LIFE CYCLE OF PROJECT USING HBIM – APPLICATION OF TOOLS

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Abstract: The heritage cataloguing is an existing problem, thanks to the lack of specific guidelines for the execution or the storage, these documents end up getting lost. Precisely for this reason and others, the use of HBIM (Heritage Building Information Modeling) will give support in this matter, due to its capacity of making documentation more solid and complete. HBIM emerged from the epiphany of utilizing BIM (Building Information Modeling) beyond new buildings using parametric tools to model theses edifications, in addition to digital resources, like laser scanner, photogrammetry, UAV (unmanned aerial vehicle), and others. The main uses are documentation, diagnostic registration, and heritage management.

Keywords: HBIM; definitions; uses; experiences; applied technologies

CICLO DE VIDA DO PROJETO COM USO DE HBIM – APLICAÇÃO DE FERRAMENTAS

Resumo: A catalogação destes patrimônios é um problema ainda existente, graças à falta de diretrizes específicas para a sua realização ou para o seu armazenamento, esses documentos acabam se perdendo. Justamente por essa razão e outras, que a utilização do HBIM (Heritage Building Information Modeling) irá dar suporte neste quesito, devido a sua capacidade de tornar a documentação mais sólida e completa. O HBIM surgiu da epifania de utilizar o BIM (Building Information Modeling) para além de edifícios novos, utilizando de ferramentas paramétricas para a modelagem destas edificações, além de recursos digitais, como o laser scanner, fotogrametria, VANTs (veículos aéreos não tripulados), entre outros. Tendo como principais usos: a documentação, o registro diagnóstico e a gestão do patrimônio.

Palavras-chave: HBIM; definições; usos; experiências; tecnologias aplicadas

1. INTRODUCTION

The historical heritage preservation is not something precise or incredibly detailed, each culture has a unique way of dealing with the legacy that has been left by their people throughout the years. The Japanese, for example, have a unique perspective over conservation, when compared to Europeans, on the grounds that they prefer to maintain form, so they usually rebuild the entire edification but with the same materials as before. Furthermore, there are a lot of theories that discuss the best way to preserve an historic building, like Eugene Viollet-le-Duc, John Ruskin, Cesare Brandi, among others [1]. Since there is no rigor in how to preserve buildings, there is no rigor in how to document, causing another obstacle in the conservation actions.

HBIM emerged from the epiphany of utilizing BIM (Building Information Modeling) beyond new buildings, but for already existing constructions and with historical and cultural values stablished throughout the years, using parametric tools to model theses edifications, in addition to digital resources, like laser scanner, photogrammetry, UAV (unmanned aerial vehicle), and others.

HBIM has a wide range of uses, being able to reach the development of games, with an intention of giving support to knowledge, to education and different ways to instruct people [2]. The main uses are: documentation, through joining geometry and specific information; diagnostic registration, it is evaluated the conservation state and it is possible to make performance analysis; and heritage management, with the possibility to make a schedule (4D), cost estimations (5D), sustainability (6D) and installations management (7D), that will assist on the heritage maintenance [3].

1.1. HERITAGE BUILDING INFORMATION MODELLING (HBIM)

1.1.1. Concepts and Temporal Evolutions

The historical heritage preservation is not something precise or incredibly detailed, each culture has a unique way of dealing with the legacy that has been left by their people throughout the years. The Japanese, for example, have a unique perspective over conservation, when compared to Europeans, on the grounds that they prefer to maintain form, so they usually rebuild the entire edification but with the same materials as before. Furthermore, there are a lot of theories that discuss the best way to preserve an historic building, like Eugene Viollet-le-Duc, John Ruskin, Cesare Brandi, among others [1]. Since there is no rigor in how to preserve buildings, there is no rigor in how to document, causing another obstacle in the conservation actions.

The heritage cataloguing is an existing problem, thanks to the lack of specific guidelines for the execution or the storage, these documents end up getting lost inside the responsible institutes that should guarantee the protection of the architectural monuments. Precisely for this reason and others, the use of HBIM (Heritage Building Information Modeling) will give support in this matter, due to its capacity of making documentation more solid and complete, besides providing an efficient management of assets.

