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GIS-HBIM applications for the analysis and management of cultural landscapes: a case study of the historic centre of Tiradentes, Brazil

The integration of Geographic Information Systems (GIS) and Historic Building Information Modelling (HBIM) has emerged in recent years as a promising methodology for the analysis and management of cultural heritage, particularly with regard to historic sites and cultural landscapes. This article explores the potential of combining these technologies to provide a more comprehensive and relational understanding of such assets, incorporating spatial, architectural, historical, perceptual, and symbolic data and indicators. Using as a case study the cultural landscape associated with the historic centre of Tiradentes, Brazil – characterised by its rich cultural heritage and the presence of the São José Mountain Range, and currently subject to processes that threaten its proper conservation – the study applies a methodology composed of four main stages: data collection; data modelling; definition and spatialisation of indicators related to local cultural identity; and cross-analysis of data within the GIS-HBIM environment, aiming to understand the interactions between territory, built heritage, intangible practices, and the subjective dimension of the landscape. The research findings highlight the presence of processes that undermine the integrity and authenticity of both the site and the landscape, largely as a result of tourism-related activities and the lack of integrated heritage management. Ultimately, the study concludes that the integration of GIS and HBIM not only enhances analytical and diagnostic capacities, but also supports the development of more effective and sensitive conservation strategies that encompass both the tangible and intangible dimensions of heritage sites and landscapes.

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BACKGROUND

From the mid-nineteenth century onwards, it is possible to identify, in Europe, the emergence of a foundational awareness regarding the conservation of ancient urban sites and their associated landscapes. At that time, numerous European sites were undergoing intense transformation as a result of the Industrial Revolution, with their landscapes increasingly characterised by the presence of new "steam engines, automated factories, railways, extensive new industrial zones" (Berman, 2007, p. 28) [our translation]. In England, the cradle of the aforementioned revolution, the art critic John Ruskin – regarded as a forerunner of the notion of historic urban heritage – recognised the cultural and environmental issues associated with this process. He thus warned of interventions that inflicted damage upon the fabric constituting the essence of the city (Choay, 2010, pp. 193–194), while simultaneously expressing his sorrow at the "defiled landscape" marked by the "lamentable concretions of lime and clay that [sprang] forth, prematurely contrived, from the fields compressed around our capital [...]" (Ruskin, 2008, p. 57) [our translation].

The major urban reforms undertaken in the mid-nineteenth century across the European continent, aimed at addressing hygienic, circulatory and even aesthetic concerns in the old urban centres – such as those of Barcelona, Paris, and Vienna – likewise contributed to reinforcing the need for particular attention to be paid to ancient sites and their landscapes. Initially, the contrast between the old and new urban fabrics facilitated the recognition of ancient cities as sources of historical knowledge (Choay, 2010, p. 193). Over time, as the approach dedicated to these cities matured, they came, by the early twentieth century, to be regarded as monuments to be preserved in their entirety – that is, not as a mere assemblage of buildings or isolated elements, but also taking into account their landscape dimension.

In this context, the fundamental contribution of the Italian engineer Gustavo Giovannoni is especially noteworthy, as he played a decisive role in the consolidation of the concept of urban heritage. Giovannoni acknowledged the inherent dynamism of ancient sites, which he recognised simultaneously as monuments and living organisms, as well as the necessity for their transformation to be undertaken with due care for the preservation of their identity-defining components. Accordingly, in his capacity as theorist, consultant and legislator in the field of heritage in his native country, he adopted an integrated approach to old urban nuclei, considering them at both the urban and architectural scales, as well as from a landscape perspective. He advocated for their incorporation into master plans and landscape planning instruments. Giovannoni ultimately understood the existence of deep and intrinsic interrelations between these scales, such that intervention in one would inevitably entail repercussions upon the others.

During the second half of the twentieth century, the growing concern over the intensification of transformation processes and the disfigurement of ancient sites and their landscapes prompted the adoption of a series of initiatives aimed at ensuring the protection of cultural assets in the face of threats such as the replacement of historic structures with modern buildings, the alteration of traditional environments, the erasure of local identities, and the fragmentation of landscapes that had evolved organically over centuries. These initiatives, including, most notably, the 1964 Venice Charter, the establishment of the International Council of Monuments and Sites (ICOMOS) in 1965, and the 1976 Nairobi Recommendation, echoed the Giovannonian approach and underscored the consolidation of a paradigm based on the dual nature of ancient sites. These sites were then understood simultaneously as testimonies of the past and as living, dynamic entities, bearing historical, cultural, symbolic, and landscape values, and thus to be preserved in their integrity.

In this regard, particular attention should be paid to the text of the "Recommendation concerning the safeguarding and contemporary role of historic areas". This document, by recognising the risks of homogenisation, depersonalisation, and destruction resulting from interventions driven by the logic of expansion and modernisation (United Nations Educational, Scientific and Cultural Organization – UNESCO, 1976, p. 20), highlighted the necessity for integrated public policies combining urban and territorial planning with heritage conservation. Such policies were to encompass transformations in accordance with local identity, social memory, and the values attributed to the ensembles and their surrounding environments; thereby emphasising the inherent complexity of their appropriate conservation and management. Subsequent initiatives, notably the 1987 Washington Charter, the 2000 European Landscape Convention, and the 2011 Recommendation on the Historic Urban Landscape (HUL), confirmed the evolution in the understanding of heritage as an inseparable component of social and territorial dynamics. It is observed that all of these initiatives converge upon a common point: the necessity for the effective integration of sites and their landscapes into urban and territorial planning, with the aim of preserving their identity, promoting their sustainable development, and ensuring a high quality of life for individuals and their communities.

