Long Paper

Reality vs Virtual Modelling

From Building to Landscape Heritage Representation

Ambra BARBINI, Department of Civil, Environmental and Mechanical Engineering (DICAM), University of Trento, Italy
Chiara CHIONI, Department of Civil, Environmental and Mechanical Engineering (DICAM), University of Trento, Italy

Abstract: The development of digital representations of the cultural heritage is symptomatic of the broader trend toward digitisation that the Architecture, Engineering, Construction and Operation (AECO) sector is facing, combining the act of drawing with the act of modelling geometries and information. New approaches, such as Historic/Heritage Building Information Modelling (HBIM) or Landscape Information Modelling (LIM) and Geographic Information System (GIS), offer possible solutions for the digital representation of the existing environment, from building to landscape. New technologies and processes are progressively allowing the merging of several kinds of data in virtual models to understand the past, represent the present, and design the future. These virtual models support both the digital visualization of different static configurations and the dynamic update of data in input/output through sensors and actuators. The connection between virtual and real environments is always more investigated and has different possible applications (e.g., management, simulation, transformation, valorization), not only in the cultural heritage field. After defining the term 'model' and the evolution of this concept in the AECO sector, this contribution presents an overview of different outputs of virtual models to outline the most innovative approaches in information communication, concerning the building scale and wider elements of the natural and built environment.

Keywords: *Virtual Model—Cultural Heritage—Multi-Dimensionality—Multi-Scalarity*

CHNT Reference: Barbini, A. and Chioni, C. (2025). 'Reality vs Virtual Modelling: From Building to Landscape Heritage Representation', *Proceedings of the 26th International Conference on Cultural Heritage and New Technologies*, Vienna and online, November 2021. Heidelberg: Propylaeum. doi: 10.11588/propylaeum.1449.c20776.

Introduction

The relationship between reality and its representation is a philosophical conundrum that has fascinated humanity since the beginning of rational thinking. Nowadays, developing digital representations of landscape and architectural heritage is symptomatic of the broader trend toward digitisation that the Architecture, Engineering, Construction and Operation (AECO) sector is facing. This growing interest in the existing environment, spacing from building to landscape, involves different approaches, such as the Historic/Heritage Building Information Modelling (HBIM) or the Landscape Information Modelling (LIM) and Geographic Information System (GIS). However, besides the brand-new terms, the question is still the same: what is a model of the built environment? (see Figure 1).

Fig. 1. Word cloud around the term "model" (© Ambra Barbini and Chiara Chioni, 2021).

In the framework of two on-going doctoral research projects, the authors are currently investigating the representation of building and landscape heritage through virtual models as tools with a crucial role in several possible applications (e.g., management, simulations, transformation, valorisation) and especially in the planning and design processes. The aim of this paper – based on a scoping literature review combining online database and library research – is to analyse the current approaches to move from the complexity of reality to virtual modelling.

First, the notion of model in architecture is explored by comparing an historical and theoretical framework with the operative opportunity that new technologies are progressively offering to the AECO sector, considering in particular the possibility to survey and represent the built heritage. Then, by analysing current workflows to construct a virtual model, not only at the building scale, but also considering wider elements of the natural and built environment, this research aims to outline the most common approaches to virtual models' development. Finally, existing gaps and transferable methods in modelling at the different scales are pointed out.

The notion of model in architecture

In the architectural field, the notion of "model" – from the Latin *modus, modulus*, measurement – has been associated with different concepts: from a tangible object, namely a maquette, to a mental construction, a "scheme" in its etymological meaning.