HBIM emerged from the epiphany of utilizing BIM (Building Information Modeling) beyond new buildings, but for already existing constructions and with historical and cultural values stablished throughout the years, using parametric tools to model theses edifications, in addition to digital resources, like laser scanner, photogrammetry, UAV (unmanned aerial vehicle), and others.

The first author to ever mention the term HBIM was [4], when they described as a BIM concept for historical buildings, mapping BIM objects through point cloud, which characterizes as a reverse engineering process. Later, Murphy et al. [5] defined as a new solution, which uses parametric objects inside a 3D model, designed by point clouds or photogrammetry. From this point on, other authors, like Oreni [6], who portrayed it as a "parametric representation in three dimensions", that allows the user to "draw, model and manage information in historic architectural elements", although, warns the need of discussions and experiments to obtain models of some irregular objects, that is common on this type of construction. In the same year, Brumana et al. [7] elaborated a similar definition, however, added the possibility of format permutation, that way, aiding the problem of interoperability between software.

For Dezen-Kempter et al. [8], HBIM is survey of existing buildings, by reverse engineering process, mentioned before by Murphy et al. These surveys could be manual, through drawings and direct measurement, or automated, using technology like photographic camera, laser scanner, drones (UAV), etc. Khodeir et al. [9] defines as a system to model historical structures, working like a BIM plug-in, reaching state-of-art through the widespread use of laser scanning and photogrammetry. Although, Tolentino [10] explains that "is nothing more than the extension of the BIM concept to historic buildings", having as a focus structural and energetic analysis, documentation and, specially, conservation.

For being a new system to model historical edifications, Osello et al. [11] reports that HBIM enjoys all BIM's characteristics, managing to storage historical construction data and interventions inside the building's model. Given that HBIM is seeing as a versatile approach for Brutto et al. [12], the management of heterogeneous information collection, allows to create a digital knowledge repository, where it is possible to storage and update different sets of information, in that way, improving the object understanding. Although, Brusaporci et al. [13] highlights that the complex geometric form can be done by a parametric way, starting to be assessed inside HIBM, where is not necessary to know no computer language, as it is manipulated by graphic elements.

Li et al. [14] It describes HBIM as a manager of heritage information, in a way that the model "is built […] representing specific form, material, style of the building while ignoring detailed, subtle differentiations: deforms, defectives or irregularities. In other words, guaranteeing the model's information, through material of building elements components (walls, doors, windows, etc.) and through the building's 3D model, despite the focus is regularized surfaces inside the software, while reality manifests itself differently, being visible through point clouds, mesh models and as-found drawings.

For Cuperschmid et al. [15], HBIM model allows the combination of information with the geometry within a single database, guaranteeing multidisciplinary of information through parametric objects, that way, having a great potential for building management (operation, maintenance, and documentation), making possible to share information among the professionals involved, restricting the errors caused by handling.

In the opinion of Silva et al. [16], BIM paradigm can handle life cycle, besides being a local to storage information, whether graphic (surfaces generated by point clouds) or alphanumeric (constructive details behind the surfaces). When applied to a

heritage building, where there is a necessity of research and conservation documentation, and active management, it becomes HBIM, that has been potentialized by the association of technologies like 3D laser scanning, photogrammetry, or Dense Stereo Matching (DSM).

BIM is in constant evolution, going from 3D to 7D, through planning, estimation, sustainability and finally, management and maintenance. According to Salam [17], HBIM is part of the evolution and dissemination of BIM and the data collection technologies, already mentioned, and rising as a sustainable need in manage heritage constructions. In view of all the BIM features, for Costa et al. [18], it has a massive potential, and it has been not explored well enough yet, since it guarantees a character to register and to document, while the conservation can be managed, with capacity of integrating information in geometric and semantic data in a unique digital model. For Bagnolo et al. [2], HBIM already has become a proven methodology to manage all aspects related to the built heritage.

