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# THE NEED TO IMPLEMENT CULTURAL HERITAGE MÁSTER PLANS THROUGH THE BUILDING INFORMATION MODELLING METHODOLOGY

## *LA NECESIDAD DE IMPLEMENTAR A TRAVÉS DE LA METODOLOGÍA BUILDING INFORMATION MODELLING LOS PLANES DIRECTORES DEL PATRIMONIO CULTURAL*

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### Abstract

The Master Plans (MP) used for Architectural Cultural Heritage conservation require specific standards for the documentation process. They must facilitate the achievement of the intended objectives about the knowledge acquisition and conservation of the building assets throughout the entire building lifecycle. Over time, the documentation of an MP, once the heritage building is under use, tends to become dispersed and the documentation generated during the building use is rarely introduced in the MP. Therefore, this contribution has the following objectives: 1) study of the requirements of MP deliverables; 2) study of the maturation requirements of the documentation processes and deliverables that are generated when applying the Building Information Modelling (BIM) methodology to an MP; 3) investigate if the application of the BIM strategies are suitable to respond to the needs of an MP in such a way that knowledge and conservation of heritage buildings are achieved; 4) verify that the exchange of information and the collaborative work among the different disciplines that generate documentation and deliverables guarantee a single, comprehensive, open, three-dimensional, and clear repository.

**Keywords:** Cultural Heritage; Facilities Management; Heritage Building Information Modelling (HBIM); Master Plan.

### Resumen

Los Planes Directores (PD) sobre el Patrimonio Cultural arquitectónico requieren de unos estándares específicos de organización de la documentación que faciliten la obtención de los objetivos pretendidos sobre el conocimiento y la conservación de los bienes edilicios a lo largo de todo su ciclo de vida. A lo largo del tiempo, la documentación de un PD tiende a dispersarse e incluso es raramente integrada en el PD durante el uso del edificio. Por ello, se plantea la presente contribución con los siguientes objetivos: 1) Estudiar los requisitos de los entregables de los PD. 2) Estudiar los requisitos de maduración de los procesos y entregables documentales que se generan al aplicar la metodología Building Information Modelling (BIM) en un PD. 3) Verificar si la aplicación de las estrategias BIM son adecuadas para dar respuesta a las necesidades de un PD de tal forma que se logre el conocimiento y conservación de las edificaciones patrimoniales. 4) Verificar que el intercambio de información y el trabajo colaborativo entre las diferentes disciplinas que generan documentación y entregables garanticen un repositorio único, integral, abierto, tridimensional y claro.

**Palabras clave:** Patrimonio Cultural; Plan Director; Heritage Building Information Modelling (HBIM); Gestión.

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## 1. INTRODUCTION

*Heritage is the cultural legacy that we receive from the past, that we live in the present and that we will pass on to future generations*. 1972 UNESCO Convention for the Protection of the World Cultural and Natural Heritage (1972). Knowing and enjoying cultural heritage dignifies people in such a way that it restores a sense of appreciation and strengthens the bond between them and between them and the territory.

The present contribution arises in the context of the investigations performed by the members of the Department of Expresión Gráfica Arquitectónica, Universitat Politècnica de València and Construcciones Arquitectónicas, Universidad de Alicante by using the acquired knowledge achieved during their participation in interdisciplinary teams for the study and management of Cultural Heritage Buildings. Both aspects are being applied in the R+D+i project funded by the Ministry of Science and Innovation in the 2020 call, entitled: Analysis and development of HBIM integration in GIS for creation of a cultural heritage tourism planning protocol of a destination (HBIMSIG-Tourism). Project awarded to the Universitat Politècnica València, Spain. And, together with the contribution provided by researchers from the McWhorter School of Building Science University of Auburn University, USA.

Recent contributions made by Francisco Pinto (2021) and Antonio Almagro (2019) propose that to guarantee the success of any protection action applied to a heritage asset, the action must be guided by appropriate knowledge and conservation criteria.

At the beginning of the elaboration of the building or heritage complex geometrical plans, the process is driven by the analysis of the factors and the remains until it is achieved an appropriate cognitive apprehension that must allow a complete building representation. These representations, including 2D plans and 3D models, are the necessary tools that will facilitate the study and the attainment of knowledge by the set of disciplines involved in the elaboration of a cultural heritage property MP. These representations must be available to the rest of the involved experts and must be the product of capturing the building topographic morphology of the current state of knowledge presented through graphic representations or visualizations.

When addressing this question about the feasibility of implementing the documentation and deliverables generated by the different disciplines involved in the development of an MP through Building Information Modelling (BIM) methodology, the question arises: Why is BIM the best tool to organize the information repository of an MP? Immediately comes the answer: BIM is an adaptive methodology that can be applied to any type of building or infrastructure, therefore to heritage architecture, that provides a dynamic repository open to all the involved stakeholders during the complete building lifecycle..

## 2. THE MASTER PLANS, HERITAGE, AND BIM

The MPs are documents that define the strategy for the conservation and restoration of heritage buildings and program investments according to the needs. The MPs also coordinate the participation of the different stakeholders. In this sense, the Architectural Heritage National Plans (NP), from the first of them (the National Plan for the protection of the Cathedrals of 1999), establish the need to unify the existing knowledge about these buildings and the documentation about the conservation and restoration activities carried out over them.

MP is designed as an instrument for heritage management in which the actions and interventions that need to be carried out over it are programmed. The objective is to allow proper coordination among the stakeholders involved in the protection, conservation, and restoration of the monument, study, and research, as well as interpretation and dissemination.

A MP is designed as an instrument for the heritage global management in which the actions and interventions that need to be carried out over it are programmed. The objective is to allow a correct coordination among the stakeholders involved in the protection, conservation and restoration of the monument, study, and research, as well as interpretation and dissemination.

Among the several objectives that an MP aims to reach, establishing a Common Data Environment (CDE) for the available knowledge, both obtained during the elaboration of the Plan and during the building lifecycle, is the most important. This CDE must improve the efficiency and coherence of future actions, defining the interoperability of the information between disciplines.

Providing CDEs for proper building management is one of the objectives of the use of BIM strategies during a building's lifecycle. BIM provides a digital repository that can gather many types of information with the aim of offering it to any stakeholder that interacts with the building during its life span. It can be understood as a collaborative paradigm where building efficiency management is the main goal (Volk and Schultmann, 2014).

Succar (2008), stated in 2008 that for proper development of a BIM environment, research about technology, processes, and policies must be carried out. That means that new tools (e.g., software and equipment, etc.) were needed, people, companies, and firms must be involved, and governance and academia (e.g., standards and laws, guidelines, protocols, specifications, studies, research, etc.) must show their interest. (Fig. 1).

