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The Common Data Environment in Monument Master Plans

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Abstract

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

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

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

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

1. Introduction

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

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

It is possible to assimilate a Common Data Environment (CDE) BIM-GIS structure to the framework of a master plan, as both approaches share the objective of centralising and managing information in an integrated and coordinated manner. A master plan, which guides a heritage site's long-term planning and management, can significantly benefit from the precision and detail offered by a CDE BIM-GIS platform, ensuring more effective and sustainable conservation.

The digital twin, a precise virtual representation of a physical building, emerges as a vital tool. It acts as a Common Data Environment (CDE) that centralises all relevant information and as a management and recovery instrument for architectural heritage. By simulating environmental phenomena and situations that affect the deterioration of buildings, the digital twin aids in developing sustainable conservation strategies.

2. Applicability of a CDE in a BIM-GIS Environment for Master Plans

A master plan is a fundamental strategic document for planning the conservation and management of heritage buildings. This document provides a broad and detailed vision of a monument or heritage site, addressing contemporary management and conservation needs. It should be designed to be precise and versatile, allowing its application in diverse circumstances and contexts. The Alhambra Master Plan, for example, reflects this complexity and versatility by providing a contemporary perspective necessary for acting upon the monument, with direct involvement of the managing body and public participation, making it a well-anchored management instrument in a democratic society (Villafranca Jiménez, 2015).

In Spanish, the National Plans for Architectural Heritage (PN) emphasise the importance of unifying knowledge and documentation about these buildings. Since the first National Plan for the Protection of Cathedrals in 1999, the need to coordinate conservation and restoration activities has been established. The National Conservation Plans are a synthesis of two key figures: the National Information Plans outlined in the Historical Heritage Law, under the competence of the Heritage Council, and the Conservation and Restoration Plans. National plans, in particular, set the groundwork for Master Plans (MP), which are essential as they define the long-term strategy for conserving and restoring heritage buildings. These documents schedule investments according to identified needs and coordinate the involvement of various stakeholders (MECyD, 2015).

A master plan is conceived as an integral tool for the comprehensive management of heritage, involving the programming of necessary actions and interventions, allowing proper coordination among the agents involved in the protection, conservation, restoration, study, research, interpretation, and dissemination of the monument. In this sense, it can be said to function similarly to a Common Data Environment (CDE), where efficient integration and collaboration between different disciplines and actors are also sought. A CDE must gather the knowledge obtained during the plan's development and accumulate it throughout the building's life cycle. Its purpose is to improve the efficiency and coherence of future actions, ensuring information interoperability among disciplines. Often, it involves a platform that integrates construction information models (BIM) with geospatial data (GIS) in a familiar environment. This integration enables more efficient and collaborative management of construction projects and asset management, providing a comprehensive and detailed view of spatial and non-spatial information related to physical assets.

In the context of a monument master plan, a BIM-GIS CDE plays a decisive role by enabling a comprehensive understanding of the plan's structure and its relationship with the monuments and their surroundings. This integration of geospatial data and HBIM models is crucial, as a master plan requires a detailed understanding of the monuments' location, structure, and geospatial context. It provides an accurate and detailed representation of their location and geometry within the protection environment. Additionally, it facilitates the visualisation and analysis of spatial and non-spatial information related to the monuments and their surroundings in a shared digital environment. This is fundamental for identifying spatial relationships and complex patterns, contributing to planning and decision-making in a monument master plan.

Another significant advantage is its capacity for data management and fostering collaboration. It provides a centralised environment for storing, managing, and sharing data and models related to the monuments and their surroundings, facilitating stakeholder collaboration. This collaboration is essential for effectively developing and implementing the master plan.

Implementing a BIM-GIS CDE is helpful for impact analysis and simulation, allowing for analyses of the monuments and their environment, which is crucial for evaluating the impact of potential interventions proposed within the framework of the master plan.