Bastem et al. [3] decomposes the definition of BIM in three different ones: BIM, for construction of new buildings, having the technology implemented since the beginning of the project; EBIM, for already existing edifications, but with no historical value, using just for sustainability, repair and manage; and HBIM, for existing buildings with cultural, architectural, and historical values, being able to as a method of data gathering, that guarantees the data sharing.

Through point cloud and/or photogrammetry, HBIM can develop by an accurate mapping, ensuring maximum information, like geometry, textures, materials and the relations between objects inside a structured and parametric model, generating a complete 2D and 3D representation, which includes all kinds of surface detail, relating to the construction technique and the materials used [19].

1.1.2. Uses

HBIM has a wide range of uses, being able to reach the development of games, with an intention of giving support to knowledge, to education and diverse ways to instruct people [2]. The main uses are: documentation, through joining geometry and specific information; diagnostic registration, it is evaluated the conservation state and it is possible to make performance analysis; and heritage management, with the possibility to make a schedule (4D), cost estimations (5D), sustainability (6D) and installations management (7D), that will assist on the heritage maintenance [3].

The Brazilian historical heritage was not properly documented, by reason of a lack of a registration system [10], because of that, there is still a huge neglect with the architectural heritage in Brazil. Therefore, by way of HBIM, documentation will be precise, through 3D digital models, which will assist on its value comprehension (material or immaterial) [18], that way it will serve to public awareness [20].

Through diagnostic registration, it is possible to map all pathological manifestations, where surveys, exams, and tests will be conducted, to determine the conservation state of the heritage building in question. Thus, it will be able to create a damage map, which characterizes as a graphic-photographic representation, where it is illustrated all the pathological evidence of the building; that would be a scrupulous analysis to determine the best way to intervene, since each case is a special case [16].

Because of the singular conditions of conservation, maintenance and restoration, the cultural heritage preservation has been favored with the utilization of

Information and Communication Technologies (ICT), like BIM [8]. BIM application in heritage buildings shows enormous potential, due to a possibility of managing its conservation, serving as an imperative instrument to the careful management of the building's life cycle. As a result of that, University of Brescia adopts the acronym BHIMM (Built Heritage Information Modelling/Management) [18], for being an alternative in the fight against the deterioration of the Brazilian heritage.

1.1.3. Challenge and experiences

The main objective of HBIM is to assist documentation, management, and operations of buildings with historical nature, being able to create a plan to intervene in its conservation state [15]. Therefore, it is essential a reality capture that reflects geometric precision, that way would be possible to generate a precise model, guaranteeing the improvement of intervention projects, which could be done by laser scanning [2], [9], [15].

BIM software were designed to be used, specially, in new edifications, being, eventually, applied to buildings with historical value, therefore, HBIM is still poorly researched and stimulated, which reveals a few challenges found, particularly when it comes to complexities and inaccuracies, in comparison to as-built [20]. Furthermore, since it is a technology still under study and considerably new, there is the adaptation, training, and skill development cost [21] and it lacks protocols and specifications, by having one of the greatest challenges to model, the families, elements that constitutes a BIM model.

These families, in the case of historic buildings, are elements of a lot of complexity, besides being unique and exclusive, which makes it difficult to its availability on the market, since it is not a commercial product, ergo there is no commercial interest, consequently, the models end up with generic objects with no specific properties and no true-to-life constructive details [13], [18]. For these reasons, it is often preferred to manually model these elements [2], that makes it more expensive modelling the building, since it needs image captures, like photogrammetry and point cloud, an equipment and labor that are costly [21].

Despite that, for being a BIM tool, it is possible to have a very precise cost estimate, according to the model's precision [6], which ends up in opposition to the difficulties of modeling objects, where model in place tools become insufficient or not convenient, from the point of view of time, which leads the use of other external means to assist in the modeling, since the current software do not attend to all the requirement to model [2], [22], leading to another problem, to stablish the dialogue among different software [8].