Under this statement, this research can be allocated in the scope of the BIM Policy as its objective is performing a comparative analysis between the technical requirements for the elaboration of an MP and the degree of maturity of the implementation of the BIM methodology in cultural heritage management.

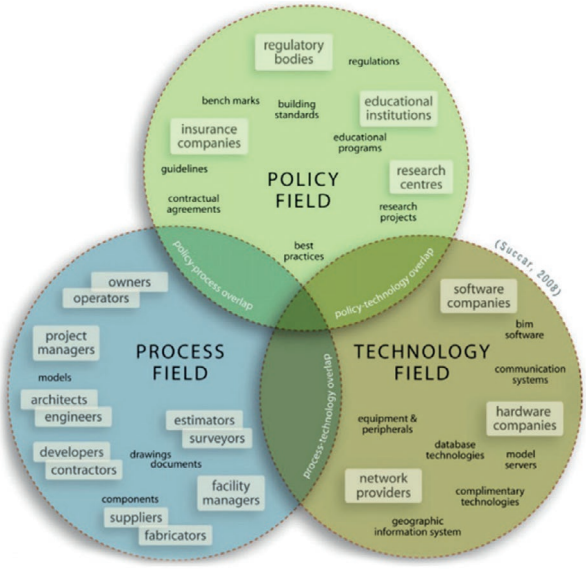


Fig. 1. Interaction of Succar's BIM fields Source: Succar (2008).

## 2.1 EVALUATION OF THE BIM MATURITY LEVEL

The BIM maturity level can be analysed through the Maturity Diagram (Fig. 2). The use of BIM intends to provide an interactive solution to move from level zero to levels 2 and 3. Allowing the movement through the levels, it is a continuous data updating exercise and an effective management process. However, a portion of the building market keeps working with processes located at level 1. Only the most advanced stakeholders are experiencing significant benefits at level 2 (Oreni et al., 2014; Porwal and Hewage, 2013).

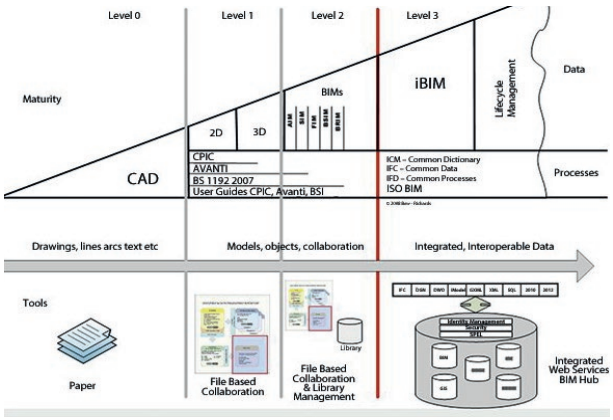


Fig. 2. BIM maturity diagram. Bew et al. (2008); Porwal and Hewage, (2013).

It is expected that BIM may be placed at level 3 in the near future. The shaded area in Fig. 2 identifies the open platform that supports building and compartmentalizing historical libraries, as outlined by Naglaa (2015). The objective is to verify, as it is stated in the Construction Strategy 2025 document (HM Government, 2013) that the BIM model can contain all the asset information and therefore if the model can achieve maturity level 3 as expressed in the Bew-Richards diagram collected in the British Standards Institution, (2014) (Fig. 2).

Currently, many practitioners and stakeholders are implementing a BIM maturity level 2. It is considered that it meets the expectations of efficiency and sustainability in asset management. However, it will be feasible to reach level 3 if progress is made in the interoperability of equipment and programs, as well as in the training of professionals and firms in the sector.

As shown in the Bew-Richards diagram, BIM maturity level 2 is considered to be collaborative (Fig. 2) as it is based on a Common Data Environment (CDE) where all the building information is in connected databases. The database generated by the BIM model and the extended database with the information outside the BIM model. Both are linked together by means of plugins and bidirectional links. As a result of the combination of the two databases,

the corresponding deliverable documents are generated, such as reports, drawings, reports, tables, graphs, etc.

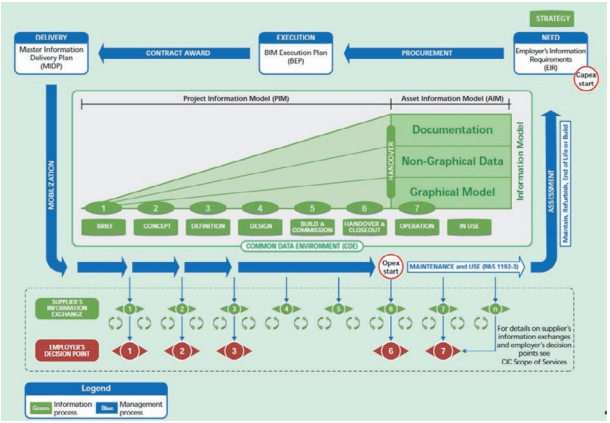


Fig. 3. PAS 1192-2 information delivery cycle adapted for asset management. Source: British Standards Institution (2014).

## 2.2 HERITAGE BIM (HBIM)

The implementation of BIM over heritage buildings is one step behind the implementation over the new buildings and the maturity level can be lower.

Castellano-Romá (2013; 2015) describes the different possibilities offered by the BIM environment applied to Heritage and names it Heritage Building Information Modelling (HBIM). HBIM is considered the tool that allows effective architectural and cultural heritage building management.

Most of the research on HBIM is based on case studies where the implementation methodology is being experimented with. However, the yielded result of this preliminary research demonstrates the ability of the BIM strategies to achieve more effective management. The implementation of this methodology leads to the generation of new methods, protocols, and processes. These new documents are more suitable for dealing with the documentation related to study files, intervention projects, conservation, and maintenance, as well as building lifecycle management. (García-Valldecabres et al., 2022)

Numerous studies show the benefits of HBIM to record and document the current state of cultural building assets and BIM is proposed as the best repository to manage the documentation of an MP (Castellano-Romá and Pinto-Puerto, 2019; Santori et al., 2020).

Moreover, the generated 3D-HBIM model is available to be used during the development of cultural studies, including the analysis of the closest environment, description of the building's particular properties and its construction record (Fig. 4). For this reason, most of the performed research state that the model must be left open for new uses and requirements, such as preventive conservation, dissemination, diagnosis, maintenance, etc. (Fig. 5).