2.1. BIM and GIS for Heritage Management

The use of BIM strategies in the lifecycle management of heritage buildings is one of the main objectives of providing effective CDEs. The integration of BIM and GIS can function as a centralised digital repository, bringing together various types of information accessible to any stakeholder interacting with the building throughout its lifecycle. This approach is a collaborative paradigm whose main objective is efficient building management. Integrating BIM and GIS in a CDE offers a holistic approach to heritage management, combining architectural and construction details with geospatial and environmental context data. A BIM environment applied to heritage allows for comprehensive management of heritage buildings' legal, architectural, and cultural aspects. Implementing HBIM leads to new methods, protocols, and processes for the building's intervention, conservation, maintenance, and lifecycle management (García-Valldecabres, J.L. et al., 2022).

There are similarities between HBIM and GIS as they share a common goal of representing geospatial data and properties, albeit with slightly different approaches. While HBIM focuses on the three-dimensional representation of data, GIS works primarily in two dimensions. What unites these platforms is their importance on data and its presentation. The key lies in connecting these databases to achieve effective integration, regardless of whether the representation is 2D or 3D. Significant changes have been experienced in work methods in recent years, moving from application and result-centered approaches to a more management-oriented and automated information approach. In this sense, 3D representation is not always necessary in GIS; what is fundamental is having a well-structured and connected database that allows access to relevant and updated data when needed (Colucci et al., 2020).

GIS files are primarily characterised by using points, lines, and polygons to represent geographic entities. In contrast, HBIM requires a high level of geometric complexity due to the need for greater detail in the information. This can pose challenges in integrating both platforms and the need for a connected database. In recent years, the benefits of HBIM for recording and documenting the current state of cultural building assets have been demonstrated, positioning it as the best repository for managing the documentation of a Master Plan. The 3D-HBIM model generated can also be used during cultural studies, including analysing the surrounding environment, describing the building's particular properties, and the construction history.

For this reason, most research asserts that the model must remain open to new uses and requirements, such as preventive conservation, dissemination, diagnostics, and maintenance. This flexibility ensures that HBIM serves current needs and adapts to future demands in managing cultural heritage.

3. Methodology

The implementation procedures of the BIM methodology ensure the quality of the information repository by allowing the testing of the generated model or models. It must be possible to test the model information and its federation. This BIM management involves creating a centralised system around the information models, which must be comprehensive, traceable, and accessible according to defined roles and responsibilities.

The HBIM model is created and updated proportionally throughout the project's development, and deliverables are generated from this model and linked to external documents, thus documenting the traceability of each deliverable.

Specifically, the conditions of the HBIM methodology in a Cultural Interest Property (BIC) are as follows:

1. Procedures must be defined through a working protocol that promotes knowledge of the heritage building, its conservation and restoration, and enables proper management. These pieces of information must be reflected in the BEP.
2. There must be procedural continuity in developing proposed actions for the MP, considering foreseeable requirements in future actions that enrich the information model. These objectives should reflect those outlined in the Master Plan of the building.
3. The model must adapt to the capabilities of the managing entity of the heritage asset to facilitate its continued use throughout all phases of the building's lifecycle.
4. A CDE linked with all BIM-GIS models must be established.

These zone models can be subdivided into disciplines, delineations, or federated models. This division can be based on criteria such as the building's size not exceeding a certain number of units. The organisation of native working files is defined in the BIM Execution Plan (BEP) for each required BIM use. Likewise, deliverables must be produced as specified in the BEP. Necessary testing and adjustments must be made so that the information structure of native models can be exported to open BIM formats.

The model organisation must have a previously agreed-upon coordinate origin. The definition of model categories, subprojects, the interference matrix, and the process map to obtain specific BIM should be included in the overall connection process diagram. It should also include the connection of documentation with deliverables and the deliverable and people review process. Finally, it should include tables with adequate information organisation by categories previously detailed according to a standardised classification such as UniClass.

Once the different HBIM models of the historic building, which may be linked to different sub-models, are generated, a linkage to a GIS database is created. This is made possible by linking IFC files with software such as ArcGIS Pro or QuantumGIS (QGIS). Within this database lies the building's environment, enabling the incorporation of general information and topographic parameters, visual tours, etc.