Therefore, considering the aforementioned complexity inherent in the processes of conservation and management of such sites and landscapes – which involves, in addition to distinct scales, various temporal, symbolic, and other dimensions – it becomes essential to employ tools capable of systematically and coherently integrating spatial, historical, architectural, and related data. Such integration enables a more comprehensive understanding and more effective monitoring of the cultural assets in question. Within this context, digital technologies developed since the second half of the twentieth century, including Geographic Information Systems (GIS) and Building Information Modelling (BIM), have increasingly proven to be strategic instruments.

Regarding GIS, since the 1960s geographers have used computational tools for the visualisation and analysis of spatial data, a development that became a key technology by also enabling the stor-

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age and management of such data within a digital environment. Over time, the possibilities offered by these tools have extended their application beyond the field of Geography, reaching areas such as urban and territorial planning as well as heritage management. In the field of heritage management, however, their vast potential remains largely underexplored, as their use is still limited to a small proportion of sites worldwide.

Among these, one example is the city of Seville, in Spain, which, in its master plan, proposed the creation of a digital data repository related to the cultural assets under the responsibility of the municipality. The objective was to centralise, organise, and facilitate access to these data, which include cadastral information, conservation status reports, intervention histories, among others. The repository was named the "Sistema de Información del Patrimonio Histórico Municipal de Sevilla" (SIPHiM) and was developed using GIS tools. Another example is the city of Ouro Preto, in Brazil, recognised as a World Heritage Site by UNESCO in 1980. The municipality has a system called the "Infraestrutura de Dados Espaciais de Ouro Preto" (IDE-OP), which, developed with the use of GIS, centralises these data and enables their updating and dissemination. Aiming to facilitate data consultation, Ouro Preto even provides an open-access platform on a web portal, where various pieces of information are available regarding its geomorphology and hydrography, infrastructure and urban zoning, as well as its cultural heritage, including the location of both tangible and intangible assets, their respective protection perimeters and areas of influence, etc. The integrated analysis of this information supports urban planning and environmental management, also contributing to the preservation of Ouro Preto's cultural heritage.

In the case of BIM, which emerged from the evolution of computer-aided design (CAD) systems, its conceptual formulation began in the 1970s and, from the 1990s onwards, it started to be developed and employed under the name and with the functions it presents today (Sutherland, 1963). It is a technology that incorporates geometric rep-

resentations of different types of elements, in addition to rich and structured data concerning such elements. More recently, around the 2000s, it was adapted specifically to the field of cultural heritage as Historic Building Information Modelling (HBIM), which has enabled not only the precise documentation of complex constructions, but also the monitoring of their conservation state, the simulation of intervention strategies, as well as the articulation between physical and symbolic aspects of the buildings, ensembles, and urban sites under analysis (Eastman, 1999; Murphy et al., 2009; Ye et al., 2004).

An example of its application is provided by the Italian city of Pompeii, which, in 2020, developed a digital model of the existing archaeological site. This model was created through the articulation between geospatial data, structured within a GIS environment, and three-dimensional models developed according to the HBIM methodology (Biancardo et al., 2020). This integration enabled the linkage between spatial attributes and constructive and symbolic information of the heritage elements, allowing for more comprehensive analyses of the site, including aspects of its morphological configuration, conservation status, and intervention simulations.

Considering, therefore, precisely this articulation of the two technologies, GIS and HBIM (Pontran-

Fig. 1 - View of Rua Direita, located in the historic centre of Tiradentes. . Source: Authors' collection (2020).

dolfi et al., 2020; Avena et al., 2021; Zhu et., al 2021), it must be stated that it has been consolidated in recent years as a promising approach to the study and management of cultural heritage, notably with regard to ancient urban sites and their associated landscapes. The combined application of both technologies makes possible a better understanding of the characteristics and processes related to these assets, also facilitating the development of more comprehensive and dynamic diagnostics. However, there are still significant challenges to be overcome, among which stand out the interoperability of their respective platforms, the incorporation of intangible heritage and of heritage indicators related to the symbolic dimension of sites and landscapes, which constitutes a fundamental support for the meanings and values attributed to them and thus influences their conservation (De Falco et al., 2024; Hidalgo-Sánchez et al., 2022; Quintilla Castán, 2021).