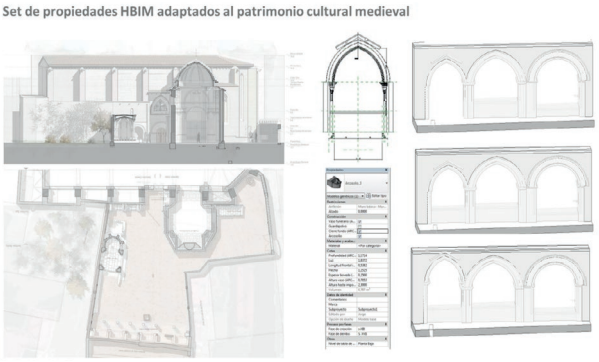


Fig. 4. Application of the Set of properties of the model of San Juan de Hospital de Valencia. Source: García-Valldecabres et al. (2016).

With an open model, Bruno et al. (2018) and Lo Turco et al. (2017) state that it is possible to integrate the information coming from the monitoring of buildings through sensors that feed with new information with the 3D HBIM models and the associated databases, during the building's whole lifecycle.

However, the greatest potential of BIM in existing buildings can be found in the use and exploitation phase as expressed by Parn and Edwards (2017). In the same direction Lin et al., (2018) indicate that from the BIM as-built model, a BIM model should be prepared and delivered to the heritage manager for maintenance, operation, and use of services.

The Spanish BIM users' guide applied to Cultural Heritage (BuldingSMART Spanish Chapter, 2018) proposes the use of BIM to generate deliverables to allow heritage preventive conservation. These documents must allow the analysis of the building use and management, the identification and assessment of the deterioration risks, programming control actions and conservation protocols, and monitoring guides for the control and planning of emergency actions.

The first time that it is provided a protocol for the implementation of HBIM strategies over heritage

buildings that encompasses the complete project cycle including the usage phase and the cultural dissemination is provided by Jordán, et al. (2018; 2020) (Fig. 5).

To define this protocol, a Design Science Research (DSR) method adapted to BIM implementation for buildings with Historic and Heritage character values was carried out following Professor Patricia Tzorzopoulos of Integrated Design at the University of Huddersfield, (Tzorzopoulos and Formoso, 1999; Khan and Tzortzopoulos, 2018).

Likewise, for the collection of supporting data in Social Science according to the methods of Professor Eugenio Pellicer of the Polytechnic University of Valencia (Pellicer et al., 2017; Castillo, Alarcón and Pellicer, 2018).

This protocol is inspired by CTC's BIM cycle diagram, and it is composed of 3 phases and 8 steps. This definition makes an important contribution to the adaptation of BIM to Cultural Heritage by establishing the need for more in-depth studies for the usage phase.

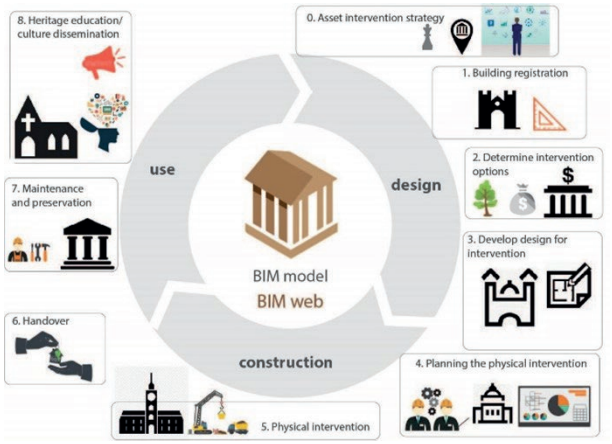


Fig. 5. The complete HBIM protocol for managing interventions during their life cycle in a Cultural Heritage asset. Source Jordán-Palomar (2018).

Salvador et al. (2019; 2020) perform a comparative analysis of the different cyclical diagrams defined in the guidelines, protocols, and scientific literature on HBIM applied for cultural heritage management (Fig. 6). This study allows it to identify the steps needed to perform the maintenance, preventive conservation, dissemination, and visitor management of heritage buildings by using BIM technologies.

## 2.3 CONCLUSIONS TO THE ANALYSIS

The analysis of the available literature about the development of preventive conservation plans using HBIM confirms that this is a new field of research with few robust research lines. Most of the experiences are based on where the strategy of development is tested (García-Valldecabres et al., 2022).

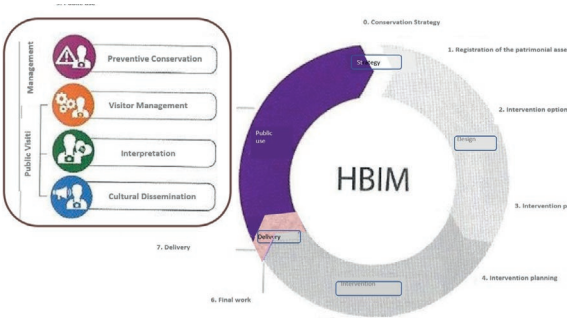


Fig. 6. Cyclic diagram of a HBIM project. Source: Salvador-Garcia (2020).

Traditionally, the information about heritage buildings consisted of a collection of individual documents; reports, drawings, and CAD files, in 2D or 3D formats. This information was completed with various data collections provided by the professionals involved, each working with their own tools and standards. This information, over time, is usually dispersed in repositories, both physical and digital, databases and archives. For this reason, in many cases, since there is not a single information source for the heritage buildings, long searching processes are needed as the organization of the Information doesn't receive the needed valuation. This situation leads, not infrequently, to errors in the decision-making process that negatively affects the conservation of heritage assets. (Historic England, 2017), study and dissemination proposals.

## 2.4 OBJECTIVES AND METHODOLOGY

As previously stated, BIM has the potential to provide an answer to the problems that arise with the information generated before, during, and after the elaboration of an MP. However, it hasn't been demonstrated that with BIM strategies is possible to develop a documentary repertoire that facilitates the exchange between the stakeholders involved in the heritage building management and that allows the incorporation of new information when it is generated,

Therefore, the objective of this research is to identify the confluences between the information needed by an MP and the BIM repositories and if BIM methodologies have enough level of maturity to be used in heritage buildings effectively.

To achieve this objective the methodology applied has been analytical, descriptive, and comparative. The first step is the analysis of the information requirements and the type of deliverables of an MP. In the second step, it is performed an analysis of the requirements of a BIM repository. Finally, a comparative study of the documentary requirements of an MP and the BIM is performed to contrast and verify the confluences.

## 3 THE DOCUMENTARY REQUIREMENTS FOR THE ELABORATION OF A MP

The MPs applied to heritage are drafted in accordance with the specific technical characteristics of each of the monuments. They must be adjusted to the guidelines and criteria defined by each of the National Plans (NP) for heritage protection (if they exist). In the drafting process, a commission formed by experts of different disciplines must be involved.

