Doi: https://doi.org/10.4995/HEDIT2024.2024.17799

# 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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How to cite: López-González, C., Viñals, M.J. & García-Valldecabres, J. (2024). 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). In *International Congress proceedings: International Congress for Heritage Digital Technologies and Tourism Management HEDIT 2024*. June 20th – 21st, 2024. Valencia, Spain. https://doi.org/10.4995/HEDIT2024.2024.17799

## *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.

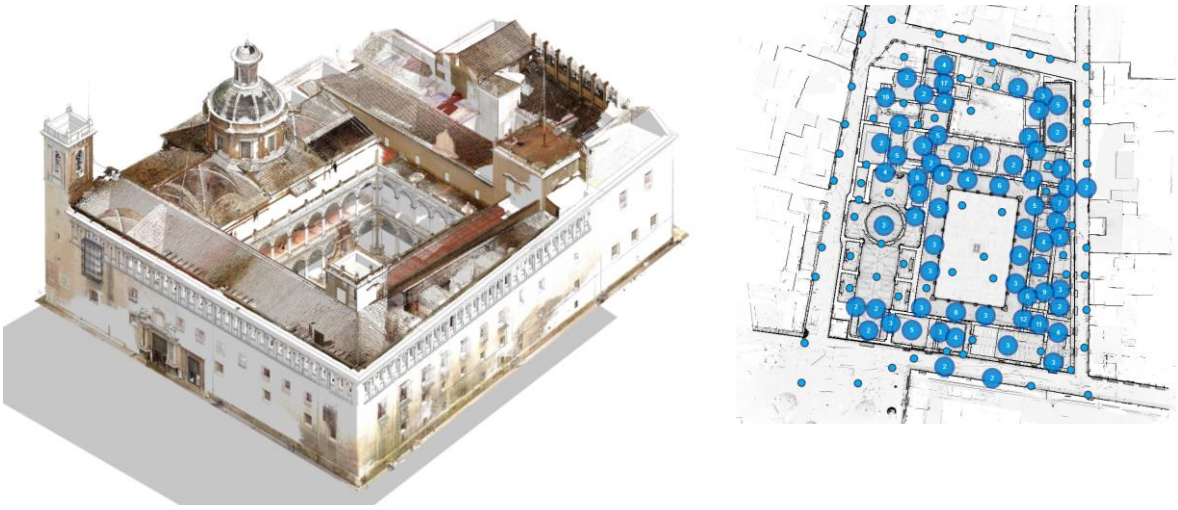

**Figure 6**. Left. Perspective of *El Patriarca* extracted from the point cloud. Right. Scan positions of *El Patriarca*. Source: Rolim, R.

**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).

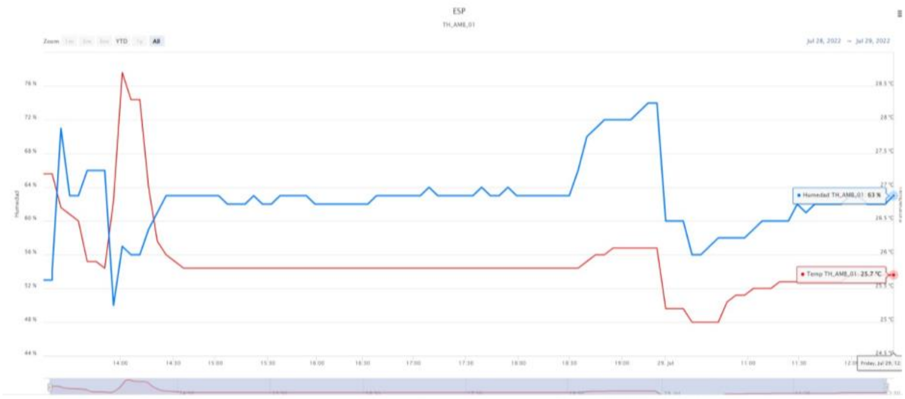

**Figure 8**. Graphs of humidity and temperature in the month of July in the Holy Chalice Chapel (*Cathedral* of Valencia)

### 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.

## 5. Funding

This research was funded by the project “Analysis and Development of HBIM Integration into GIS for Creating Cultural Heritage Tourism Planning Protocol” (ref. PID2020-119088RB-I00), funded by the Ministry of Science and Innovation, Government of Spain.

## 6. Acknowledgments

The authors of this work would like to thank José Verdeguer and Carlos Gener of the *Valencia Cathedral*, Jorge Nava and Elena Salvador-García from *San Juan del Hospital* and Juan José Navarro and Miguel Navarro from *El Patriarca* for their support in this project. We would also like to thank Botao Li for his support in the translation of this work.

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