On the other hand, HBIM brings BIM characteristics alongside with it, that can be put to good use, even so early in maturation, as ease in representation, even if takes more time to model, its views are simultaneously updated, that allows the representation become more faithful, since they are automatically generated, independent of human interpretation, which leads to the lowest percentage of errors between sheets [19], [23]. Furthermore, it is possible to combine all the information in the geometric representation of the constructive elements, such as wall, it can be inserted constructive method, used materials, age, for example, that way facilitating

the creation of a database of the building and the protection of these information [9], [12], [18], [24].

Creating these databases for each building, documentation will be more precise and more agile, making management and preservation of assets more efficient [15]. Besides this, all the information can be made available to the public and to other researchers, to provide greater access to cultural buildings, which it will have a direct impact in cultural and creative industries [25]. Another problem found in the conventional ways to document these types of constructions is the dispersion of information, which is corrected when using HBIM, since there is the possibility of sharing the model with the responsible agents, consequently increasing right decisions made, accomplishing an efficient workflow [15], [18].

1.1.4. Activities and technologies associated

Before any prospecting conducted in the building, it is necessary to carry out historical research, in which the political, socioeconomic, technical, and artistic aspects are sought [10] relevant to the intervention, that way identifying and having complete knowledge to the building in question [16]. After this phase, it is initiated capture planning [8], an indispensable step, because, often, these buildings are in places that make it difficult to obtaining information using laser scanning and photogrammetry. In addition to saving time for the professionals responsible for the capture, service schedules, facilities and equipment mapping are also conducted [10].

The next step is to capture information, in which the capture of geometric data and environmental conditions of the site are performed [21], through using technologies such as rectified photography, photogrammetry, orthoimages, theodolite [5], laser scanning, dense stereo matching (DSM) [8], cloud point, among others. Still on site, a typological analysis is conducted, that is, the identification of materials, architectural, structural, and constructive system prospections [10], that will assist loading information into the 3D model. From all the information collected, it is necessary to carry out the data processing, since it is still raw information, refining them to be used in building modeling, such as merging point clouds [8]. Based on this, it is initiated modeling the building, where it is inserted all constructive, historical, and material information inside the geometric elements [8], [17], [21].

Building diagnosis is the next phase, in which the conservation state analysis is carried out, analyzing different aspects, such as constructive and aesthetic. In addition to that, a damage mapping is also conducted [10], raising the pathological manifestations and the prospections, tests and tests are prepared, for the property to be evaluated in terms of its state of conservation. Finally, an intervention proposal is made, in favor of building maintenance [16], that can characterize as structural and aesthetic maintenance.

2. METHODOLOGY

The methodology used in this paper is Design Science Research (DSR), that is based on the direct and indirect research and in the collection gathering related to “manage of integrated projects”, “new technologies applied to the conservation and restoration area” and HBIM paradigm. Considered to be a method to conduct research

of technological nature, such as manage technologies, stablishing an approach that produces effective scientific rigor.

DSR is a method that allows to understand adherence of the concept to projects related to information and communication technologies. To [26], it is about a paradigm of pragmatic research that demands to create innovative artefacts to solve problems in the real world.

In this methodology, a practical problem is responsible for guiding the research, based on DSR, other problems and questions about its knowledge will appear. To [27], these problems and questions are chained to a real cycle, that the author called “regulator cycle”. In a macro way, DSR is considered as a meta-theory, capable of assisting the researcher in the generation of theorical knowledge during artifact design processes, based on the necessary rigor to constitute scientific research.

3. RESULTS AND DISCUSSION

It is possible to notice the similarities of how each author has defined what it is HBIM, so it is plausible to say that HBIM is a redirection of a technology that was made initially to suit only new buildings, which it was called BIM (Building Information Modeling). As applied to historical existing buildings, it transforms to HBIM (Heritage Building Information Modeling), that can use all of BIM’s characteristics and showing the need to create its own.