In general, the requirements for the elaboration of an MP proposed by the different specifications defined by different administrations in relation to the information and the repository to house it can be summarized in the following conditions:

1) The elaboration of studies and deliverables must be carried out by multidisciplinary teams; archaeologists, restorers, geographers, historians, architects, technical architects, technicians in interpretation and communication, documentalists, technicians in tourism, etc.

2) The vision of the whole of the documentation in the repository must be holistic.

3) The coordination of work to be carried out among the participating disciplines and agents must be coordinated and collaborative.

4) The repository must be open and interoperable with the capacity to be updated with new information as it is produced.

5) Interoperability of the information according to its use.

6) The repository in which all the information will be integrated must be unique.

And, finally, 7) A clear and transparent organization of the information, in such a way that it fulfills the objectives proposed by the MP. It can provide knowledge about the building; revalue it; facilitate an appropriate intervention for conservation and maintenance; and offer an adequate explanation to appreciate the values and provide relevant information to the agents interested in the public management of the property. The requirements related to each of the phases of the building lifecycle must be focused to respond to the following challenges: knowledge, analysis/ diagnosis, and definition/programming of action strategies.

The requirements regarding the model need to facilitate the identification of the building and its environment, in the different parts that form it.

The technical specifications for contracting the elaboration of an MP establish that this must be a guiding tool for adequate conservation, restoration, enhancement, and development, as well as highlighting the heritage's singular characteristics. These will be included in the reports of the different studies that develop them, as it is stated by the specialists, Vegas López-Manzanares, Mileto, Cristini (2010), the planning of actions according to the technical conditions of the MP of the castle of Monzó, Huesca, (Ferrer Casaña, 2010), the Master Plan of the Castle of Enesa, El Puig de Santa María, the technical conditions of the MP of the castle of Alcalá de Xivert, Castellón (Ferrer Casaña, 2020) and the MP of the Temple and complex of San Juan del Hospital of Valencia, La Sala et al. (2000).

The MP should bring together in a single technical document all the information necessary for a correct understanding of the heritage building. The MP should also define the necessary actions for conservation and repair, the maintenance needs, and the proposed management modality for the monument. At the same time, it should define the dissemination program, the economic studies, the sustainability analysis, and the accessibility plan, both physical and intellectual. Finally, it should define the needs and conditions for the exploitation of the building.

Thus, the requirements of an MP are the following: 1) The compilation of the Previous Studies carried out to date; 2) To know the monument, improve its conservation, and prepare strategies for intervention and its dissemination; 3) To diagnose correctly and in detail about the

situation of the current state, from all the points of view that affect it; 4) Propose, evaluate and prioritize future actions from a global perspective that contemplates the constructive, historical-cultural, environmental, and functional vision; 5) Any other vision that helps to enhance the value of the monument, its recognition, and enjoyment by society, with the establishment of strategies for better tourism management.

These requirements must be fulfilled in the following deliverables: 1) The final document or report of the MP must contain the Previous Studies elaborated on the heritage building. It must also contain the framework and needs for action, the identification and general description of the building, the legal framework and the study of the regulations that affect it, the study of the natural environment, and the territorial study. 2) The report of the historical study must deal with the historical value, history, building interpretation, building morphology and typology, functions, adaptation, structural system, roofing systems, hydraulic systems, characterization of materials, recent actions, the stratigraphic study of the walls, study of pathological manifestations and archaeological study. 3) The maintenance and conservation report must contain the previously developed actions, the prevention directives, the risk areas, studies on the current state of conservation, temporary proposal of solutions, and prioritization according to the risk of loss and the actions to be carried out. 4)The study of the building's public management must be focused on the diagnosis of the current state and the intrinsic and touristic valuation of the resources. It must also provide an analysis of the exhaustion level due to the different uses, the analysis of the landscape from a touristic perspective, the analysis of the climate, the analysis of the equipment and facilities, and the analysis of the impact generated by the visitors. 5) It must be the plan of action and strategies defined to achieve the objectives.

The requirements will be achieved through the appropriate selection of certain profiles defined as human resources. They must cover the scope of the disciplines involved in the elaboration of the MP and which correspond to the following: Architecture, Archaeology, Technical Architecture, History, Physical and Human Geography, Public Relations and Tourism, Dissemination and Advertising; Geomatics Engineering, Industrial Engineering, Fine Arts and Restoration (Fig. 7). Based on these disciplines, it will be defined the matrix of use and roles to carry out the activities assigned in each process foreseen to achieve the objectives of the MP.

| STRUCTURAL REQUIREMENTS OF THE D.P. | | | |
|---|---|---|---|
| Multidisciplinary | Coordinated | Holistic | Open |
| **REQUIREMENTS FOCUSED ON QUALITIES** | | | |
| Inter-operative | Unique | Integrated | Sure |
| **REQUIREMENTS FOCUSED ON THE PURPOSE OF THE USE** | | | |
| Knowledge | Revaluation | Preservation recovery | Explanatory |

Fig. 7. Summary table MP requirements for heritage protection and conservation. Source: Own elaboration.

## 4. THE REQUIREMENTS FOR THE IMPLEMENTATION OF BIM METHODOLOGY IN THE FIELD OF CULTURAL HERITAGE

The required disciplines for the implementation of the BIM methodology for architectural and infrastructure projects are, according to the BIM manuals, charters, and protocols, project manager, BIM coordinator, BIM manager, and BIM modelers. These are the same regardless of whether the real estate asset is cultural heritage or not.

Once the first information model or models have been created, finalized, and approved, they must be able to be used for subsequent work. Therefore, it needs to be adjusted to the defined workflow and allows to assign roles and responsibilities for each defined task. It must also allow the definition of the BIM processes, the organization of the nomenclature, the intermediate milestones, and reaching the final milestones with the contracted deliverables.

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

The BIM model is created and updated proportionally throughout the project development and the deliverables are generated from this

model and the linked external documents, in such a way that the traceability of each of the deliverables is documented.

Specifically, the conditions of the BIM methodology in a Cultural Interest Asset (BIC) are the following: 1) that all the effort is concentrated in the development of models and information systems; 2) all the procedures must be defined through a work protocol focused on promoting the heritage building knowledge, promoting its conservation and restoration and allowing proper management; 3) there is a procedural continuity in the development of the actions proposed for the MP, taking into account the foreseeable requirements in future actions that enrich the information model; 4) it will be adapted to the capabilities of the managing entity of the heritage asset to facilitate the continued use of the BIM model during all phases of the building lifecycle; 5) a linked Common Data Environment (DCE) is established (Fig. 8).

