage conservators (Dore & Murphy, 2022). First, accurate documentation of the building's structure and architectural details allows for a better understanding of its history and evolution, which in turn allows for more informed decisions to be made about the conservation and restoration of the building. The digitalisation techniques combine various historical data sources into a detailed digital model, enabling a comprehensive understanding of a building's original design, construction methods, and subsequent modifications (Fregonese et al., 2021).

This integration of historical data and advanced modelling techniques is crucial for the effective preservation of architectural heritage, ensuring that these cultural landmarks are accurately represented and sustainably maintained for future generations.

The integration of BIM in architectural heritage conservation is particularly relevant for structures of significant historical and cultural value, as it facilitates not only the preservation of physical attributes but also the intangible aspects, such as the socio-cultural context and design philosophy. The Santa María Micaela complex, renowned for its innovative mid-20th century design and socio-cultural significance, serves as an ideal case study to explore the capabilities and benefits of BIM in documenting and preserving such heritage. By leveraging archival research, on-site surveys, and advanced digital tools, this research aims to create a precise 3D model that can serve as both a preservation tool and an educational resource. This approach underscores the importance of incorporating modern technology in heritage conservation, providing new avenues for research and public engagement (Banfi et al., 2020).

GIS plays a crucial role in the documentation and inventory of heritage sites, providing spatially accurate databases that include detailed information about the location, condition, and historical significance of buildings and monuments. This capability is relevant for creating a thorough registry that informs preservation planning and decision-making. Furthermore, GIS facilitates condition assessments of heritage structures by enabling the visualisation and analysis of spatial data related to structural health, environmental conditions, and potential threats. This kind of spatial analysis helps to identify areas that require immediate intervention, ensuring timely and effective conservation efforts. The integration of GIS with BIM enhances data management by assisting the management of both spatial and building-specific data within a unified framework. This integration enables improved analysis and visualisation techniques, such as 3D GIS, which can visualise the spatial context of a heritage. Such combined capabilities support comprehensive analyses, including impact assessments, environmental simulations, and structural evaluations. Interdisciplinary collaboration is greatly facilitated by the combined use of GIS and BIM.

## 2. Aims and objective

The primary aim of this study is to demonstrate the effectiveness of contemporary digital tools, specifically BIM, in improving the preservation and understanding of 20th-century architectural heritage. By focusing on the Modern architecture complex recognised in the DO.CO.MO.MO Ibérico, the research seeks to achieve several interconnected objectives. Firstly, it aims to create a detailed and accurate digital model of the complex that integrates various historical data sources, including architectural plans, photographs, and archival documents. This model will serve as a comprehensive repository of information, documenting the original design, construction techniques, and subsequent modifications of the building. Secondly, the study aims to analyse this data to gain deeper insights into the architectural and historical context of the complex, highlighting its significance in the broader landscape of mid-20th-century architecture. Thirdly, the research extends the utility of the BIM model by integrating it with webGIS technologies, enhancing accessibility and interaction.

This integration allows a broader audience, including researchers, educators, and the public, to engage with the digital model, navigate through it, and retrieve detailed information about various elements. Additionally, users can analyse the architectural and historical context of the complex, making it a valuable tool for education and public outreach. Ultimately, the study aspires to contribute to the broader discourse on digital heritage conservation, advocating for the adoption of advanced modelling and visualisation techniques in preserving modern architectural icons. This approach ensures that the legacy of such structures is preserved for future generations, fostering a deeper appreciation and understanding of 20th-century architectural heritage (López et al., 2020; Bruno et al., 2021).

## 3. Methods and procedure

### 3.1. The approach to the digitisation process and the motivations behind the use of BIM/GIS software

GIS and BIM are two digital technologies that are widely used in the architecture, engineering and construction (AEC) sector but were originally designed to work in two different areas. GIS is a system for the creation, management, analysis and mapping of geospatial data, merging and combining spatial information with tabular data archives in a single system, widely used for the analysis of the geospatial characteristics of large areas and for the analysis of environmental data and natural hazards, while BIM is a system based on enriched 3D models for building management, combining many aspects related to building design, from architectural conception to the definition of installations.