With this respect, Filippo Brunelleschi and Michelangelo Buonarroti considered the model as the physical representation of an idea already fully formed in the mind and intended to serve as a guide to the construction process (Empler, 2002, p. 14). According to Leon Battista Alberti, the model was a proper working tool, which had to evolve and multiply to sift through the diverse project solutions (ibid). Later, following a similar concept, Francesco Milizia highlighted the visual value of the model

to better understand the project, both for the architect and for the audience (ibid). In the nineteenth century, the term “model” denoted an object to replicate, namely a prototype, as reported by Antoine Chrysostome Quatremere de Quincy, who used the term “type” to refer to the idea of an element that should itself serve as a rule for the model, intended as “paradigm” (Ugo, 1992, pp. 9−23). In its modern notion according to Vittorio Ugo, the model is configured more as a construction than as an object to be copied or reproduced, a “scheme” as a set of properties, such as dimension, geometry, material, aesthetic, and function (ibid). Subsequently, in 2000, Decio Gioseffi highlighted the operative purpose of a model, as an “intermediate” structure representing both a statement, and a concrete referent (Gioseffi, 2016, p. 8). More recently, Elisa Guagenti associates this term with the concepts of prototype and archetype referring to the possibility of better understanding and explaining an idea, through measurements, tests, and simulations, on the one hand, and capturing and exploring original aspects of ‘reality’ on the other (Guagenti, 2010, pp. 99−108).

Virtual models of the built environment

Today, considering both the theoretical and the operative levels, new technologies applied to the built environment allow the development of new approaches to merge in a virtual model several kinds of data (e.g., geometric, material, technological, historical).

Also, it is important to highlight that, despite new technologies offering wide options for data collection, elaboration, management, and communication, an informative selection, as well as the interpretation of acquired data, is still crucial to move from the complexity of reality to a functional virtual model, as illustrated by Jorge Luis Borges in the paradox of the 1:1 map of the Empire (Borges, 1999). Such an interpretative paradigm, reflecting the purpose of the model, its object and its cultural framework, is a key element for the model development (see Figure 2).

Fig. 2. The picture summarizes the stages of a virtual model development, highlighting the need to select and interpret information from the data acquired (© Ambra Barbini and Chiara Chioni, 2021).

One of the main drivers towards the digitalization of the built and natural environment is the management of cultural heritage. Through collection, elaboration and communication of data, virtual models can offer precious tools to represent the present, understand the past and design the future considering specific purposes in various contexts and at different scales.

Nevertheless, even the most advanced technologies and procedures for geometry acquisition, reconstruction, and semantic enrichment are unable to entirely communicate the attributes of a heritage item, or to evoke an experience – sensory, emotional, perceptual – analogous to a fragment of real life (Menchetelli, 2019). Indeed, cultural heritage is characterized by a wide amount of data, by one side already available in historical-archival documents and by the other side acquired through digital surveys or continuously generated through remote sensing technologies. The management of this massive amount of data is certainly an important issue because by decreasing the volume of data it is possible to increase their informative value (Sultan et al., 2021). For this reason, organizing data of the built environment into a more meaningful structure, such as a model, can support mindful

decision-making processes in several possible applications including the facility management, the simulation of specific performances, a transformation project or also the communication of contents to a wide audience.

New technologies and cultural heritage

A significant increase in projects on the built environment is expected both to avoid further loss of greenfield lands and to adapt the existing buildings to the new standards of internal comfort, energy consumption and environmental emissions, according to the logic of sustainable development and circular economy. Within the framework of industry 4.0, the Architecture, Engineering, Construction and Operation sector is currently adopting various technologies that will facilitate the application of circular economy principles in the built environment (Sultan et al., 2021). Among these technologies, the most well-established approaches to model information – even if born in different fields – are the Building Information Modelling (BIM) for the building scale and the GIS for the territorial scale. Both allow to develop multidisciplinary models for design and planning, but also for representing the built environment, with variable levels of information detail and accuracy.

Raising awareness about the worth and vulnerability of built heritage is bringing the need to preserve and protect the values to transmit to future generations. The growing attention for the cultural heritage is leading to shaping these technologies to more specific methods such as HBIM and Historical GIS, but also to develop multi-scale approaches, taking advantage from the combination of the two scales of building and landscape, through integration of BIM-GIS technologies, with the subsequent interoperability issues that this causes; finally, also to transfer knowledge about information modelling from the building scale to the landscape one (from BIM to LIM).