OBJECTIVES

Considering the need to ensure effective conservation and management of ancient urban sites and their landscapes in the face of the various threats currently affecting them – uncontrolled urban expansion, real estate speculation, disfigurement and elimination of traditional referents, mass tourism exploitation, deforestation, etc. – as well as the growing interest in the use of digital technologies in the field of heritage preservation, this article aims primarily to explore the potential of integrating GIS and HBIM technologies as a methodology applied to the analysis and management of ancient urban sites and their associated landscapes. It investigates how this integrated approach can contribute to a more comprehensive and relational reading of cultural heritage, articulating spatial, historical, and constructive data, along with those of a perceptive and symbolic nature. In doing so, the study seeks to contribute to methodological and conceptual advancement in the use of digital technologies aimed at the preservation of cultural heritage, addressing aspects

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still little explored, yet fundamental to the understanding and definition of appropriate strategies for the protection of cultural sites and landscapes. As a case study, the landscape associated with the historic core of the city of Tiradentes (Fig. 1), located in the State of Minas Gerais, Brazil, is adopted. It is a landscape characterised particularly by the presence of a vast cultural collection and the São José Mountain Range, and which has undergone, especially over the last five decades, processes that have caused alterations to its traditional configuration.

CASE STUDY: THE LANDSCAPE ASSOCIATED WITH THE HISTORIC CENTRE OF TIRADENTES, IN MINAS GERAIS, BRAZIL

The urban core of the city of Tiradentes began to take shape in the early eighteenth century, in an area situated at the foot of the imposing São José Mountain Range. The construction of buildings was carried out in accordance with the local topography and was initially concentrated along a main thoroughfare extending from the elevated ground of the main church – Mother Church of Santo Antônio, the construction of which began around 1710 – to the adjoining bank of the Santo Antônio Stream. During the first half of the same century, with the wealth derived from gold mining – whose discovery in the region had, indeed, motivated the establishment of the original settlement – the locality expanded its occupied areas into adjacent zones, thus defining what would become its traditional urban and landscape configuration. (Fundação João Pinheiro – FJP, 1980).
With the decline of mining activity in the city, which occurred around the early nineteenth century, a process of economic stagnation also began. This process led, on the one hand, to a change in the profile of activities undertaken by its inhabitants – who began to engage in livestock farming, agriculture, spinning, and weaving – and, on the other hand, contributed to the preservation of the site's and landscape's original configuration, which remained largely unaltered. This condition began to

Fig. 2 - Partial view of the city dated 1921, highlighting the Mother Church of Santo Antônio and the São José Mountain Range. Photograph by João Batista Ramalho. Source: (Santos Filho, 2010, p. 14).

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Fig. 3-4 - Elements associated with the presence of tourism in Tiradentes: former residential properties now converted into tourism-oriented establishments and horse-drawn carriages around the main square offering city tours. Source: Authors' collection (2025).

change partially only towards the end of that century, with the implementation of a railway and new roads. These developments contributed to a renewed expansion of the occupied territory and the arrival of new materials, such as iron and glass, which made it possible to incorporate the eclectic architectural style into buildings that originally exhibited colonial features. (FJP, 1980).
In 1924, Tiradentes received a visit from a group of modernist intellectuals who, a few years later, from 1937 onwards, would be associated with the Serviço de Proteção do Patrimônio Histórico Nacional (SPHAN, now Instituto do Patrimônio Histórico e Artístico Nacional - IPHAN), created that same year with the objective of identifying, documenting, and preserving assets considered representative of Brazilian national identity. In 1938, these intellectuals, recognising the city's state of preservation (Fig. 2) and its representativeness for the nation, decided to place it under legal protection ("tombamento"). This action contributed to the city undergoing a process of increased valorisation and dissemination of its heritage, standing out as a focus of interest for scholars and for its potential in the tourism sector (FJP, 1977).
It was, however, only from the 1970s onwards that this potential began to be effectively explored, with the arrival of individuals from other regions of the country, endowed with greater purchasing power, who acquired residences – mostly for temporary use – and/or opened new establishments aimed at the still incipient tourist demand. From

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the 1990s, tourism development was intensified through the implementation of city marketing strategies and the increasing media exposure of the locality, which led to the consolidation of the process of socio-spatial and symbolic reconfiguration of Tiradentes' historic centre, initiated in the aforementioned 1970s. Since that period, indeed, certain significant changes were already observable in the area, notably the alteration of the traditional use of properties located therein and the progressive displacement of the population traditionally residing there to peripheral zones, as well as the emergence of new residential condominiums and buildings in the vicinity of the listed nucleus. In parallel, modifications also began to be observed in the nature of cultural practices and manifestations: residents, now engaged in tourism-related occupations, no longer had the time to participate in traditional celebrations, which, exhibiting a certain symbolic depletion, came to resemble performances staged for visitors (Bolson; Ferreira; Vieira Filho, 2006, p. 36).

It is necessary to note that Tiradentes at that time lacked a clearly defined protection perimeter, as well as a planning framework for its urban development and for the implementation of tourism in a consistent manner with the preservation of its heritage. This context prompted, between the 1970s and 1980s, a series of studies carried out by the Fundação João Pinheiro (FJP) – a public research and education institution affiliated with the State Secretariat for Planning and Management of Minas Gerais – in which the delimitation of a preservation area amounting to approximately 35% of the municipal territory was proposed (FJP, 1980, pp. 68-69), along with guidelines to steer the city's growth and the sustainable promotion of its touristic activity. The guidelines developed by FJP, however, were not implemented by the local authorities and, given the impacts that became increasingly evident in the historic urban nucleus and the surrounding landscape, in 1994 IPHAN conducted a study to determine the protection perimeter, based on FJP's research.

