HBIM: The digital transformation of cultural and existing heritage

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Abstract. BIM, or Building Information Modelling, is the future of architecture, engineering, construction and operations. We very often associate this definition with new buildings, while 80% of buildings in 2050 already exist today. A significant part of them are historical buildings. It is important to know how we can use BIM in this context and how this modern design tool serves to model and manage the unpredictable situations and complexities of historic buildings. The dissimilarity, the difficulty of data exchange between interested parties and therefore the difficulty of standardization is in this regard the challenge to be overcome with older buildings. In connection with architectural heritage, information modelling of heritage buildings is referred to under the name of HBIM, which is a built architecture representation system composed of libraries of semantically structured and parameterized objects. The basic process is the processing of the data in our possession, which are all transferred to a BIM-type model. SCAN to BIM is an operation that allows you to connect a point cloud created by laser scanner or photogrammetry to develop historical building management models that can be used in different application areas: accessibility and improvement, archival documentation research, conservation and visualization of cultural heritage, reconstruction and management of heritage, artificial intelligence (AI) and virtual reality (VR). The purpose of the paper is to provide an basic overview of the concept of HBIM. The contribution provides a brief overview of the regulatory framework and an overview of the methodology and workflow in the mentioned area with the appropriate conclusions.

1 Introduction

NIBS (National Institutes of Building Science) defines BIM as the "digital representation of the physical and functional characteristics of an object" [1]. The first definition of Heritage Building Information Modelling (HBIM) appeared in 2009 as an information representation system for built buildings consisting of a library of semantically structured and parametric objects.

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Since its inception, HBIM has created new possibilities for sharing disparate information in a single digital environment and, in the context of cultural heritage, has been configured as a way to increase portability and make data available to a wider community of users for different purposes. The concept of collaborative work is integrated into BIM itself and its principles are an efficient approach to building design and maintenance for effective information management throughout a building's life cycle.

In the field of cultural heritage, HBIM's great potential lies in its ability to combine multidisciplinary knowledge and skills: BIM methods applied to heritage require an interdisciplinary and collaborative approach, starting from reliefs, passing through modeling, historical analysis, database implementation, etc. to continue to engage in specific skills.

HBIM can be understood as a holistic process, as a tool in which information and models on different scales can be kept interconnected in space and time and allows experts with different skills to share work in order to collect all the information from the analysis phase to meet maximum knowledge in support of conservation, dissemination and enhancement.

The workflow begins with the survey as a database and ends with the development of management models of the historic building that can be used in different application areas: accessibility and enhancement, archival document research, conservation and artificial intelligence.

Thanks to the integration and linking of different knowledge and skills, it is possible to reuse information obtained directly or extracted from in-depth research to provide a comprehensive and all-encompassing knowledge framework in order to improve accessibility, fruition but also to increase the intrinsic historical and documentary value of cultural heritage.

2 Literature review

2.1 Overview of BIM technology on existing buildings

A substantial part of building in Europe is older than 50 years with many buildings in use today that are hundreds of years old. More than 40% of our residential buildings have been constructed before the 1960s when energy building regulations were very limited. Countries with the largest components of older buildings include the UK, Denmark, Sweden, France, Czech Republic and Bulgaria. A large boom in construction in 1961-1990 is also evident through analysis where the housing stock, with a few exceptions, more than doubles in this period [2].

Developments in information and communication technologies (ICT) have led to a significant renewal in recent years in different sectors such as the design, enhancement, restoration and conservation of historic buildings and are still today, implying the need to apply new approaches to Heritage.

Traditional techniques of graphic representation and building management are constantly revisited with new knowledge and updated through the appropriate use of new generation tools to transform the process of information processing into digital data.

BIM was introduced to facilitate the building process and the management of orders by professionals, without neglecting the fundamental contribution provided by this process in simplifying the exchange of data during the design process. Its success is internationally recognized, but the fact remains that this constantly evolving method has been designed fundamentally for the design of the new.

