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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.

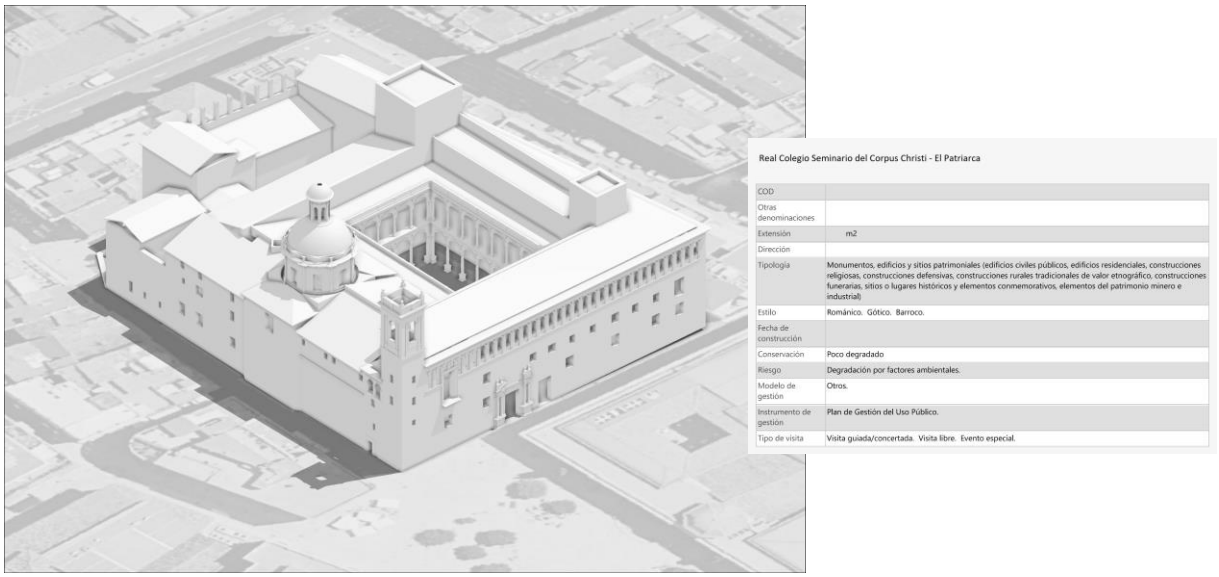

Figure 1. Example of an HBIM model of a building along with its data sheet in ArcGIS. OLOD3, LoD500.
Source: Own elaboration.

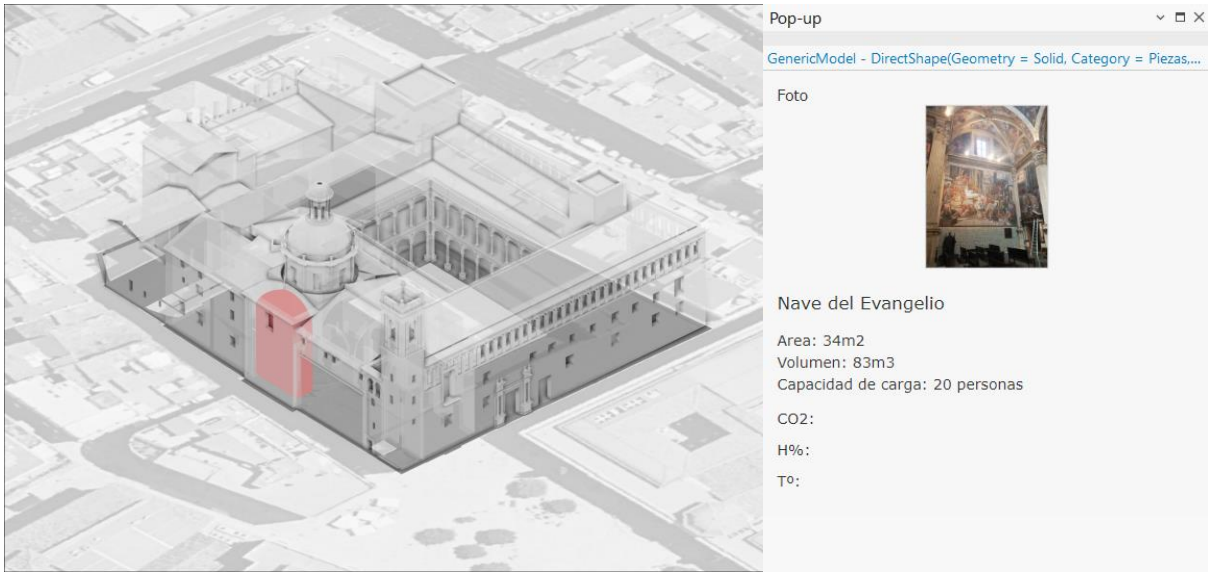

Figure 2. Example of an HBIM model highlighting a room along with its data sheet in ArcGIS. ILOD1, LoD500.
Source: Own elaboration.

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.

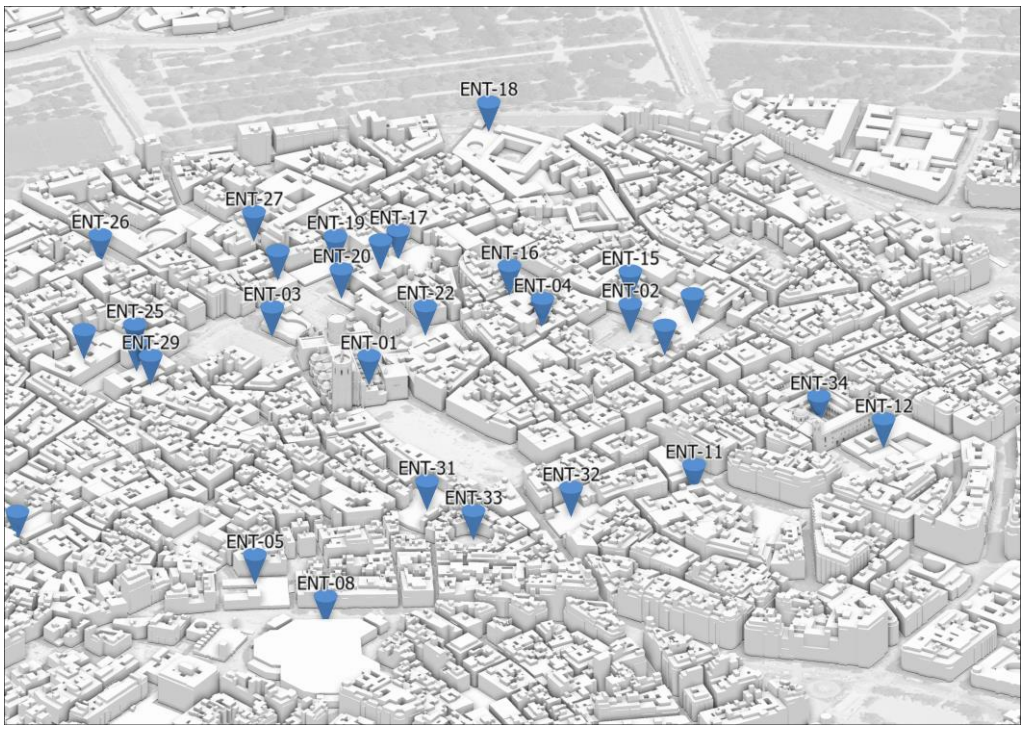

Figure 5. Example of OLOD1 building context in ArcGIS where points elements with information about points of interest were added. Source: Own elaboration.

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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