In 1979, the federal institute initiated the listing process for the São José Mountain Range, which,

Fig. 5-6 - New constructions emerging in the landscape, located around the protected core. Source: Authors' collection (2025).

however, remains incomplete. In 1990, the mountain range was designated an Environmental Protection Área and, in 1994, it was recognised as a Biosphere Reserve by UNESCO. More recently, in 2022, it was listed at the municipal level. It should also be added that in 2015 the Municipal Master Plan was approved, in which it was proposed that the "territory be treated as a cultural landscape, encompassing the integration between human action and nature, and between tangible and intangible heritage" (Prefeitura Municipal de Tiradentes, 2015, p. 6) [our translation]. The plan also introduced a zoning scheme for the territory, including the so-called Historical-Cultural Zone, subdivided into eight subzones. The Historical-Cultural Zone I, located in the central portion of the historic nucleus, was listed as the "Historic Nucleus of Tiradentes" by the municipality in 2022.

Nonetheless, despite these advances, it remains the case that processes that negatively impact the old nucleus and its associated landscape are still ongoing in the city today (Fig. 3-6). This situation may be attributed, in part, to the weak enforcement of current urban planning and heritage protection guidelines and regulations. However, it is believed to result primarily from the absence of a truly integrated approach to the various components of the aforementioned nucleus and landscape, encompassing both tangible and intangible aspects. Such an approach should enable an expanded un-

derstanding of the interrelations between these elements and of the processes underlying them, articulating, within a perspective that recognises the landscape as a dynamic and complex cultural asset, preservation, urban planning, and the appreciation of traditional ways of life.

METHODOLOGY

In light of the considerations presented, the methodology adopted in this research encompassed an integrated approach combining GIS and HBIM technologies applied to the historic core and landscape of Tiradentes. To ensure both the practical feasibility and analytical depth of the study, the focus was placed on the section comprising Câmara and Chafariz streets, which represents one of the most significant portions of the historic core of Tiradentes, both for its historical value and its notable landscape quality. This section includes three essential landmarks of the colonial city, all dating from the first half of the eighteenth century: the São José Fountain, the former Court Building (currently the seat of the Municipal Chamber), and the Mother Church of Santo Antônio, the principal symbolic and landscape reference of the city, located in the highest part of the area under consideration (Fig. 7). Particularly from the latter, privileged views of the historic urban core's

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landscape are obtained, highlighting the intrinsic relationship between the natural and built environment, defined by the interactions between the buildings, the urban layout, and the São José Mountain Range (Fig. 8).

Regarding the aforementioned methodology, it was divided into four main stages. The first stage involved the collection of spatial, architectural, and historical data concerning the territory and cultural assets of the city. This data gathering was conducted through consultation of documentary and bibliographic sources – particularly materials produced by IPHAN, the Instituto do Patrimônio Histórico e Artístico de Minas Gerais (IEPHA-MG), FJP, and the Municipal Government of Tiradentes –, including the use of photogrammetry for the generation of orthophotos.

The subsequent stage involved the digital modelling of the data collected on the municipality's Digital Terrain Model (DTM) and the São José Mountain Range (INPE, 2025). These data were initially processed in QGIS (Fig. 9), where contour lines were generated. Subsequently, the contour lines were exported to Blender, where a three-dimensional mesh was created based on them, in order to obtain a georeferenced 3D model of the topography (Fig. 10.1-10.2). This model enabled an accurate representation of the landscape surrounding the historic centre.
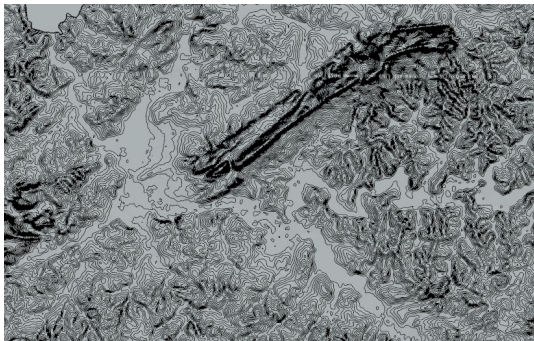

Fig. 7 - View of part of the section comprising Câmara and Chafariz streets, highlighting the Mother Church of Santo Antônio situated on the highest portion. Source: Authors' collection (2025).
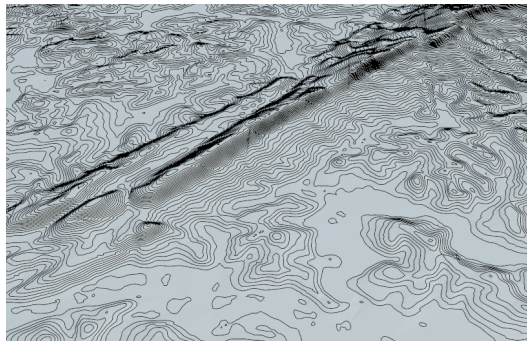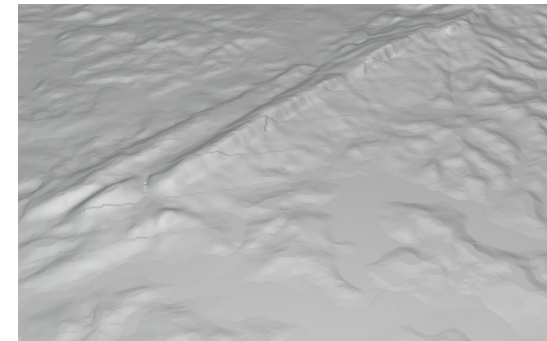

Fig. 8 - View of part of the landscape of Tiradentes obtained from the churchyard of the Mother Church of Santo Antônio. Source: Authors' collection (2025).