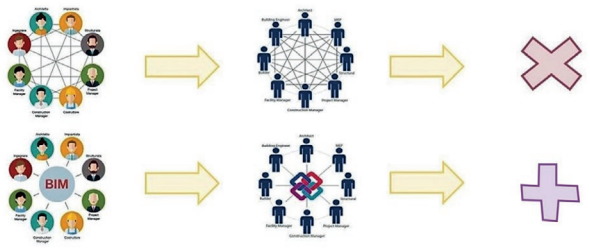


Fig. 8. Interoperability in a closed and an open system. Source: Own elaboration.

The BIM requirements defined by the promotor, EIR (Employer Information Requirements), establish the set of properties and the levels of information. The set of properties or layouts related to the non-graphical information of the elements of the models (metadata) will be structured around the grouping of the properties. These sets of properties that compose the different BIM models, will be organized in a homogeneous and standardized way. It will not be admitted any element that does not contain this set of properties structure. However, improvements or modifications authorized by the asset managers are allowed. These parameters will be fully visible and operable both in native formats and in OpenBIM (IFC) format (Industry Foundation Classes, 2013) (Fig. 9).

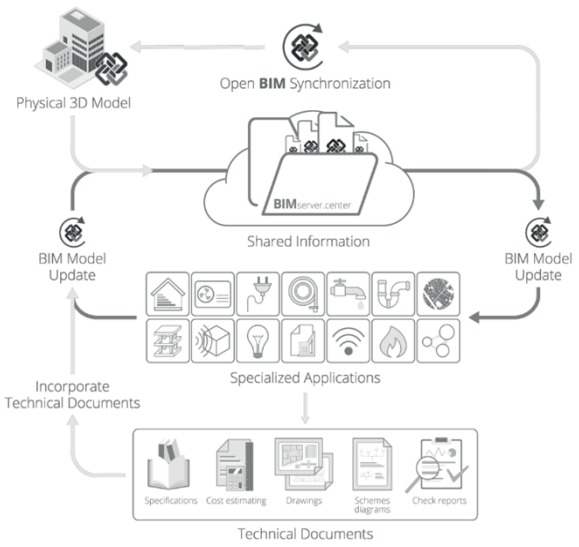


Fig. 9. OpenBIM flow. (Consultation 3.06.2022); Source: http://open-bim.cype.es/

The levels of development (LOD) are detailed in a specific annex that is established in the EIR requirements and they must be adapted to a heritage building. The morphology and topographic information must come from scanning campaigns to obtain the up-to-date as-built point cloud called Scan to HBIM (Fig. 10). The definition of the graphic/geometric detail will be adapted to the "Level of Development Specification" defined by the BIM Forum, which details by categories, from the conceptual LOD 100 to the LOD 500 model "as-built". These will define the matrix of development levels of the models of the different categories of elements of the BIM models that are set in the deliverable's tables and in the information requirements.

Fig. 10. As-built point cloud of the arcosolium compositional succession of San Juan del Hospital de Valencia. Source: García-Valldecabres et al. (2016).

It is of special attention the need for a elements standardized designation, which should be performed according to the AEC (UK) BIM (2012)

Standard for Autodesk Revit, 8 Folder Structure and Naming Conventions, and that, in this case, will be applied, according to the simplified criterion, to the needs of the asset managers. Uniclass, 2015, is the classification system (Unified Classification for the Construction Industry) created by the Construction Project Committee. It defines a hierarchical structure that serves to uniquely designate each of the elements. For the case of the adaptation of BIM to heritage, a similar classification will be proposed that includes all the construction elements.

The model is defined by zones: a) Territory; Ensemble; b) Immediate surroundings; c) Zone 1; d) Zone 2; e) Zone 3, etc.

This division may be subdivided into smaller spatial units so that the native files do not exceed a certain number of storage units.


Fig. 11. Schematic of the classification system process, according to Uniclass 2015. Source: Own elaboration.

At the same time, each of the models in these zones may be subdivided into disciplines, delimitations, or federated models. This division can be done under criteria due to the building size not exceeding a certain number of units (Fig. 11).

The organization of the native working files is defined in the BIM Execution Plan (BEP) for each required BIM use. Likewise, the deliverables must be performed as specified in the BEP. The necessary tests and adjustments must be carried out so that the information structure of the native models can be exported to OpenBIM open formats.

The organization of the model must have a previously agreed origin of coordinates. The definition of the categories of the models, the subprojects and the interference matrix, and the process map to obtain the specific BIM uses must be included in the connection process general diagram. It must also include the connection of the documentation with the deliverables, as well as, with the review process of deliverables and people. Finally, It must include tables with a proper information organization by previously detailed categories according to the UniClass classification (Fig. 11):

Building: describes a project as a whole. It can refer to all types of coherent groupings of buildings and infrastructures delivered and in operational use.

Entities: constitutes one of the parts (zones) that form part of a real estate asset that is in use within a more complex system.

Activities: represents the activities to be carried out in a building during the operation of the real estate asset. The table also includes research, functionalities, maintenance, and services.

Spaces: they can host one or more activities, within an element or in relation to non-point if not linear works such as all types of infrastructure systems.

Elements: they are the main components of a structure, as, for example, in a house, they are the elements that coincide with the pillars, slabs, walls, etc. (Fig. 13).

Systems: are a set of components grouped together to form an element or to fulfill a function. For example, the covered system is composed of slab, vapor barrier, insulation, tile, etc.

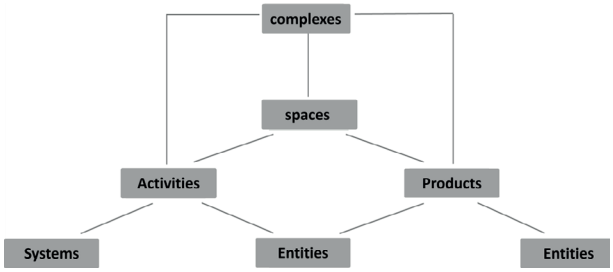


Fig. 12. Uniclass 2015 classification system. Source: Own elaboration.

The BEP must contain a folder structure, the process maps, the set of properties to populate LOI model data, and the BIM style book which is the document detailing all the BIM production standards. It will be appropriate to the level of BIM maturity of the building manager.

The BIM model with the basic geometry will facilitate the coordination of the information exchange, validation of the data structure, and classification. The model will be federated with the territorial model and the model of the monument as a whole, which will be composed of the immediate surroundings and the different interior zones; Zone 1, Zone 2, Zone 3., etc (Fig. 14).