The uses for it are wide, reaching the development of games, but having its main use on documentation, through joining geometry and information in one single place; diagnostic registration, allowing the professionals to analyze a series of aspects and helps it to keep track of the changes and maintenances made along the years, as it also helps at heritage management.

As said before, HBIM has been little researched and stimulated, which reveals some challenges in modelling the buildings and its details, since they are usually buildings with many constructive details, causing imprecisions in the model. Among all the problems, it is still considered to be difficult to use and embrace this new technology yet, not to mention, expensive too. Although, each professional should put the difficulty and benefits of using HBIM in the balance, in other to properly conservate the building.

4. CONCLUSION

This paper allowed an approximation of the new applied HBIM technologies, such as point cloud, photogrammetry, laser scanning, among others. Those technologies are still in development alongside with HBIM, trying to capture with more precision. Furthermore, it has been possible to state the experiences that some authors have been through, so that HBIM can be improved more.

5. REFERENCES

[1] F. Choay, *Alegoria do patrimônio*, 2nd ed. Edições 70, 2014.
[2] V. Bagnolo, R. Argiolas, S. Cuccu, and N. Paba, “Beyond HBIM: Serious games and procedural modelling for Heritage Dissemination,” in *International Archives of the Photogrammetry, Remote Sensing and Spatial Information*

Sciences - ISPRS Archives, Oct. 2021, vol. 46, no. 4/W4-2021, pp. 55–60. doi: 10.5194/isprs-archives-XLVI-4-W4-2021-55-2021.

[3] S. S. Bastem and A. Cekmis, “Development of historic building information modelling: a systematic literature review,” *Building Research and Information*, Oct. 2021, doi: 10.1080/09613218.2021.1983754.

[4] M. Murphy, E. McGovern, and S. Pavia, “Historic building information modelling (HBIM),” *Structural Survey*, vol. 27, no. 4, pp. 311–327, Jan. 2009, doi: 10.1108/02630800910985108.

[5] M. Murphy, E. McGovern, and S. Pavia, “Historic Building Information Modelling - Adding intelligence to laser and image based surveys of European classical architecture,” *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 76, pp. 89–102, 2013, doi: 10.1016/j.isprsjprs.2012.11.006.

[6] D. Oreni, “From 3D Content Models to HBIM for Conservation and Management of Built Heritage,” 2013.

[7] R. Brumana *et al.*, “From survey to HBIM for documentation, dissemination and management of built heritage. The case study of St. Maria in Scaria d’Intelvi,” 2013.

[8] E. Dezen-Kempter, L. Soibelman, M. Chen, and A. V. Müller Filho, “Escanemento 3D a Laser, Fotogrametria e Modelagem da Informação da Construção para Gestão e Operação de Edificações Históricas,” *Gestão & Tecnologia de Projetos*, vol. 10, no. 2, pp. 113–124, Aug. 2015, doi: 10.11606/gtp.v10i2.102710.

[9] L. M. Khodeir, D. Aly, and S. Tarek, “Integrating HBIM (Heritage Building Information Modeling) Tools in the Application of Sustainable Retrofitting of Heritage Buildings in Egypt,” *Procedia Environmental Sciences*, vol. 34, pp. 258–270, 2016, doi: 10.1016/j.proenv.2016.04.024.

[10] M. Tolentino, “A utilização do HBIM na documentação, na gestão e na preservação do Patrimônio Arquitetônico,” 2018.

[11] A. Osello, G. Lucibello, and F. Morgagni, “HBIM and virtual tools: A new chance to preserve architectural heritage,” *Buildings*, vol. 8, no. 1, 2018, doi: 10.3390/buildings8010012.

[12] M. lo Brutto, D. Ebolese, L. Fazio, and G. Dardanelli, “3D survey and modelling of the main portico of the Cathedral of Monreale,” in *2018 IEEE International Conference on Metrology for Archaeology and Cultural Heritage, MetroArchaeo 2018 - Proceedings*, Oct. 2018, pp. 271–276. doi: 10.1109/MetroArchaeo43810.2018.13685.