In the following phase, the simplified geometries of the historic centre's buildings were imported into a BIM environment (Autodesk Revit). These geometries incorporate descriptive and analytical information associated with each building, and are georeferenced using parcel-based data. Finally, the topographical model and the building geometries were integrated with the aim of developing a more detailed study of visibility, volumetric relationships, and the potential vulnerabilities of the historic landscape.

In another stage, different indicators related to the local cultural identity were defined, that is, the

elements and conditions that shape and influence the traditional character of the historic core and landscape of Tiradentes. The selection of these indicators proved fundamental in the analysis of the historic centre, as it allowed the identification of attributes that contribute to heritage value, the understanding of processes of change, and the assessment of the extent to which the built environment maintains its historical, functional, and symbolic significance.

The indicators were determined based on the study of documentary and bibliographic sources, field research, and interviews. Each of them seeks

Fig. 9 - Contour lines based on the Digital Terrain Model of Tiradentes, developed on a GIS platform. Source: Prepared by the authors (2025).

Fig. 10.1 - Contour lines based on the Digital Terrain Model of Tiradentes, developed in Blender. Source: Prepared by the authors (2025).

Fig. 10.2 - Mesh based on the Digital Terrain Model of Tiradentes developed in Blender. Source: Prepared by the authors (2025).

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to reflect a specific dimension of heritage assessment: the historical period of construction, the functional dynamics of the properties, the continuity or transformation of traditional uses, the physical preservation of the built fabric, the relationship between buildings and local cultural expressions, the existence of formal protection instruments, and the role of visual perception - both of the buildings within the landscape and of the landscape itself (Table 1).

The spatialisation of the indicators can be observed in the figures presented alongside. These highlight the characteristics of the area concerning former and current uses of the properties (Figs. 11.1 - 11.2), revealing the maintenance or alteration of the traditional uses of these properties from the early 1990s to the present day; the characteristics relating to the association of the buildings with local cultural manifestations (Fig. 11.3); as well as the visibility that such properties have within the landscape, particularly from the churchyard of the Mother Church of Santo Antônio, for which a visibility analysis was carried out in QGIS (Fig. 12).

This analysis revealed a good correspondence be-

Fig. 11.1-11.2 - Mapping of the uses of properties located along Câmara and Chafariz streets in the early 1990s and at present. Source: Prepared by the authors (2025).

Fig. 11.3 - Mapping of the properties located along Câmara and Chafariz streets that are associated with local cultural manifestations. Source:

tween the legally protected perimeter of the historic centre and of the São José Mountain Range, and the areas visible from the church. However, several zones were identified that are fully visible from the church yet lack any form of protection, indicating that they are not adequately safeguarded, particularly considering their potential impacts on the landscape.

By integrating information from different platforms, such as BIM and GIS, a model has been developed in Blender that incorporates the topography, territorial information from GIS, including lot and building data and architectural features imported from the BIM model. In this way, the Blender model has allowed the visibility areas from the church to be contrasted in a 3D environment, as

Table 1 - Base indicators for the analysis of the historic urban core and landscape of Tiradentes. Source: Prepared by the authors (2025).
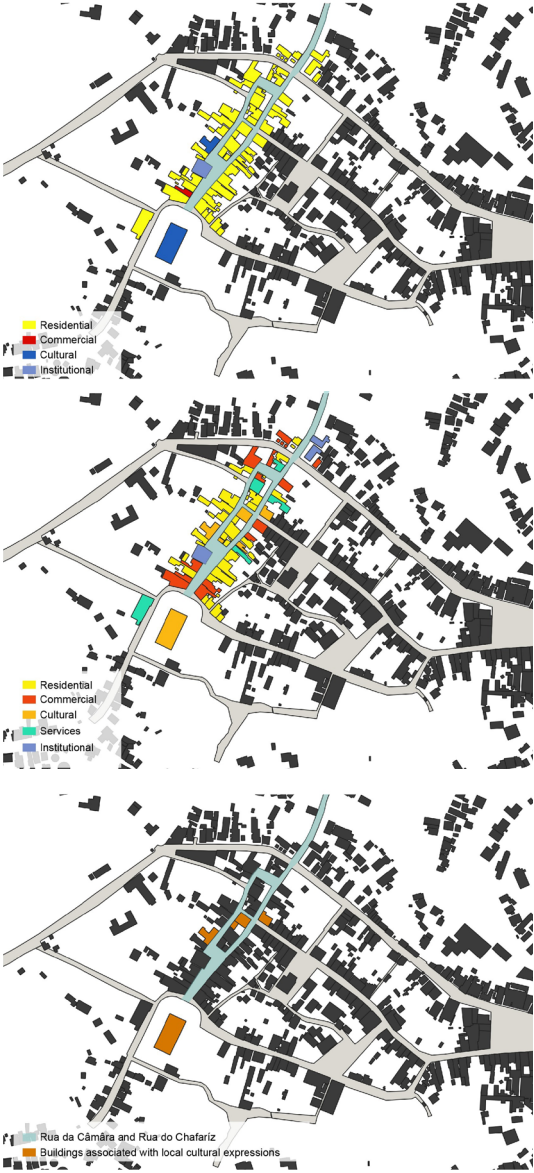
Criteria	Values
Construction period	18th century | 19th century | 20th century | 21st century
Current use	residential | commercial | services | institutional | cultural | mixed
Maintenance of traditional use	use maintained | use changed | not applicable (for new constructions)
State of conservation	good | fair | poor | disfigured | demolished
Association with local cultural expressions	associated | not associated | not applicable (for intangible assets)
Application of individual protection instruments	existing | not existing
Visibility in the landscape	high visibility | low visibility | no visibility | not applicable (for intangible assets)
Visibility of the landscape	high visibility | low visibility | no visibility | not applicable (for intangible assets)

