Materials Research Proceedings 40 (2024) 350-357 https://doi.org/10.21741/9781644903117-36

Traditional Architectures Along the Cultural Route of James I of Aragon in the Province of Valencia: Leveraging Laser Scanning and BIM for Heritage Management

Sandro PARRINELLO[1,a*], Alberto PETTINEO[2,b]

[1] Department of Architecture, University of Florence, Italy

[2] DAda-LAB, Department of Civil Engineering and Architecture, University of Pavia, Italy

[a] sandro.parrinello@unifi.it, [b] alberto.pettineo01@universitadipavia.it

Keywords: Traditional Architecture, Cultural Routes, Laser Scanning, BIM (Building Information Modeling), Heritage Management

Abstract. This research explores the traditional architectures along the cultural route of James I of Aragon in the province of Valencia, with a particular focus on the implementation of Laser Scanning and Building Information Modeling (BIM) technologies for heritage management. The study centers on a prominent case study, the Almonecir Castle located in the province of Castellon, near Valencia, where a comprehensive 3D model has been constructed using BIM to showcase the castle's evolutionary stages from its Arab origins to its current state. The research highlights the benefits of adopting laser scanning and BIM technologies in heritage management, specifically in the context of the Almonecir Castle. By digitizing and preserving the architectural evolution of this significant historical site, these technologies play a crucial role in safeguarding cultural heritage and enhancing visitor experiences. Moreover, the study sheds light on the potential for widespread application of laser scanning and BIM in managing and conserving other traditional architectures along the cultural route of James I of Aragon in the province of Valencia and beyond. In conclusion, this research exemplifies the transformative impact of laser scanning and BIM technologies in preserving and interpreting historical architectural treasures. The study advocates for the integration of these advanced tools in heritage management practices, facilitating a more profound understanding and appreciation of the cultural heritage that has shaped the province of Valencia throughout its illustrious history.

Introduction

The present work starts and develops from cultural heritage enhancement actions carried out within the project PROMETHEUS - PROtocols for information Models librariEs Tested on HEritage of Upper Kama Sites", funded by the EU Horizon 2020 - R&I - RISE - Research & Innovation Staff Exchange program (Marie Skłodowska-Curie grant agreement No 821870). Prometheus project activities are being conducted by the University of Florence (Italy), the University of Pavia (Italy), the Polytechnic University of Valencia (Spain), and Gdansk University of Technology (Poland), in collaboration with other international corporate partners, with the aim of promoting interdisciplinary action for documenting and structuring information on architectural heritage [1]. The investigation, by delving into the historical significance of the cultural route of James I of Aragon, unravels its architectural heritage as a testament to the region's rich cultural past. Through extensive field surveys and archival research, key architectural elements that have withstood the test of time are identified, creating a foundation for subsequent digital documentation. The study introduces the implementation of Laser Scanning technology to capture precise and detailed point cloud data of the Almonecir Castle's physical structure. By employing this advanced technique, the researchers have been able to create a highly accurate 3D representation of the castle, capturing its intricate details and subtle transformations over the centuries. Subsequently, Building

Materials Research Proceedings 40 (2024) 350-357 https://doi.org/10.21741/9781644903117-36

Information Modeling (BIM) is used to consolidate the gathered data and construct a comprehensive digital model. This BIM model serves as a powerful tool for heritage management, enabling a dynamic representation of the castle's various evolutionary phases up to contemporary times. The integration of BIM facilitates a holistic approach to heritage preservation, promoting informed decision-making and efficient planning for restoration and conservation efforts.

The historical footprint of James I's Route

The development of cultural and landscape routes allows for the integrated management of various elements of environmental and cultural heritage. These thematic routes play a central role in the preservation of cultural heritage and tourism enhancement of the involved municipalities, promoting cooperation for the joint enhancement of territorial resources. Currently, the European Union is focusing special attention on the establishment of actions for the preservation and enhancement of cultural and natural heritage on the territory [2]. The definition of the James I Route is part of this process, aiming to develop a protocol for the documentation and representation of Cultural Heritage Routes. The Route, as it has been defined, does not follow a linear path, but is adapted to the morphology of the Valencian territory, retracing the emblematic places in the history of the province, witnesses to the conquest of the territory by James I. The definition of this itinerary not only contributes to the enhancement of the region's cultural heritage, but also offers the possibility of appreciating the historical and identitary elements that are the result of the monarch's legacy: the enclaves of Alto Palancia, where the advance toward the new territories started; the massive castles of Cullera and Morella; the monastery of Santa María and the ruins of the ancient castle in the city of Puig.

Unlike popular perception, there is no real continuity between the earlier Muslim kingdom and the later Christian kingdom after the conquest of James I [3]. The Arabs ruled Valencia from an uncertain date, generally estimated to be around 714, until 1238 [4]. During these centuries, Valencia and its region generally depended on emirs, caliphs, and kings who ruled in Cordoba, with some exceptions during specific periods [5]. The geographical, linguistic, ethnic and political differences in the territory also influenced the architectures, as they are the result of continuous transformations and historical stratifications. The Arabs first and the Christians later used their construction knowledge to transform, expand and rebuild architecture. James I's permanence in the Valencian territory had an impact on the local architecture, leaving a cultural heritage of considerable importance that can still be read today within the different historical and cultural stratifications. In the context of the research project, were identified and analyzed only a few of the most significant and interesting sites among more than 200 [6] related to the monarch's feats. These sites were categorized according to their original function, including religious buildings, monasteries, and churches, as well as defensive structures such as castles and city walls. Included the Almonecir Castle, which has been the subject of an indepth study.