This aspect represents a great limitation of BIM, especially in a historical period in which the theme of safeguarding historical and built heritage has assumed great importance. In the wake of these limitations and in the attempt one day to overcome them completely, we are
now witnessing continuous experimentation of BIM approaches on existing heritage, with the aim not only of documenting the state of the art, but also with a view to future maintenance and design of buildings.

Nowadays, Building Information Modelling is at the center of scientific debate and has achieved important milestones, first in the field of new buildings and then in that of existing buildings.

Unlike newly built projects, BIM application in the heritage sector is a relatively new field of academic research. The challenge with historic buildings is that the elements are not similar and therefore difficult to standardize. Most elements are unique, implying that many have irregular geometries and shapes along their length.

Heritage buildings are still managed using the traditional method that does not provide heritage data in a single digital database but through a multi-format system where different parties are involved. The multi-format system is characterized by various formats such as PDF documents, word reports, Excel spreadsheets, etc., which are hardly linked and lack integration. It is also supported by 2D representation, therefore lacking 3D visualization, making it difficult for managers to make critical decisions.

Retrieving and updating information from such a system is challenging. In addition, the exchange of data between stakeholders is difficult because the various formats create a lack of collaboration and a communication gap. The adoption of such a traditional method creates many problems during the different building processes (management, reuse and FM).

**Fig 1.** Age categorisation of housing stock in Europe. Source: BPHE survey

### 2.2 Heritage Building Information Modelling (HBIM)

In recent years we have seen experimentation with the application of approaches such as BIM to existing assets and in this regard the acronym HBIM is used to describe this particular area of interest.

The term was coined in 2009 by Professor Maurice Murphy of the Dublin Institute of Technology, whose meaning emerged a few years later in an article in the journal INSPR Photogrammetry and Remote Sensing: "Historic Building Information Modelling (HBIM) is a novel solution whereby interactive parametric objects representing architectural elements are constructed from historic data, these elements (including detail behind the scan surface) are accurately mapped onto a point cloud or image based survey " [3].

From this definition it is clear that BIM, usually used to create projects from scratch, has expanded its typical scope by exploring existing markets. A new challenge, in fact, is represented by the possibility of modeling existing building components in the territory by creating parametric digital models containing different types of information.

In the last decade, the scientific community has recognized HBIM as the real modeling process from relevant data, with the aim of creating libraries of parametric objects and combining them with informative data to enrich them. The main purpose of the BIM methodology applied to the heritage that already exists is the acquisition of a digital twin [4].
to be used as a model and database to insert geometric and technical information useful for acquiring awareness and knowledge of the building in question.

BIM, applied to built heritage, greatly increases the intrinsic potential of the system itself because it increases its use in the creation of existing models not only as their digital and geometric restitution, but above all as intelligent collectors of data and information, parametric and with a well-defined semantics. With HBIM a sort of reverse engineering process is applied to existing buildings, the constructive evolutions are studied and, in the modeling phase of the architectural artefact, the procedures that led to the construction of that on the false (imaginary?) line of the final goal building organism are studied.

The BIM models of the Architectural Heritage (AH) are made up of intelligent objects that, despite the uniqueness of the artifact, can be re-used and adapted to other architectures that present constructive and architectural style similarities. In addition, the elements of the parametric libraries of HBIM models contain real and extremely heterogeneous information on the graphic documentation, the type and the main construction characteristics of the construction period to which the building belongs, information that can be updated, replaced and added. Ultimately, the HBIM paradigm is able to produce real "data collectors" populated by both geometric and non-geometric information related to various topics: historical documents, monitoring data, structural information, conservation or maintenance status.

2.3 The methodology and workflow of the HBIM

The workflow from data acquisition to the HBIM three-dimensional model is now consolidated and consists of a sequence of key operational phases in the process for the realization of models for the management of the historical architectural heritage [5].