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well as including a simplified modelling of the historic centre's buildings (Fig. 13). Furthermore, through the use of visualisation filters based on queries of the BIM-GIS database, it has been possible to observe the different analytical indicators. Finally, with the structured models and indicators at hand, a cross-analysis was conducted within the GIS-HBIM environment to understand the interactions between the territory, the built heritage, intangible practices, and the symbolic dimension of the landscape. Integration between the systems was achieved through a database designed in SQL, which serves as the central hub for the different platforms, enabling the centralised connection of the BIM and GIS environments, as well as systematic queries and the extraction of data related to heritage indicator. In this regard, Blender queries the information from the BIM database in Revit and the GIS database in QGIS to cross-reference and combine the data, with the aim of achieving a comprehensive and integrated 3D visualisation of the indicators and the territory.
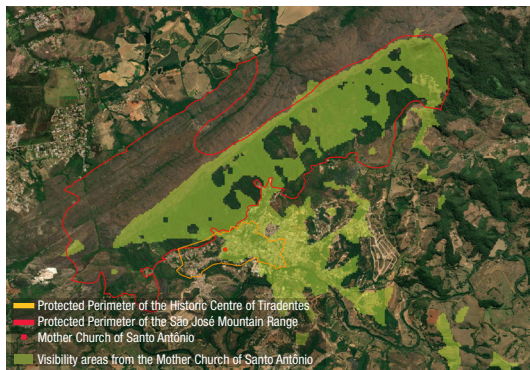

Fig. 12 - Visibility of the historic urban core and landscape of Tiradentes from the Mother Church of Santo Antônio. Source: Prepared by the authors.
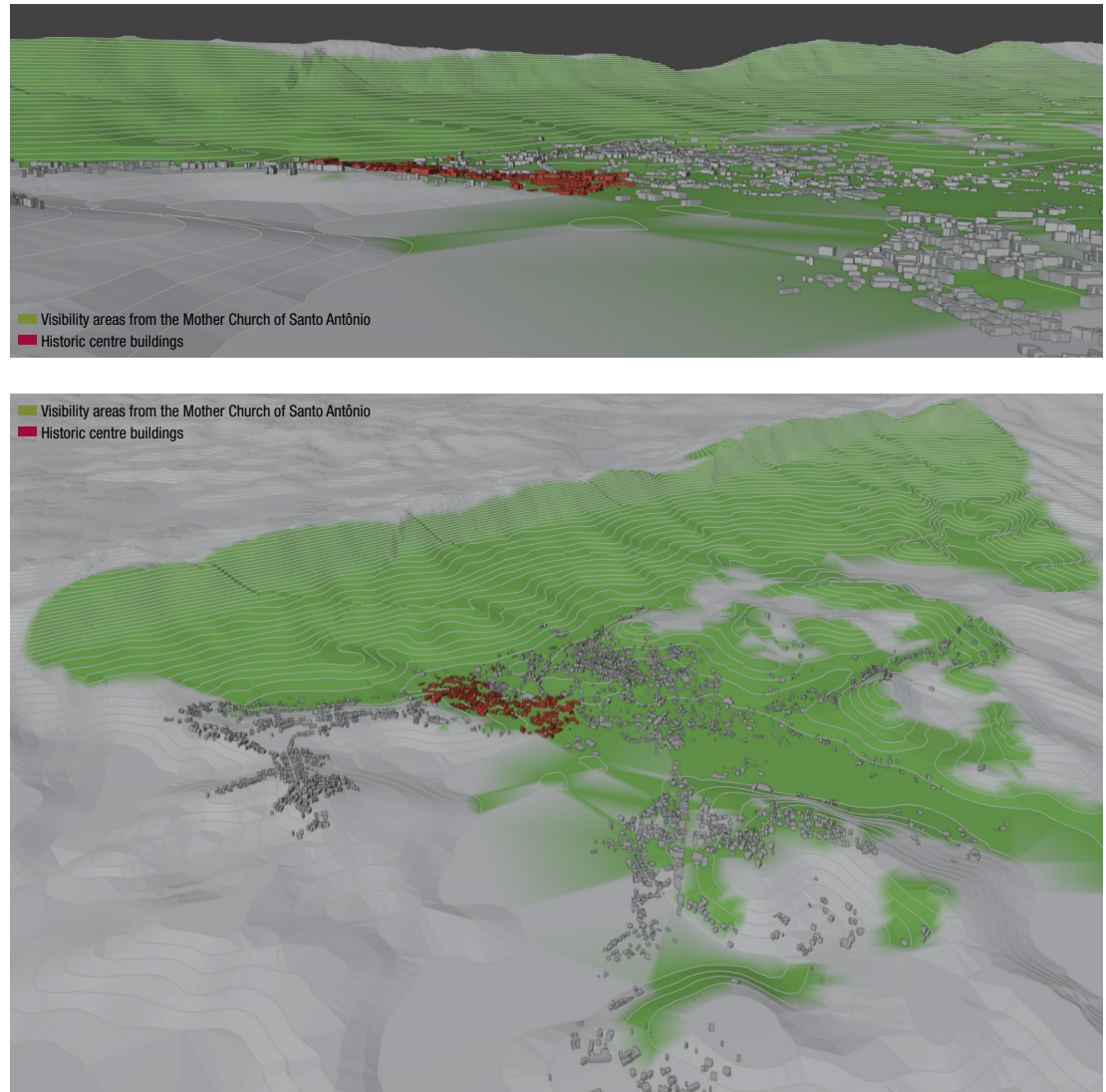