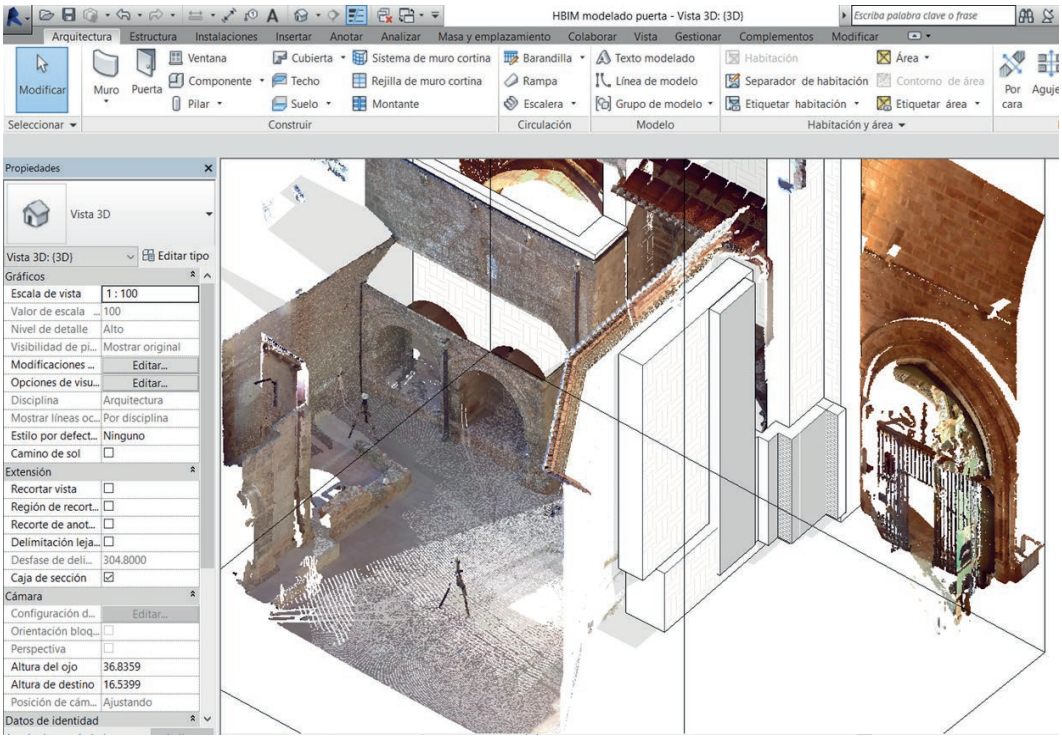


Fig. 13. Elements and walls of different typologies. Source: García-Valldecabres et al. (2016).

The documentation and structuring of the processes will be obtained from the BIM model and the linked information: a) The coordination model of information exchange and validation of the data structure and classification. b) The federated model will contain the information of the previous studies, of the diagnosis. And c) the final coordination model will contain the previous studies, the diagnosis, the validated schedule, and the action plans (Fig. 15 and Fig. 16).

| | | | | | |
|---|---|---|---|---|---|
| FEDERATED MODELS | Actual state | LINKED MODELS | MODEL ENVIRONMENT | location model | Area A1 A2 .... |
| | | | | site model | infrastructure model — Area B1 B2.. |
| | Archaeological Stratigraphic | | JOINT METRIC MODEL | archaeological model | archaeological model below ground 1 — Zone C1 C2 C3... |
| | | | | statigraphic model | Stratigraphic model above ground 2 — Zone D1 D2... |
| | Construction systems State of pathological manifestations | | | construction model | Construction systems — Zone E1 E2... |
| | | | | | manifestations pathological lesions — Zone F1 F2... |
| | Constructive historical evolution | | | model historical periods | Period G1 G2... |

Fig. 14. Table of the Federation of models according to Uniclass 2015. Source: Own elaboration.

| BIM STRUCTURAL REQUIREMENTS (EIR) Multidisciplinary | | | |
|---|---|---|---|
| Common Data Environment | Development Levels | Property set | LOD matrix by element categories |
| Multidisciplinary | Coordinated | Holistic | Open |
| **REQUIREMENTS FOCUSED ON THE ADAPTATION OF BIM TO HERITAGE** | | | |
| Unique and Inter-operable | Open, accessible and coordinated | Adaptation of the property Set and coordinate | Clear, integrated and holistic models |

Fig. 15. Summary table of BIM requirements adapted to heritage. Source: Own elaboration.

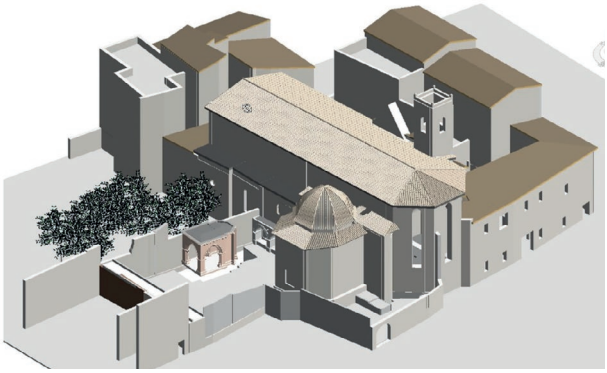

Fig. 16. Federated model of the medieval complex of San Juan del Hospital in Valencia. Source: García-Valldecabres et al. (2016), adapted and completed by Salvador-García (2020).

## 5. DISCUSSION

From the study of the comparative table, (Fig. 17) it can be established that the requirements of an MP to achieve effective and sustainable management of cultural heritage assets coincide with the BIM requirements.

| COMPARISON BETWEEN PD AND BIM REQUIREMENTS (EIR) | | | |
|---|---|---|---|
| **BIM STRUCTURAL REQUIREMENTS (EIR) Multidisciplinary** | | | |
| Common Data Environment<br><br>Multidisciplinary | Development Levels<br><br>Coordinated | Property set integrated<br><br>Holistic | LOD matrix by element categories<br><br>Open |
| **REQUIREMENTS FOCUSED ON THE ADAPTATION OF BIM TO HERITAGE** | | | |
| Unique and Inter-operable | Open, accessible and coordinated | Adaptation of the property Set and coordinate | Clear, integrated and holistic models 3D |
| **REQ REQUIREMENTS FOCUSED ON ADAPTATION TO CULTURAL HERITAGE** | | | |
| **Knowledge**<br>Multidisciplinary<br>Inter-operative | **Revaluation**<br>Coordinated<br>Unique | **Preservation Recovery**<br>Integrated<br>Holistic | **Explanatory**<br>Open<br>Of course |

Fig. 17. Comparative table of MP and BIM. Source: Own elaboration.

As stated by Castellano-Romá and Pinto-Puerto (2019) and Martín-Talaverano et al. (2021), among others, BIM is a methodology designed for buildings and infrastructures regardless of their class or age. At the same time, it is a system that is implemented according to a holistic vision contemplating the useful life cycle of the assets in which the traceability of each and every one of the steps in each of the phases that constitute the life of the asset is contemplated.