The design activity for the recovery or restoration of an existing structure, which is based on the BIM methodology, starts from the in-depth knowledge of the artifact: the history and evolution must be investigated, the constructive stratifications that determine the current state of the art, reaching a high level of knowledge of the building in its entirety and complexity.

The historical investigation and the relief activity lead to the knowledge of architectural, structural, geometric and material characteristics of the building system to be preserved in the design of the recovery activity. Upstream, it is therefore essential to undertake an accurate and in-depth analysis and historical investigation that, through consultation of documents and documents, historical sources, archival documents, drawings and description of the techniques and materials used, allow to reconstruct the entire life of the artifact.

This must be accompanied by the relief and measurement activity on the site, which takes place through the instruments and technologies offered and made available based on the investment and the economic budget of the project. For this reason, the first phase of knowledge, data collection and awareness, is one of the main ones. The information collected lays the foundations that allow diagnostic analysis to be carried out on the building, to identify and define the recovery interventions to be implemented and the subsequent maintenance activities. The technologies adopted for the collection of data and information applied in the HBIM methodology can be multiple: photogrammetry and laser scanner detection, which in turn allow to associate geometric information to images, in such a way as to provide a virtual model highly faithful to reality.

The next step to be undertaken is the processing of the data collected as a result of the relief campaign. In the use of laser scanner and photogrammetry, usually, following a post-production and data processing activity, which also requires the insertion of georeferenced coordinates, we arrive at the realization of a point cloud that constitutes the basis for the modeling of the artifact, defining in detail volumetry, dimensions and colorimetric information. The processing of survey data allows to obtain a point cloud from which it is possible to create meshes that lead to a first definition of 3D model.
The next step is that of the actual digitization and realization of the three-dimensional and parametric BIM model, which relies and reflects on what has been detected in the previous phases. The information and data entered concern historical information, analysis of degradation or deformation, materials used and level of reliability of the data present.

In this way it is possible to create a complete model, which collects all the data relating to the history of the building and which will therefore allow to produce all the necessary design drawings: from technical drawings to orthographic projections to the production of intervention schedules. Obviously, of relative importance is to be aware of the purpose for which the BIM model of the artifact is made, inserting and collecting more detailed data based on the recovery or restoration intervention that is planned to be performed.

HBIM, therefore, explains a working method that allows you to design the existing from the point of view of modelling, or a model is created that simulates the construction of the building and that presents most of its characteristics. The application of the methodology to the existing heritage provides the possibility of optimizing its management, maintenance, and protection, allowing the monitoring of degradation, the planning of restoration interventions, the simulation of catastrophic events.

### 2.4 HBIM and the regulatory framework

In the last ten years, the use of Building Information Modeling (BIM) has been discussed and experimented, which was born and developed in the sectors of new buildings, infrastructures and industrial production, thanks to the evolution of digital tools and methods typical of Industry 4.0.

In December 2018, ISO 19650 was adopted, in its parts 1 (Concept and principles) and 2 (Delivery phase of assets), which through the mechanism of direct adoption of the Vienna Agreement becomes a European (EN) and national standard for each member state during 2019.

ISO 19650, we can say that concludes, with the first international standard of "principle" (in the vein of ISO 9000-quality, 14000-environment, 55000-asset management, 31000-risk, etc.) a first phase, "historical", of the regulatory world (and not) on BIM and digitization of the construction sector. A first phase much more oriented to IT aspects, to its beginnings (ISO STEP 10303-11-21), and then increasingly aimed at information management and processes.

In parallel, national standards have been developed as a corollary, which are now being revised to align with the concepts introduced with the ISO 19650 series and make them operational in their own country. So we have the English PAS 1192 - process, the Italian series UNI 11337 - application, the German DIN 91392 - CDE and the French AFNOR PRXPP07-150 - products.

ISO 10650, in its main characters (part 1), maintains the approach and concepts that have been consolidated over the years throughout the world "BIM": Information Specifications, Information Management Plan, etc. [6].