Fig. 13 - Blender model constructed based on queries of the database containing information on topography, buildings, visibility, and associated data. Source: Prepared by the authors (2025).

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RESULTS

Based on the adopted methodology, grounded in the integrated application of GIS and HBIM technologies, it was possible to obtain a range of analytical and operational results that enhanced the understanding of the cultural landscape associated with the historic urban core of Tiradentes.

Firstly, it was found that the spatial and three-dimensional modelling of the data collected during the surveys facilitated the systematic visualisation and interpretation of the constituent elements of the historic urban core and its associated landscape, considering both their physical configuration and their historical, cultural, and symbolic attributes. The cross-analysis of the indicators defined for the study of the core and landscape enabled, for example, the mapping of the dynamics of changes in property use and the assessment of how these changes have contributed to altering the traditional character of the city (Fig. 14-15). As previously mentioned, from the 1970s onwards, there was a progressive replacement of residential use within buildings in the historic core, which came to accommodate uses primarily aimed at meeting tourist demand. Associated with the displacement of the traditionally resident population, this process of substitution has also affected the cultural manifestations rooted in the territory, threatening the continuity of the social dynamics that sustain them.

By correlating the indicators corresponding to current uses with the maintenance (or otherwise) of historical uses and their connection to cultural manifestations, the methodology employed also enabled the identification of areas at risk of heritage loss, with the potential for erosion of local identity. Taking as an example the Festa de Santo Antônio – one of the most important religious and community celebrations in Tiradentes – it is observed that takes place at the Mother Church and encompasses the streets of Câmara and Chafariz. Historically, it involved the active participation of the resident community, with rehearsals, masses, processions, and festivities organised locally. However, its insertion into a context now
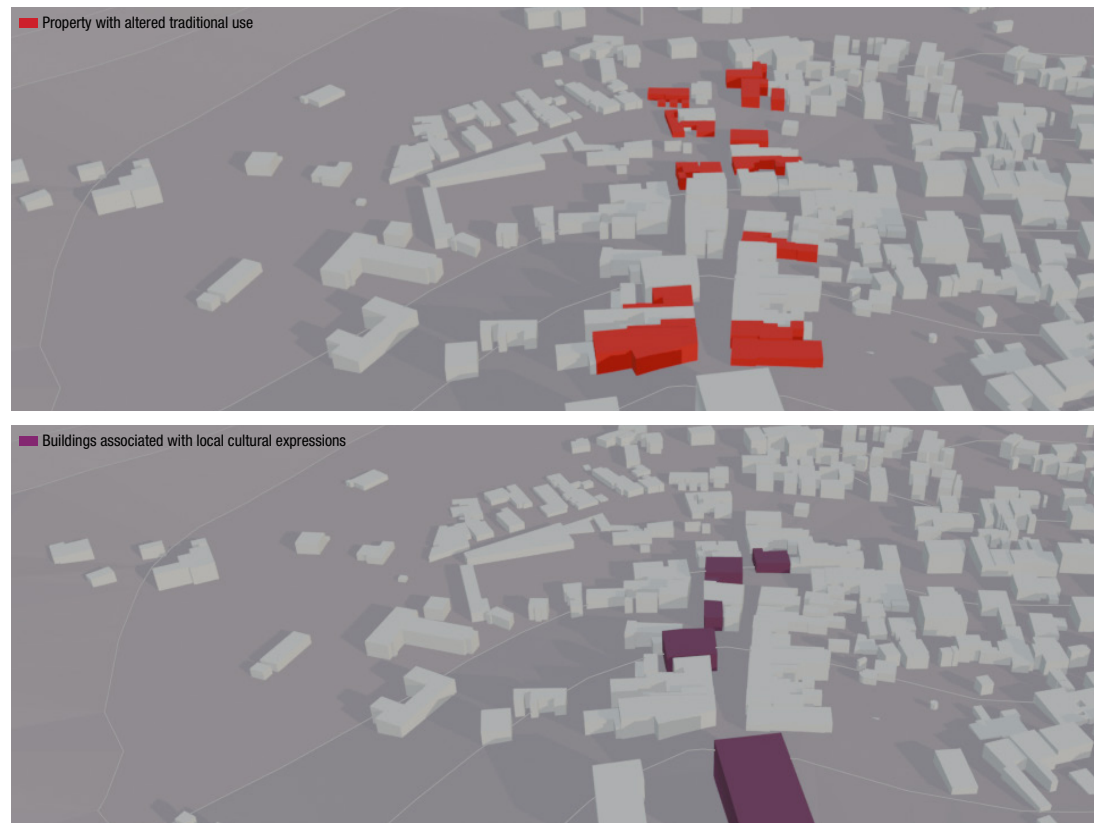
increasingly characterised by tourism-oriented establishments, as well as properties used for seasonal residence, may transform it into an event more geared towards visitor consumption, as already noted by some authors (Bolson; Ferreira; Vieira Filho, 2006, p. 36), resulting in the gradual loss of its identity and communal dimension. In other words, the analyses made possible by the research include the assessment that the commodification of urban space may lead to the decharacterisation of cultural manifestations, as well as a decline in local engagement and a disruption in the intergenerational transmission of