At the building scale (see Figure 3), most of the approaches move in the direction of HBIM which was firstly intended as a library of parametric historic building components (Murphy et al., 2007, pp. 27–29). HBIM has subsequently evolved into a process known as scan-to-BIM, which involves the semi-automatic generation of complex geometries from point clouds used to recognize and inform building components (Lopez et al., 2018). Point clouds obtained either from a laser scanner survey or from the elaboration of a photogrammetric survey can be processed manually or through some automation such as the semantic segmentation (Grilli et al., 2017, pp. 339–344). Currently, the different approaches are trying to find a trade-off between visual fidelity and parametric flexibility, as well as between the geometric accuracy and the semantic richness of the model. A possible solution for this issue, currently under investigation, could be a layered structure combining models of different types (Radanovic et al., 2020). Moreover, built heritage often presents irregular and complex shapes, raising the need to choose between different modelling strategies that are not equivalent in terms of time and resources requested, lack in impartiality, involving several arbitrary choices of the operator and reflecting a personal interpretation of the heritage item.

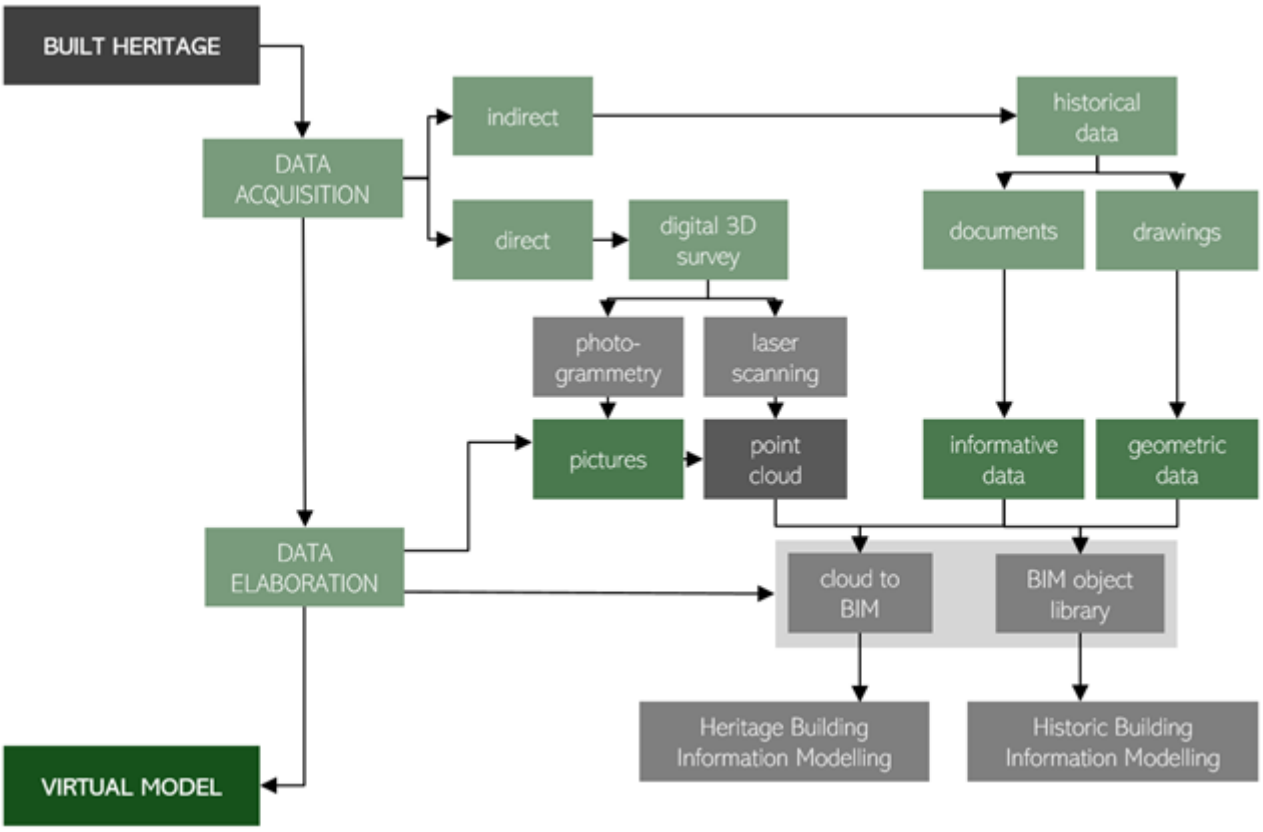

Fig. 3. The image outlines possible workflows to develop a virtual model of the built heritage, showing the integration of the data acquisition with the elaboration phase (© Ambra Barbini, 2021).