The integration of HBIM and GIS can be comparable, for example, to the methodology proposed by the National Cathedrals Plan through the fundamental steps outlined in the action method. Firstly, it addresses identifying cultural assets by providing technological tools for developing detailed inventories and catalogues of cathedrals, which can be perfectly achieved with HBIM. Then, regarding asset protection, the protection environment can be incorporated into GIS to provide a deeper understanding of the state of historic buildings and their surroundings. This technological approach allows for precise diagnostics of the conservation status of monuments, which in turn facilitates the formulation of general conservation and management strategies. The application of this methodology promotes the implementation of continuous projects for documentation, preventive conservation, and dissemination of cultural heritage. This aligns with the long-term vision that a Master Plan must-have, which seeks to conserve these monuments and promote their valorisation and understanding by the general public.

Below, we present a table illustrating the adaptation of the structure of a monument master plan in a CDE using HBIM and GIS. This approach combines the rigour and integrity of the master plan with the effectiveness and versatility of advanced digital tools.

Table 1. Phases of an MP in a BIM-GIS CDE Environment.

Phase		Data base
1	Degree of protection of the monument and its surroundings, along with protection proposals.	GIS
2	Comprehensive description of the monument in all its aspects.	CDE
3	Historical and chronological memory of the monument.	CDE
4	Memory of previous interventions.	CDE
5	Legal analysis on ownership and other legal aspects.	CDE
6	Architectural and structural description of the monument.	BIM
7	Compilation and cataloguing of graphic, archaeological, bibliographic, etc., documentation.	CDE
8	Evaluación del estado de conservación y situación urbanística del monumento.	BIM
9	Intervention proposals with economic evaluation.	BIM
10	Description of movable heritage.	CDE
11	Compilation and cataloguing of graphic and bibliographic documentation on movable heritage.	CDE
12	Study of movable heritage and its conservation status.	BIM
13	Description of intangible heritage linked to the monument.	CDE
14	Compilation and cataloguing of graphic and bibliographic documentation on intangible heritage.	CDE
15	Risk analysis and assessment.	BIM
16	Diagnosis and general intervention criteria.	BIM
17	Protection plan and preventive conservation.	BIM
18	Periodic maintenance plan for the monument.	BIM
19	Conservation and restoration plan for the monument and movable heritage.	BIM
20	Documentation and research plan for the monument.	BIM
21	Plan of training, accessibility, and dissemination proposals.	CDE
22	Management proposals plan for the monument.	BIM
23	Schedule for the implementation of proposed plans.	BIM
24	Planimetric, photographic, sound documentation, and other relevant documents.	BIM
25	Historical and archaeological research, analysis of socio-economic context, community participation, budget and financing, legislation and regulations, monitoring and evaluation, environmental sustainability, and inter-institutional collaboration.	CDE

4. Results and conclusions

Creating a CDE in a BIM-GIS environment offers numerous advantages for managing Master Plans. Firstly, it facilitates interoperability and collaboration among different disciplines and tools. Architects, engineers, conservators, cultural managers, and other stakeholders can work efficiently, exchanging information and coordinating efforts without obstacles often arising from the lack of communication between disparate platforms.

Centralised data management is another critical benefit. Integrating BIM and GIS data into a single centralised repository allows easier access and more coherent information management throughout the building's lifecycle. This simplifies data handling and ensures that all involved parties work with the same up-to-date information.

A CDE enhances data-driven decision-making and provides a solid foundation of accurate and updated data, enabling more informed planning and execution of conservation and restoration interventions. With access to detailed and relevant information, stakeholders can better assess needs and effectively prioritise actions.

The combination of BIM and GIS in a CDE allows for detailed spatial and contextual analysis, which is essential for understanding the environment and conditions affecting heritage buildings. With more profound and more precise analysis, interventions can be designed to address current issues and anticipate and mitigate potential future challenges.

Finally, efficiency in planning and execution is significantly improved with a CDE. The availability of integrated information reduces the time and costs associated with data duplication and lack of coordination. This translates into faster and more cost-effective planning and execution of Master Plans, ensuring that resources are used most effectively and that conservation and restoration projects are completed on time and within budget.

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