Fig. 14 - View of properties along Câmara and Chafariz streets with altered traditional uses. Source: Prepared by the authors (2025).

Fig. 15 - View of buildings along Câmara and Chafariz streets associated with local cultural expressions. Source: Prepared by the authors (2025).

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associated knowledge and practices. This may, in turn, lead to the weakening of the bonds and values that still support the traditional identity of Tiradentes' cultural landscape.

Specifically regarding landscape perception, analyses of considerable relevance to the context of Tiradentes were conducted. As previously mentioned, the city has been experiencing a process of urban expansion, marked by the emergence of new constructions surrounding its historic core. It is well established that such buildings, when introduced without adequate criteria, may compromise both the ambience of the historic core and the traditional character of the associated cultural landscape. Consequently, it is essential to carefully assess the location and manner of integration of these constructions, with particular attention to maintaining the visibility conditions of cultural assets within the landscape and the visibility of the landscape from key viewpoints, such as the churchyard of the Mother Church of Santo Antônio. Concerning the visibility obtained from this point, the study revealed that it includes recently occupied areas - among which are those previously shown in Figures 5 and 6 -, indicating the need to define and implement appropriate urban planning parameters to preserve the traditional character of the historic core and the local landscape.

Finally, the contribution of the relational database structure developed within an SQL environment (Fig. 16) is emphasised, as it enabled dynamic
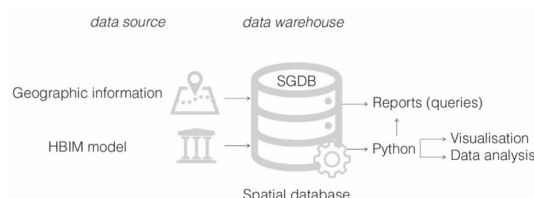

Fig. 16 - Spatial database schema for linking GIS and BIM models. Source: (Escudero, 2025).

Fig. 17 - 3D BIM model of the property located at Câmara Street, in the historic centre of Tiradentes. Source: Prepared by the authors (2025).

queries and thematic cross-analyses of heritage indicators, facilitating the performance of complex analyses that included, in addition to those previously mentioned, the overlay of temporal layers (period of construction and current condition), identification of usage and conservation states, and assessment of the effectiveness of legal protection instruments applied over time.

CONCLUSIONS

Based on the results obtained, the conclusions of this article highlight the importance of integrated and multiscale approaches in the analysis and management of cultural landscapes associated with historic urban cores. The combined application of GIS and HBIM technologies, by relating spatial, architectural, historical, and cultural data in a relational and visually accessible manner, proved to be particularly effective in producing comprehensive and accurate analyses and diagnoses. This not only enables a better understanding of ongoing transformation processes but also establishes a solid foundation to support the definition of more efficient actions and instruments for the appropriate conservation and management of the assets in question. Although this study worked with simplified volumetric representations of the buildings in the historic centre, it is considered that refining the modelling process, by represen-

ting the precise characteristics of these buildings' components (Fig. 17), may offer even greater contributions to landscape management. Such refinement would enable broader and more rigorous control over interventions in their material fabric, which may potentially generate negative impacts on the composition of the landscape.

The research also underscored the importance of considering not only physical aspects but also the social and symbolic elements that comprise cultural heritage. The combination of GIS and HBIM facilitates this expanded approach by integrating different layers of information – location, construction period, land use, links to cultural practices, and landscape perception, among others – within a single analytical environment. This relational framework allows for the identification of not only material elements of heritage value but also the understanding of the urban and social contexts in which cultural manifestations occur, thereby facilitating risk assessments, including the loss of traditional environments and cultural practices and the disruption of community dynamics.

It is therefore evident that the methodology presented in this study contributes to a more comprehensive concept of heritage protection, one that transcends the isolated preservation of buildings and incorporates, within the landscape dimension, symbolic and affective ties between the community and its territory. In doing so, it enhances the capacity to plan and implement conservation and management strategies that are more sensitive to local specificities, ensuring the continuity of the meanings and values that underpin the preservation of the identity of the cultural landscape.

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