At the landscape scale (see Figure 4), the process of developing a virtual model "traditionally" follows the GIS approach, drawing data from historical cartography or remotely sensed images, but parallelly there is an increasing pressure to conform with the third dimension and with the BIM paradigm, as demonstrated by the relatively new term LIM that could be approached both as an integration of BIM-GIS models or as a BIM extended at the landscape scale (Kolbe and Donaubauer, 2021). Indeed, the generation and segmentation of point clouds from 3D digital surveys or crowdsourced imagery (Nocerino et al., 2017) seem to be an evolving field, recently conceptualized as 'cloudism' (Girot, 2020).

However, several researchers (Ervin, 2001, pp. 49–62; Nessel, 2013; Zhang, 2021) have identified an enduring gap between mainstream tools used for landscape design and industry-standard mapping and modelling technologies capable of producing meaningful information about the natural and the built environment. Even if (H)BIM principles can be applied to (heritage) landscapes, the ontology of BIM cannot be directly borrowed: only a few components, such as historic buildings and infrastructures, in landscapes can be handled in the same way as BIM-objects because the BIM models developed so far have a limited number of classes in the scope of landscape architecture and land management.

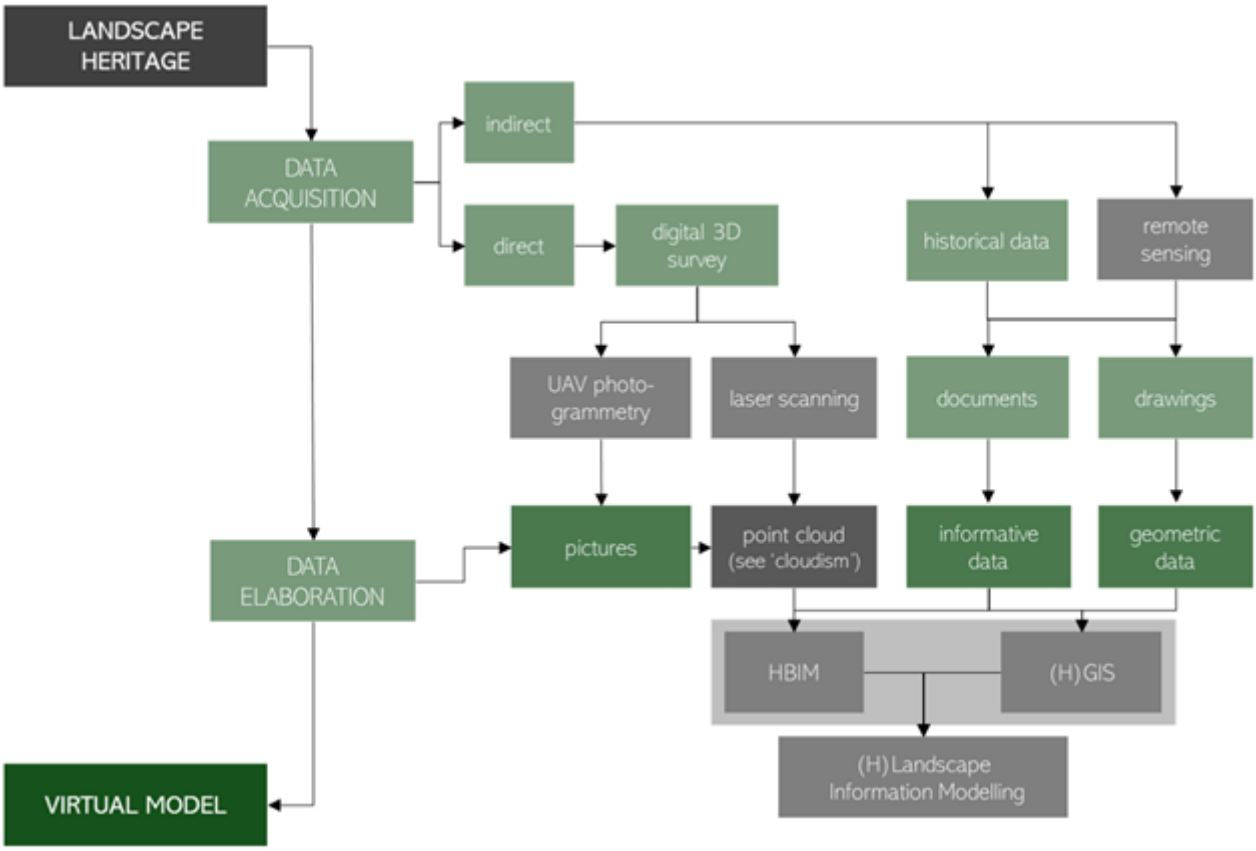

Fig. 4. The image outlines possible workflows to develop a virtual model of the landscape heritage, showing the integration of the data acquisition with the elaboration phase (© Chiara Chioni, 2021).

Finally, the main challenges of heritage modelling both at the building and landscape scale concern:

- the management of the huge amount of available data, especially in the case of a digital 3D survey, the processing of which is often time consuming and requires the interpretation of an expert for the development of a functional virtual model;
- the collaboration of many experts on the same project leading to interoperability issues, including different aspects, such as the employed technologies, the workflows adopted by different organizations, the coordination among professionals and the introduction of a common normative framework (Chioni et al., 2021).

Discussion and outlook

The opportunities for cultural heritage documentation and management are increasingly expanding through new technologies which support both the digital visualization of different static configurations and the dynamic update of data in input/output through sensors and actuators able to connect physical elements with virtual environments, supported by real time data acquisition, processing, simulations, and projections.

The relationship between reality and its model has certainly changed within the virtual environment, for example overcoming the issue of reduction/enlargement of the model, as well as including the parameter time. For example, the contemporary notion of Digital Twin (DT) specifically intends the model as a working tool for heritage and data management, operating directly on the real environment from the virtual realm, considering smaller time frames until the real-time update (Batty, 2018).