The implementation of integrated BIM/GIS systems offers important perspectives for the management, conservation and valorisation of the cultural landscape and architectural heritage, as is widely recognised by the numerous academic studies on the subject and the important technological implementations by many software houses in the sector. It offers the possibility of integrating data from numerous sources, from instrumental to archival and beyond (Colucci et al., 2023;  Misilmani et al. 2024)

The approach to the development of the materials described in this article is based on an in-depth study of state of the art and combines the most interesting insights gained from reading and studying other research in the field with a targeted approach by the entire research team that has led to the development of a web platform that aims to go beyond certain standards and features characteristic of the most widely used GIS platforms, aiming at a characterisation of information that can offer easy-to-read screens, reducing as much as possible the use of simple 'points' to denote elements and aiming at the realisation of a 3D environment.

In particular, the chain of procedures that led to the production of the material shown in the following article (Figure 2) began with a study of the architectural assets and their significant characteristics through the collection of archival material and then, in the case of the Santa Micaela complex, the ability to associate original material produced during a series of inspections.

This material made it possible to create a BIM model for this structure, in which, in addition to the architectural characteristics, the performance characteristics were added, and for the other works, the GIS cataloguing process was carried out till the realisation of the webGIS environment.

The integration and enhancement of GIS and BIM not only optimise the management and conservation of historical and cultural sites but also pave the way for innovative applications in the AEC sector. These technologies set new standards for future technological implementations and demonstrate the significant benefits of merging geospatial and architectural data for comprehensive analysis and decision-making.


**Figure 2.** The phases of research and modelling, from knowledge to modelling to web use. Source: Angileri (2024)

### 3.2. The study of the architectures and the creation of a true-to-life BIM model

The knowledge phase of the project was based on Prof. Luis Manuel Palmero's experience of the sector of architecture and his knowledge in the city of Valencia, which allowed us to identify a series of works with similar characteristics, not only from the same construction period but also from a similar architectural style, which is now internationally recognised and referred to by the DO.CO.MO.MO. as modern social housing. These architectures are largely characterised by their simple materials, such as concrete and brick, which are often not covered with plaster or stucco but are left facing the work (Bernardo, 2023).

Numerous renowned architects - Carvajal, Sert, Coderch, Corrales y Molezún, Moreno Barberá – among others following the rationalist principles of the time gave life to new neighbourhoods or settlements of high compositional and formal quality. The single-family or farmhouse typology was flanked by the so-called ‘tower’ constructions with duplex housing in a cooperative regime. This building model, developed and perfected over time, solved the problem of housing demand and land consumption without neglecting aspects related to residents' comfort and well-being. In fact, following the dictates of the hygiene movement and new knowledge in the health field, the design also considered aspects aimed at improving comfort conditions, i.e. exposure, solar radiation of the rooms and natural ventilation (Barona, 2009; Bernabeu Mestre, 2009).

The BIM model was created using ACCA's Edificius software (Figure 3), which, unlike other products in the sector, has begun to include specific functionalities for the HBIM characterisation of the model among its commands. The model of Santa Micaela was created based on archival data found on the work, to which must be added some information found during a series of direct surveys of the work and one of the apartments in the complex. In particular, during these surveys, it was possible to carry out a series of analyses and to find high-resolution photographs of the characteristic surfaces of the work, especially the surface of the concrete, the facing bricks and the various mosaics that characterise both the external and internal elements of the building.

The use of this type of approach made it possible to conform a model as comparable as possible to the real architectural organism both from a geometric dimensional and technical point of view, obtaining a true-to-life model. The benefit of this approach, however, must always be weighed against the actual application, especially considering that the modelling and construction time of the model is largely influenced by the level of detail to be accomplished and the complexity of the building to be modelled.

Moreover, many of the features that make the model realistic are often not yet well exported to different platforms and therefore, the transition from BIM software to the GIS platform greatly impoverishes the quality of the implemented model.