[13] S. Brusaporci, P. Maiezza, and A. Tata, “Computational Design for As-Built Modeling of Architectural Heritage in HBIM processes,” in *2018 IEEE International Conference on Metrology for Archaeology and Cultural Heritage, MetroArchaeo 2018 - Proceedings*, Oct. 2018, pp. 199–203. doi: 10.1109/MetroArchaeo43810.2018.13620.

[14] D. Li, X. Wang, C. Bai, and C. Wu, “Discussion on the Prorblem of Regularized Reconstructio in HBIM,” in *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, Aug. 2019, vol. 42, no. 2/W15, pp. 657–662. doi: 10.5194/isprs-archives-XLII-2-W15-657-2019.

[15] A. R. M. Cuperschmid, M. M. Fabricio, and J. C. Franco, “Hbim development of a brazilian modern architecture icon: Glass house by lina bo bardi,” *Heritage*, vol. 2, no. 3, pp. 1927–1940, Sep. 2019, doi: 10.3390/heritage2030117.

[16] F. B. Lima Da Silva, A. Regina, and M. Cuperschmid, “HBIM e Patologias das Edificações Históricas: Uma Análise Quantitativa da Revisão Sistemática da Literatura,” *Encontro Brasileiro de Modelagem da Informação da Construção e Patrimônio Cultural*, Dec. 2019, [Online]. Available: http://portal.cfm.org.br/index.php?option=com_content&id=20462:prontuario-medico.
[17] N. F. A. Salam, “HBIM- A Sustainable Approach for Heritage Buildings Restoration in Egypt,” in *IOP Conference Series: Earth and Environmental Science*, Jan. 2020, vol. 410, no. 1. doi: 10.1088/1755-1315/410/1/012072.
[18] H. A. Costa, M. P. de Souza, G. Q. Baldessin, G. Albano, and M. Fabricio, “Modelagem BIM para o registro digital do patrimônio arquitetônico moderno,” Jan. 2021.
[19] H. Riyadh and F. M. Abed, “Production of Heritage Building Information Model (HBIM) for the great Ziggurat of UR 3D Point Clouds Generation from Google Earth Imagery using Printgrammetry Technique and SfM Algorithm View project 3D Indoor Mapping View project,” University of Baghdad, Baghdad, 2021. doi: 10.13140/RG.2.2.35519.79520.
[20] C. Jr. M. Ribeiro, “HBIM (Heritage Building Information Modeling) na Documentação do Patrimônio Cultural Brasileiro,” Mar. 2021.
[21] D. Backes, C. Thomson, L. Malki-Epshtein, and J. Boehm, “CHADWICK GREENBIM: Advancing Operational Understanding of Historical Buildings with BIM to Support Sustainable Use,” London, 2014.
[22] N. Bruno and R. Roncella, “HBIM for conservation: A new proposal for information modeling,” *Remote Sensing*, vol. 11, no. 15, Aug. 2019, doi: 10.3390/rs11151751.
[23] D. Heidtmann Junior and M. Padilha, “Emprego de Tecnologias em Levantamento e Diagnóstico de Edificações Históricas em Laguna, SC,” 2015.
[24] G. Bacci *et al.*, “Hbim methodologies for the architectural restoration. The case of the ex-church of san quirico all’olivo in lucca, tuscany,” in *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, May 2019, vol. 42, no. 2/W11, pp. 121–126. doi: 10.5194/isprs-Archives-XLII-2-W11-121-2019.
[25] M. Previtali, R. Brumana, C. Stanga, and F. Banfi, “An ontology-based representation of vaulted system for HBIM,” *Applied Sciences (Switzerland)*, vol. 10, no. 4, Feb. 2020, doi: 10.3390/app10041377.
[26] H. A. Simon, *The sciences of the artificial*, 3rd ed. Cambridge: MIT Press, 1996.
[27] R. Wieringa, *DesignScience as Nested Problem Solving*. Twente: ACM, 2009.