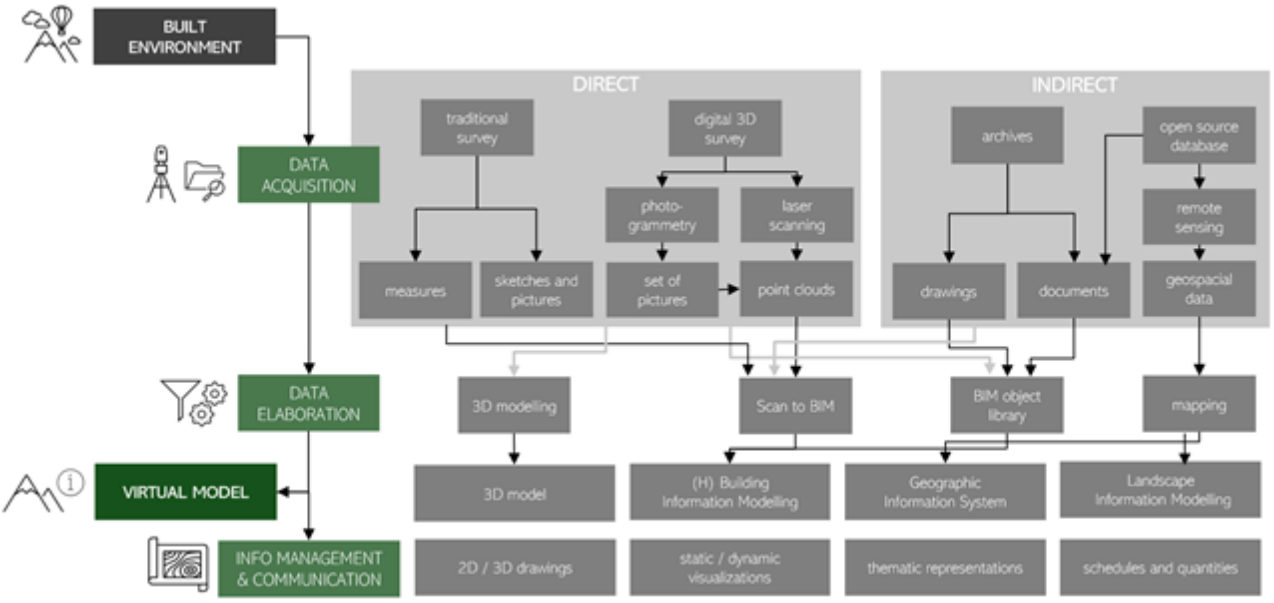

Fig. 5. Comparison of workflows to develop a virtual model of the built environment, comprehending both the building and the landscape scales (© Ambra Barbini and Chiara Chioni, 2021).

The Extended Reality (XR) environment and its declinations − Mixed Reality (MR) and Virtual Reality (VR) − refer to the reality-virtuality continuum, including useful tools for project communication. Furthermore, virtual models can also serve as references for 3D printing and Computerized Numerical Control (CNC) production processes, leading to tangible outputs. These tools are already able to support decision-making, alert and optimization systems and in the near future are likely to further expand their potential not only at the building scale, but also considering wider parts of urban aggregates and the natural environment.

To summarize, considering both the building and landscape scales, the authors noticed several overlapping elements in the process of developing a virtual model, as illustrated in Figure 5: the interpretative paradigm of a model generally reflects its object, as well as its purpose and target users. Each scale of study privileges different data acquisition techniques and returns information in different shapes, which can be mixed, integrated, and adapted depending on the specific object of study and the purposes of the analysis and project.

As further development of this research, the presented operative framework will be the main reference for the development of cultural heritage virtual models in two case studies both located in Trentino-Alto Adige region (Italy): (i) the Tinol house in Predazzo, for which the municipality is planning to restore the vaulted basement areas; and (ii) the Val di Sole, an inner mountain valley impacted by man-made and natural hazards, object of exploration and co-design processes by the research project “B4R Branding4Resilience. Tourist infrastructure as a tool to enhance small villages by drawing resilient communities and new open habitats”.

To conclude, looking back at the theoretical framework, most of the definitions of ‘model’ are still up to date for digital technologies tools, for example, a building information model, a landscape information model or a GIS can be described as a working tool, a visual tool, a prototype and a set of properties. Therefore, a virtual model of the built environment still presents all the features of a traditional model, but also integrates new aspects such as informative data, the possibility for the user to interact with it, and the opportunity to dynamically update some properties through parameters.

New technologies are enabling and empowering all these new and traditional features, bringing new challenges shared by the different scales of representation and design.

Conflict of Interests Disclosure

Authors have no conflict of interest to declare.

Author Contributions

Conceptualization: Ambra Barbini, Chiara Chioni, Giovanna A. Massari and Sara Favargiotti

Investigation: Ambra Barbini and Chiara Chioni

Methodology: Ambra Barbini, Chiara Chioni, Giovanna A. Massari and Sara Favargiotti

Supervision: Giovanna A. Massari and Sara Favargiotti

Writing – original draft: Ambra Barbini and Chiara Chioni

Writing – review & editing: Ambra Barbini, Chiara Chioni, Giovanna A. Massari and Sara Favargiotti

References

Batty, M. (2018). 'Digital twins', *Environment and Planning B: Urban Analytics and City Science*, 45(5), pp. 817−820. doi: 10.1177/2399808318796416.

Borges, J.L. (1999). 'On exactitude in science', in J.L. Borges (ed.) and A. Hurley (trans.), Collected fictions. London: Penguin Books.

Chioni, C., Barbini, A., Massari, G.A., Favargiotti, S. (2021). 'Interoperable workflows: information life cycle at landscape and architectural scales', *AMPS proceedings series* 25.

Empler, T. (2002). *Il Disegno Automatico tra progetto e rilievo*. Roma: Officina, p. 14.