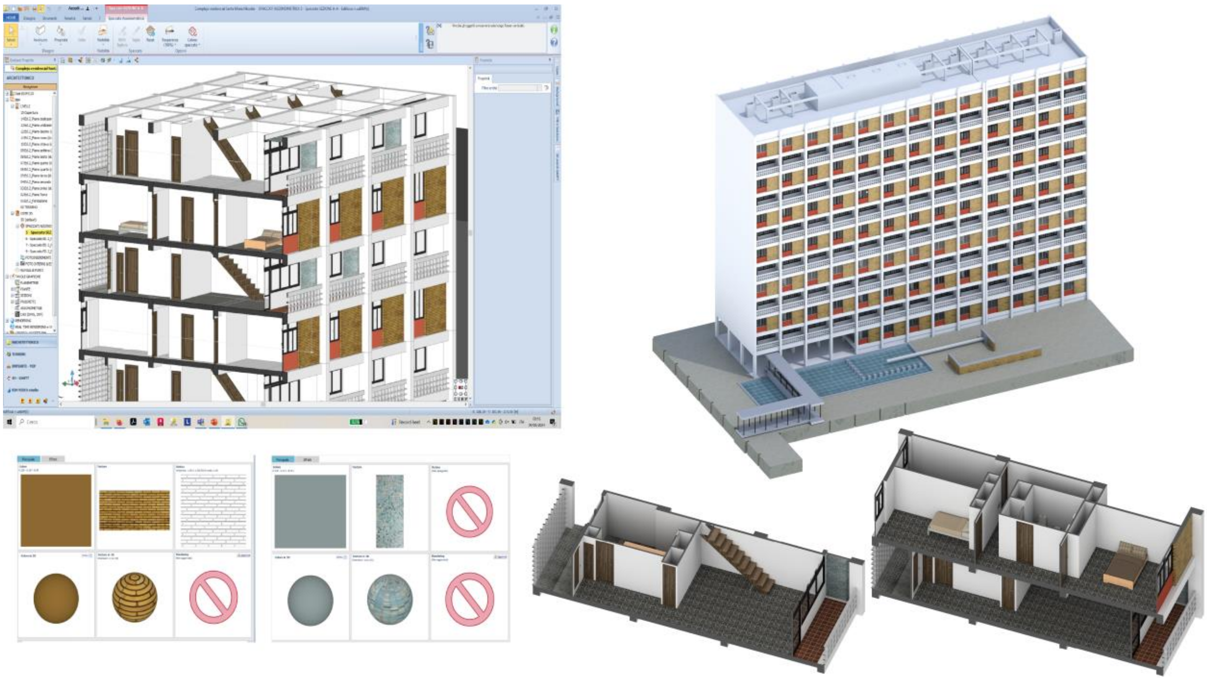

**Figure 3.** Edificius interface and examples of photorealistic exported views of the building. Source: Angileri (2024)

### 3.3. The export to webGIS-based platforms and the configuration of the 2D/3D digital experience of the projects

The first step in the implementation of the virtual fruition environment is the definition and configuration of the area of interest and the significant data of the GIS environment.

For this purpose, a data design process was initiated to define the significant information needed to characterise and identify the works. The areas identified were divided into the following six categories:

- Heritage Identification
- Historic identification
- Architectural information
- Extended information
- Heritage protection
- Attachment and External link

The software used to manage and implement the GIS environment is from the ArcGIS software house. This includes the on-premises PRO version for managing BIM models and pre-configuring fields and icons and the online version for managing and publishing to webGIS systems.

The BIM model, modelled and characterised as shown above, was exported in .ifc format, an open-access format that allows the file to be used within other software. Once the model has been loaded into the GIS platform, the first operation performed on the file is to georeference the file and position it correctly according to the geographic reference system.

After the georeferencing activity has been completed, it is necessary to carry out the process of creating and exporting a georeferenced 3D file used by ESRI software for sharing and use; the format is called Esri Scene Layer Package or ‘slpk’ and to create it is necessary to launch the create Building Scene Layer Content command.

To develop the web application or website, ArcGIS Online's Experience Builder was used. This ESRI product allows the creation of 2D and 3D web applications that integrate spatial data and 3D models. Once data is published in ArcGIS Online, it can be visualised online. To do this, it is first necessary to import the materials made on ArcGIS Pro and in particular:

 

The 2D elements identifying the building complexes are uploaded directly into the online system with a direct connection process, which leads to the generation of a 'Feature layer' containing both the graphic and the computational data of the works. With it in the realisation screen called Map Viewer, it is possible to configure what will become the actual base map. In this screen, it is also possible to define and characterise the pop-up screens that open when the icons identifying the complexes are touched.