Therefore, the repository of an MP developed according to the BIM methodology will contain all the information related to the heritage asset under study for consultation and dissemination in a simple, direct, useful, and clear way at the same time. Thus, in this way, the difficulties of the management of the information bases of an MP of heritage building assets are satisfied, improving the workflow, increasing productivity, minimizing errors, and facilitating decision-making in the case of intervention, enjoying the use and knowledge of the heritage asset (Fig. 17).

## 6. CONCLUSIONS

According to the analysis performed in this research three conclusions can be obtained:

1) From the early stages of the model development, it is worked simultaneously in the elaboration of Previous Studies, Consolidation, and Action Projects, as well as, in the MP of the different heritage buildings or archaeological ensembles as it is stated by Angulo-Fornos (2012), Castellano-Romá and Pinto-Puerto (2019) until finding the probably the first MP proposed to be elaborated by means of the BIM methodology, Ferrer Casar (2020).

2) One of the advantages is the capacity of this digital BIM repository to manage a big amount of information obtained by the concurrence of different disciplines (Architecture, Technical Architecture, Archaeology, History, Anthropology, Geodesy, Ethnology, Tourism, Cultural Management, etc.). This information can be oriented to an operational convergence of knowledge that facilitates the rational application of practical results for the conservation and management of the architectural, historical, and cultural heritage over which the guardianship is exercised.

3) New digital documents have been generated for the knowledge, memory, and protection of the building, in such a way that the BIM requirements respond to the needs of the repository of the deliverables of an MP, according to the recommendations of the Charter on the Preservation of Digital Heritage (UNESCO, 2009).

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## REFERENCES

AEC (UK) BIM, 2012. Protocol Implementing UK BIM Standards for the Architectural, Engineering and Construction industry. Version 2.0 September 2012.

Almagro Gorbea, A. 2019. “Half a century documenting the Architectural Heritage with photogrametry.” *EGE Revista de Expresión Gráfica en la Edificación*, Nº 11, Valencia: Universitat Politècnica de València. pp. 4-30. https://doi.org/10.4995/ege.2019.12863

AlSehaimi, A., Koskela, L., and Tzortzopoulos, P. 2013. “Need for alternative research approaches in construction Management: Case of Delay Studies.” *Journal of Management in En-engineering*, Vol. 29, No. 4, October 1, 2013. © ASCE, ISSN 0742-597X/2013/4-407-413. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000148

Angulo Fornos, Roque. 2012. “Construcción de la base gráfica para un sistema de información y gestión del patrimonio arquitectónico: Casa de Hylas.” *Arqueología de la Arquitectura*, 9, enero-diciembre 2012, 11-25. Madrid / Vitoria. ISSN 1695-2731.eISSN 1989-5313. https://doi.org/10.3989/arqarqt.2012.10005

Bew, M., Underwood, J., Wix, J., Storer, G. 2008. *Going BIM in a commercial world In eWork and eBusiness in Architecture, Engineering and Construction*. Londres: Taylor &Francis. https://doi.org/10.1201/9780203883327

British Standards Institution. 2014. PAS1192-3 2014. Specification for information management for the operational phase of assets using building information modelling. [online]. Accessible at: https://bim-level2.org/standards/

Bruno, S., De Fino, M., Fatiguso, F. 2018. “Historic Building Information Modelling: performance assessment for diagnosis-aided information modelling and management.” *Automation in Construction*, 86, 256-276. https://doi.org/10.1016/j.autcon.2017.11.009

Buildingsmart Spanish Chapter. 2018. Guía de usuarios BIM aplicado al Patrimonio Cultural [online]. Accessible at: https://www.buildingsmart.es/bim/guías-ubim/.

Buildingsmart Spanish Chapter, 2019. Introducción a la serie EN-ISO 19650.

Castellano-Román, M. 2013. “Hacia el modelado de información patrimonial. Generación de modelos de información del patrimonio inmeble en el momento de su protección jurídica.” *Virtual Archaeology Review*, vol. 4, no. 9, pp. 7-13. https://doi.org/10.4995/var.2013.4235

Castellano-Román, M. 2015. “Generación de un modelo de información del patrimonio inmueble en el momento de su protección jurídica.” *EGA. Revista de expresión gráfica arquitectónica*, vol. 20, no. 26, pp. 266-277. https://doi.org/10.4995/ega.2015.4060

Castellano-Román, M., and Pinto-Puerto, F. 2019. “Dimensions and Levels of Knowledge in Heritage Building Information Modelling, HBIM: The model of the Charterhouse of Jerez (Cádiz, Spain).” *Digital Applications in Archaeology and Cultural Heritage*, 14, e00110. https://doi.org/10.1016/j.daach.2019.e00110

Castillo, T., Alarcon, L. F., Pellicer, E. 2018. “Influence of Organizational Characteristics on Construction Project Performance Using Corporate Social Networks.” *Journal of Management in Engineering*, vol. 4, no. 34, pp. 1-9. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000612

Constrution Industry Concil. 2018. Building Information Modelling (BIM) PROTOCOL. Standard Protocol for use in projects using Building Information Models, London.

Ferrer Casaña, J.V., 2010. Plan Director del Castillo de Enesa. (Retrieved 09.06.2022) https://docplayer.es/25387003-Plan-director-del-castillo-de-enesa-el-puig.html

Ferrer Casaña, J.V., 2020. Pliego de prescripciones técnicas para la contratación de la redacción del plan director para la conservación y el uso público del castillo de Xivert mediante metodología HBIM. Diputación de Castellón. Exp. Gestiona: 5963/2020.

García-Valldecabres, J. Galiano-Garrigos, A. Lopez Gonzalez, C., and Cortes Meseguer, L. 2022. HBIM work methodology applied to preventive maintenance: A review of the state of the art. *WIT Transactions on The Built Environment*, ISSN: 1743-3509; Vol. 205, pp. 157–169; Ashurst, Southampton. https://doi.org/10.2495/BIM210131

García-Valldecabres, J.L., López-González, Mª.C., Salvador-García, E., Jordán-Palomar, I., and March-Oliver, R. 2016. *El diseño de una base de datos, modelo para la gestión de la información y del conocimiento del Patrimonio Arquitectónico*. Inédito.

Guía nº 14 de la asociación BuldingSmart. 2018. Adaptación del patrimonio cultural a la metodología de gestión BIM. https://www.buildingsmart.es/actividades/grupos-de-trabajo/patrimonio-cultural/

Historic England. 2017. *BIM for Heritage. Developing a Historic Building Information Model*. Swindon: Historic England.