Ervin, S.M. (2001). 'Digital landscape modeling and visualization: a research agenda', *Landscape and Urban Planning*, 54(1–4), pp. 49−62. doi: 10.1016/S0169-2046(01)00125-6.

Gioseffi, D. (2016). 'L'immagine Come Modello Della Realtà', *XY*, 1, pp. 8−11. doi: https://doi.org/10.15168/xy.v1i1.14

Girot, C. (2020). 'Cloudism', in An, M., Hovestadt, L., Bühlmann, V. (eds.), *Architecture and Naturing Affairs*, pp. 96–101. Berlin, Boston: Birkhäuser. doi: 10.1515/9783035622164-013.

Grilli, E., Menna, F. and Remondino, F. (2017). 'A review of point clouds segmentation and classification algorithms', *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 42, pp. 339−344. doi: 10.5194/isprs-archives-XLII-2-W3-339-2017

Guagenti, E. (2010). 'Modello, ovvero conoscere per decidere', in Massari G.A. (ed.) *Tempo forma immagine dell'architettura. Scritti in onore di Vittorio Ugo con due suoi testi inediti*. Roma: Officina, pp. 99−108.

Kolbe, T.H., Donaubauer, A. (2021). 'Semantic 3D City Modeling and BIM' in: Shi, W., Goodchild, M.F., Batty, M., Kwan, MP. and Zhang, A. (eds.) *Urban Informatics*. The Urban Book Series. Springer, Singapore. doi: 10.1007/978-981-15-8983-6_34

López, F.J., Lerones, P.M., Llamas, J., Gómez-García-Bermejo, J. and Zalama, E. (2018). 'A review of heritage building information modeling (H-BIM)', *Multimodal Technologies and Interaction*, 2(2), 21. doi: 10.3390/mti2020021.

Menchetelli, V. (2019). 'Riprodurre per conservare. Dalla scomparsa dell'originale alla memoria moltiplicata', *XY*, 7, pp. 74−91.

Murphy, M., McGovern, E. and Pavia, S. (2007). 'Parametric vector modelling of laser and image surveys of 17th century classical architecture in Dublin', *VAST*, pp. 27−29.

Nessel, A. (2013). 'The Place for Information Models in Landscape Architecture, or a Place for Landscape Architects in Information Models', in Buhmann, E., Ervin, S.M., Pietsch, M. (eds.) *Peer Review Proceedings of Digital Landscape Architecture 2013 at Anhalt University of Applied Sciences*.

Nocerino, E., Poiesi, F., Locher, A., Tefera, Y.T., Remondino, F., Chippendale, P. and Van Gool, L. (2017). '3D reconstruction with a collaborative approach based on smartphones and a cloud-based server', *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W8, pp. 187–194. doi: 10.5194/isprs-archives-XLII-2-W8-187-2017.

Sultan, C., De Wolf, C. and Bocken, N. (2021). 'Circular Digital Built Environment: An Emerging Framework', *Sustainability*, 13(11), 6348. doi: 10.3390/su13116348.

Radanovic, M., Khoshelham, K. and Fraser, C. (2020). 'Geometric Accuracy and Semantic Richness in Heritage BIM: A Review', *Digital Applications in Archaeology and Cultural Heritage*, 19. doi: 10.1016/j.daach.2020.e00166.

Ugo, V. (1992). 'Mimesi', in de Rubertis, R., Soletti, A., Ugo, V. (eds.) *Temi e Codici del disegno d'architettura*. Roma: Officina, pp. 9−23.Zhang, A. (eds.), *Urban Informatics*. Singapore: The Urban Book Series. Springer, pp. 609–636. doi: 10.1007/978-981-15-8983-6_34.

Zhang, Z. (2021). 'Application of LIM Technology in Landscape Design', in Abawajy, J., Xu, Z., Atiquzzaman, M., Zhang, X. (eds.) *2021 International Conference on Applications and Techniques in Cyber Intelligence. ATCI 2021. Lecture Notes on Data Engineering and Communications Technologies*, 81. Springer, Cham. doi: 10.1007/978-3-030-79197-1_138.