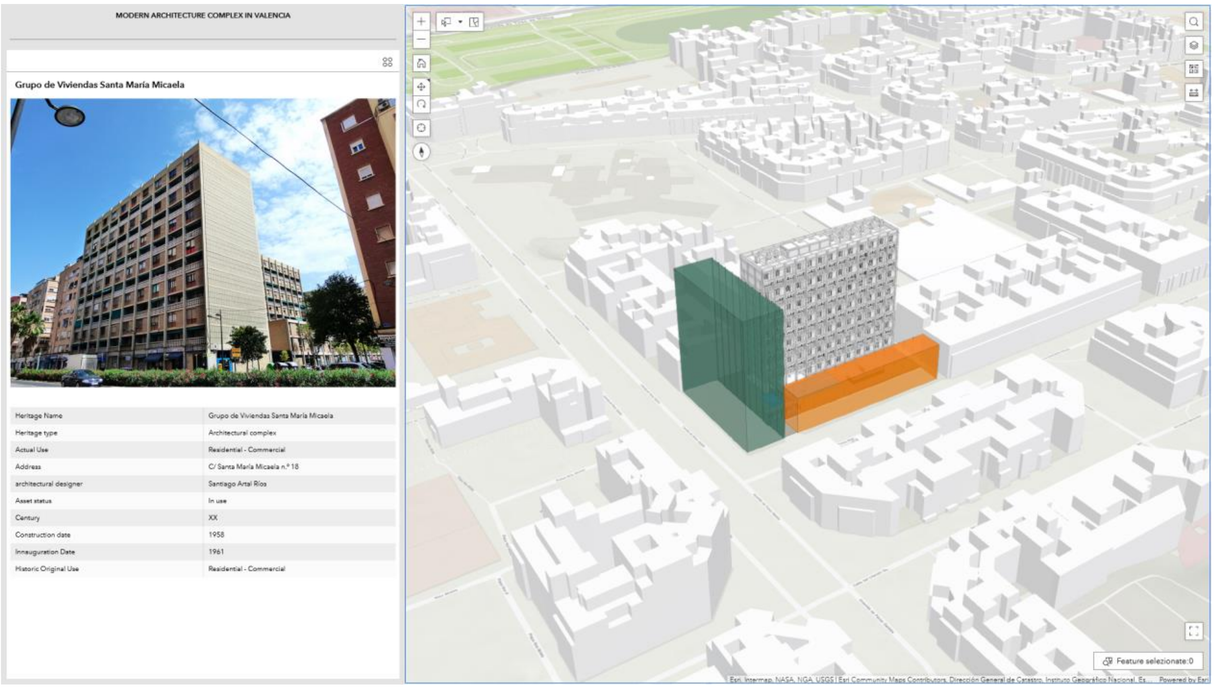


**Figure 4.** Second web interface -. 3D interface with content integration from BIM software. Source: Angileri (2024)

Regarding 3D content, the process is similar; the slpk file, once uploaded online, is uploaded into a Web Scene, which differs from the Web Map precisely because of the possibility of connecting inspectable and configurable three-dimensional data in addition to 2D data. In the Web Scene interface, it is possible to interact with the loaded BIM model and is also given the possibility of interacting with it by being able to filter the various levels that make up the structure or through vertical and horizontal section planes, thus giving the possibility of an exploratory tour of the work.

The last step of the work involved the creation of the WebGIS, and for doing this, the tool used was ArcGIS Experience Builder, which is a configurable solution for creating web apps without writing code. The tool gives the user the opportunity to choose an already prearranged template and create an immersive web experience for the audience by unifying web maps, apps, pages, interconnected widgets, and both 2D and 3D data through a flexible drag-and-drop interface.

Three types of interfaces were developed. The first (Figure 1) shows the area on which the works insist and gives the possibility both by selecting a field in the table and by selecting an element in the list to zoom in automatically, which allows a closer view of the area on which the selected good insists, clicking instead on the icon on the map will display the popup window, in which some of the significant data of the work have been reported.

To access the second type of screen (Figure 4), only it is needed to click on the 3D BIM icon next to each building on the list. This will take you to the 3D screen that contains not only the imported BIM model but also the reconstruction of the volumes of the buildings surrounding the building.