HM Government. 2015. Digital Built Britain. level 3 Building Information Modelling-Strategic Plan. UK Government, febrero, 1-47.

Jordán-Palomar, I., 2019. Protocol to manage heritage-building interventions using heritage building information modelling (HBIM). Tesis doctoral. Editorial: Universitat Politècnica de València. https://doi.org/10.4995/Thesis/10251/128416

Jordán-Palomar, I., Tzortzopoulos, P., García-Valldecabres, J., and Pellicer E. 2018. "Protocol to Manage Heritage-Building Interventions Using Heritage Building Information Modelling (HBIM)." *Sustainability*, 10(908), 1-19.

Jordán Palomar, I., García Valldecabres, J., Tzortzopoulos, P., Pellicer, E. 2020. "An online platform to unify and synchronise heritage architecture information." *Automation in Construction* (110), 103008. https://doi.org/10.1016/j.autcon.2019.103008

Khan, S. and Tzortzopoulos, P. 2018. Using design science research and active enquiry to bridge the gap between theory and practice in lean construction research. Conference: *26th Annual Conference of the International Group for Lean Construction*. July 2018. https://doi.org/10.24928/2018/0409

La Sala, V., Ordeig, M., Casar, J.I., Dies, E., Romero, F., Taberner, F., Sancristobal, M., Serra A., and Gallud P. 2000. *Plan Director del Templo de San Juan del Hospital de Valencia*. Inédito.

Lin, Y.C., C.P. Lin, Hu H.T. y Su, Y.C., 2018. "Developing final as-built BIM model management system for owners during project closeout: A case study." *Advanced Engineering Informatics*, vol. 36, no. February, pp. 178-193. https://doi.org/10.1016/j.aei.2018.04.001

Lo Turco, M., Mattone, M., and Rinaudo, F. 2017. "Metric survey and BIM technologies to record decay conditions." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, 42(5W1), pp. 261-268. https://doi.org/10.5194/isprs-archives-XLII-5-W1-261-2017

Martín Talaverano, R., Murillo Fragero, J I., and Utrero Agudo, M.ªÁ. 2021. "Reflexiones y criterios relativos a la creación de modelos BIM de edificios históricos", *Arqueología de la Arquitectura*, 18: e113. https://doi.org/10.3989/arq.arqt.2021.005

Naglaa A.M. 2015. Towards a theoretical framework for HBIM approach in historic preservation and management. *Archnet-IJAR*, vol. 9, no. 3, November 2015 - (130-147). https://doi.org/10.26687/archnet-ijar.v9i3.737

OpenBIM (IFC) (Industry Foundation Classes) 2013. Retrieved 10.06.2022) https://www.buildingsmart.org/standards/bsi-standards/industry-foundation-classes/

Oreni, D., Banfi, F., Brumana, R., and Barazzetl, L. 2014. Beyond crude 3D models: from point clouds to Historical Building Information Modeling via NURBS. Euro-Mediterranean Conference. Cham: Springer, pp. 166-175. https://doi.org/10.1007/978-3-319-13695-0_16

Pärn, E.A., and Edwards, D.J. 2017. "Conceptualising the FinDD API plug-in: A study of BIM-FM integration." *Automation in Construction*, vol. 80, pp. 11-21. https://doi.org/10.1016/j.autcon.2017.03.015

Pellicer, E., Yepes, V., Ortega, A.J., Carrión, A. 2017. "Market demands on construction management: A view from graduate students." *Journal of Professional Issues in Engineering Education and Practice*, vol. 4, no. 143, pp. 1-11. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000334

Pinto Puerto, F., (coord.) 2021. *Modelos digitales de información en la tutela sostenible del patrimonio cultural*. Contribución al conocimiento e innovación social. Universidad de Sevilla.

Planes Nacionales (PN) de patrimonio, Plan Nacional de Catedrales. 1999. Retrieved 10.06.2022. https://www.culturaydeporte.gob.es/planes-nacionales/que-son.html

Porwal, A., and Hewage, K N. 2013. Building Information Modeling (BIM) partnering framework for public construction projects. *Automation in Construction*. Vol. 31, May 2013, pp. 204-214. https://doi.org/10.1016/j.autcon.2012.12.004

Salvador-García, E., G-Valldecabres, J., Viñals Blasco, Mª. J. 2019. Integrating HBIM models in the management of the public use of heritage buildings. *Canadian Journal of Civil Engineering*, vol. 2, no. 47, pp. 228–235. https://doi.org/10.1139/cjce-2018-0338

Salvador-García, E. 2020. *Protocolo HBIM para una gestión eficiente del uso público del patrimonio arquitectónico*. Universitat Politècnica de València, València. Tesis Doctoral. Disponible en: https://riunet.upv.es/handle/10251/146811.

Santoni, A., Martín-Talaverano, R., Quattrini, R., and Murillo-Fragero, J. 2020. "HBIM approach to implement the historical and constructive knowledge. The case of the Real Colegiata of San Isidoro (León, Spain)." *Virtual Archaeology Review*, 0. https://doi.org/10.4995/var.2021.13661

Succar, B. 2008. "Building information modelling framework: A research and delivery foundation for industry stakeholders." *Automation in Construction*, vol. 18, pp. 357-375. https://doi.org/10.1016/j.autcon.2008.10.003

Tzorzopoulos, P., and Formoso, C. 1999. Considerations on Application of Lean Construction Principles to Design Management. 1999/7/26 Publicaciones. *Actas IGLC*. Volumen 7. pp. 26-28.

UNESCO. 1972. Convención de 1972 para la Protección del Patrimonio Mundial Cultural y Natural. (Retrieved 2022.05.30). https://es.unesco.org/fieldoffice/santiago/cultura/patrimonio

UNESCO 2009. Carta sobre la preservación del patrimonio digital. Accesible at: https://unesdoc.unesco.org/ark:/48223/pf0000179529.page=2.

Uniclass 2015. (Unified Classification for the Construction Industry). Consulta 2022.06.10); https://biblus.accasoftware.com/es/clasificacion-uniclass-2015-de-objetos-ifc/

Vegas López-Manzanares, F., Mileto, C., Cristini, V. 2010. "Planificar un plan: etapas y desarrollo del plan director del castillo de Monzón- Huesca." *Arché*. vol. 4-5, pp. 365-372. http://hdl.handle.net/10251/31168

Volk, R., Stengel, J., and Schultmann, F. 2014. "Building Information Modeling (BIM) for existing buildings-Literature review and future needs." *Automation in construction*, vol. 38, 109-127. https://doi.org/10.1016/j.autcon.2013.10.023

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