The absolute reference point in Europe with regard to the regulatory introduction of BIM is "European Union Public Procurement Directive" 2014/24 of 26 February 2014. The "European Union Public Procurement Directive", voted in January 2014 by the European Parliament and subsequently adopted, invites EU Member States, by 2016, to "encourage, specify or impose" through dedicated legislative measures the use of BIM, as a reference standard, for all projects and works with public funding [7].

However, within the scope of the history, procedural guidelines have not yet been drawn up that establish a shared HBIM methodology covering all phases of the process, starting from the survey and diagnostics to the design and use phase [8].
A problematic aspect that brings with it a BIM model referring to a historic building is the reliability of the measurements and information reported. In fact, research and survey activities do not always provide complete answers that allow an accurate and safe reconstruction of the artefact. For this reason, the issue of the reliability of the model and its transparency is fundamental in order to provide a precise awareness of the building to those who will then have to intervene. The indication of the reliability and interpretative level of the information in the model therefore becomes a parameter of great importance and interest in the context of HBIM.

These issues related to the reliability of the data, were introduced by referring to the concept of transparency of the model of the state of the art already starting from 2009 with the London Charter and then, subsequently integrated in 2012 in the Principles of Seville, although these were mainly aimed at the world of archeology. However, the foundations of these arguments were laid as early as 2003 with UNESCO's Charter on the Conservation of Digital Heritage.

The objective of the London Charter is to establish methodological principles to ensure correct digital display, dissemination and digital communication within the Cultural Heritage sector. The Principles of Seville, on the other hand, represent a practical implementation that lays the foundations of these issues within the world of archaeology, trying to make them implemented.

The objective is to define the process by which the image, model or information has been traced, disseminated and made available, we want to reach a scientific and unambiguous definition linked to the reliability and truthfulness of the data, whether of a geometric or informative nature.

In particular, the London Charter speaks of "intellectual transparency" referring to the result viewable by computer that reports information that is transmitted to users, while, in the Seville Principles, "scientific transparency" is introduced, with respect to which the conclusions reached through computer visualization by researchers and professionals must be able to be confirmed, refuted or modified by other experts over time.

For this reason, in these documents the concept of para-data is introduced, i.e. metadata concerning information of understanding and interpretation due to human processes that are collected within databases and have the purpose of interpreting the critical reading of an artifact performed by experts.

It is evident that, for the BIM methodology, referring to artifacts of historical and artistic interest, the theme of transparency and reliability of the visualization of the digital model is of considerable importance, both as regards the dimensional geometric aspect and the information and knowledge of the artifact.

3 Conclusions

BIM proposes a new working model: integrated, interactive, able to contain in a single platform both the individual project specifications and the contribution of all the subjects involved; but above all with a new control over the temporal component. The inconsistency between the project and the actual state has often been one of the major causes of the extension of construction times and the increase in planned costs.

The application of this methodology, certainly advantageous for the design of new buildings, can be equally valid also on existing buildings since its true potential is linked to the definition of a new collective working mode in which the different professional technicians, clients and users interact in order to limit changes and surprises.

It is no longer a question, therefore, of creating descriptive plan drawings in a more or less reliable way of the data contained in them, but it is a matter of creating three-dimensional models that allow to associate the geometries with the information necessary to correctly
describe the architectural, structural and plant elements that must be managed and updated daily by the FM and by all the subjects involved in the process.

Beyond the technical or performance specifications of the software, it is this change of perspective compared to the past that makes BIM an interesting and probably irreversible process. "Tangible cultural heritage, especially real estate (monuments, archaeological sites, and so on), is the main topic of application in the new approaches. A digital 3D model structured as part of the process of improving the architectural heritage is an urgent need today. In addition, the digital 3D model must be converted into a crucial framework for understanding and monitoring documentation, thereby creating a source of data (graphic and semantic) suitable for assisting in conservation, restoration and reconstruction projects." [9]

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