The last screen (Figure 5) is accessible after tapping the "Attachments" button located below the project card, which is present in the second interface. From there, it will be possible to view various elements divided into three categories: drawings, documents, and photos. These elements allow interaction with the documents used in the research and study phase, which were used as sources, particularly for the creation of the 3D model.

The final webGIS designed is a simple tool that provides an overview of all the heritage architectures of interest, helping the user to locate and contextualise each element first in a 2D map of the city of Valencia. This map acts as a point of access to the elements, providing little information and basic search and inspection tools.

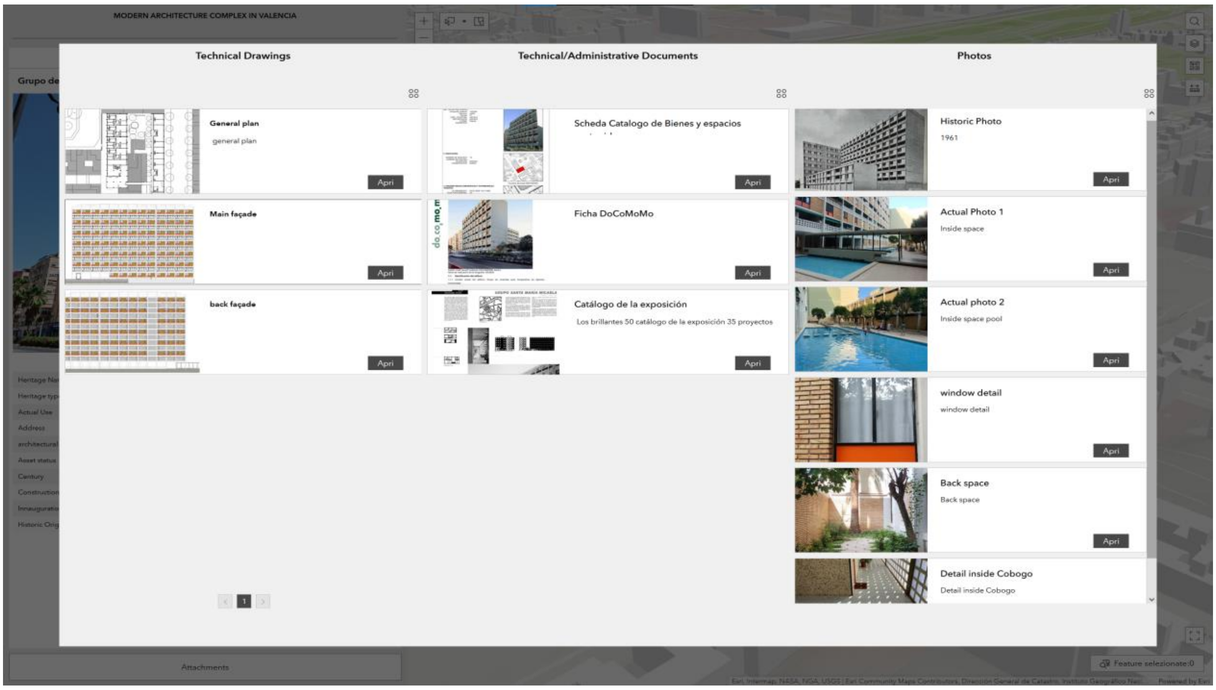


**Figure 5.** Third web interface - presentation of annexes by drawings, documents and photos. Source: Angileri (2024)

## 4. Conclusion

At present, the operational relationship between digital tools, in this case BIM and GIS/WebGIS, allows us to make a very significant advance in the management and knowledge of our buildings and our architectural heritage, as well as urban and landscape heritage. These tools, aided by complementary computer support, provide a series of parameters applied to the building itself, providing knowledge from a holistic point of view and application in various fields such as design, social or tourism.

A few years ago, the previous lack of software to be able to know the behavior of the building over time by rationalist architects was solved by a variety of software adapted to the building's comfort resources. At present, the HBIM as a more specific element for the phase of geometric knowledge and the history of the building, through the evaluation, the state of conservation of the materials, a tool that offers a three-dimensional catalogue oriented to the documentation and planning of maintenance tasks.

This previous one, with the incorporation of data from GIS, will allow a deeper knowledge of our building, enriching it with information that allows a more effective management and calculation of the impact in terms of mobility, environmental information, heritage as well as existing infrastructures.

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