Almonecir Castle through its history

Arabian influence in Spanish architecture, is reflected not only in the richly decorated palaces of Andalusia, but also in the fortified systems spread throughout the territory. Arabian construction techniques influenced the Christian way of building, particularly in the use of tapial. Located in the western area of the Sierra de Espadan, Almonecir Castle is one of the most remarkable examples in the region of work built with tapial technique [Fig.1]. Its remote location, far from main communication routes, had a major impact on the historical development of the surrounding villages, forming a natural obstacle to urban growth and at the same time giving it strategic value in different historical phases [7]. The castle's significant historical relevance in the region emphasizes its prestige as an emblematic landmark, part of a sophisticated defense system covering the entire extension of the Sierra de Espadan. This well-structured defense system has

Materials Research Proceedings 40 (2024) 350-357 https://doi.org/10.21741/9781644903117-36

proven to be crucial in preserving the security and integrity of local communities throughout the centuries.

Fig. 1 Views of the current state of the castle after partial conservation and restoration work.

The origins of Almonecir Castle are closely linked to the Arab conquest of the Iberian Peninsula and the origin of a new state known as Al-Andalus [8]. Initially part of the Umayyad Empire of Damascus, Al-Andalus separated in 756 CE and reached the height of its power with the Caliphate of Cordoba (929-1035 CE) [9].

Almonecir Castle in its early phase was a fortified monastery or ribat, inhabited by a community of Muslim warrior monks known as Murabitin. In the second half of the 11th century and the early years of the 12th century, poor administration and inefficient government caused great insecurity in the rural areas of Al-Andalus, especially in the regions of Murcia and Valencia. As a result, farmers were forced to leave their houses and farms and seek refuge in castles erected on hills and in strategic locations, including the Castle of Almonecir [10]. After the Conquest, King James I conceded to the royal chancellor Berenguer de Palou, bishop of Barcelona, the Castle of Almonecir together with all the lands, villages and inhabitants associated with it, as a form of reward for his contribution to the conquest of the kingdom of Valencia[11]. The Castle played a central role in the Espadan War, which broke out following the decree issued in 1525 by Charles V requiring all Muslims in the Crown of Aragon to convert to the Catholic religion or leave the Iberian Peninsula. Following the rebellion and expulsion of the Arabs from the Espadán area, Almonecir Castle gradually lost importance and its military functions became obsolete. Today the Castle constitutes an important historical testimony of the events that shaped the region over the centuries. Its ruins represent a tangible example of the military art and fortified architecture of the period, whose transformations reveal the complexity of the social, economic and political relations that have involved the Castle over the centuries.

Documentation activities and elaboration of a digital database

The scientific analysis of the castle and its architectural elements offers the opportunity to deepen understanding of the construction techniques used, the materials employed, and the various transformations. This study provides a more complete and accurate view of the castle's history, including the social, cultural and political aspects that characterised its life and role within the society of the time. Preliminary activities for the spatial knowledge of the site and the planning of survey operations started in July 2022. The field documentation actions were carried out using two different data acquisition methodologies: Range-Based, through the use of mobile laser scanner instrumentation (MLS) with LIDAR sensors to obtain highly reliable metric measurements; Image-Based (Reflex type cameras and UAVs) to acquire information related to color and surface, using SfM (Structure from Motion) photogrammetry. The documentation using the Leica BLK2GO laser scanner mobile required a series of planning actions by the operator to organize the entire data acquisition campaign. The entire fortified complex (in its accessible parts) was subdivided into different acquisition macro-zones, where for each of them scans were planned

Materials Research Proceedings 40 (2024) 350-357 https://doi.org/10.21741/9781644903117-36

according to the size of the area to be covered, internal environments and/or vertical connections [Fig.2]. The database consists of 8 scans (average time per scan: 5 minutes, total number of points: 242,656,283, average number of points per scan: 30,332,035).

Due to the conformation of the territory and the position of the castle, the portions of the walls on the external front were difficult to access and it was not possible to carry out acquisition paths. To integrate the external architectural data and to acquire the surrounding area, was used ground and aerial photogrammetric survey. The digital restitution of a survey carried out by aerial photogrammetry systems - oriented both to the correctness of the data and to the realistic reproduction of the morphology of the surfaces - produces a good basis for integrating the point cloud from laser scanner instrumentation [12]. The necessity to survey the Castle using UAVs arises from the need to acquire the upper portion of the Homenaje tower and the external areas of the walls. The acquisition phase was carried out through the planning of several manual flights structured on two different scales: a punctual one around the tower; and a territorial one involving the castle and part of the surrounding space. For each flight, a radial path was carried out with variations in height [Fig.3].

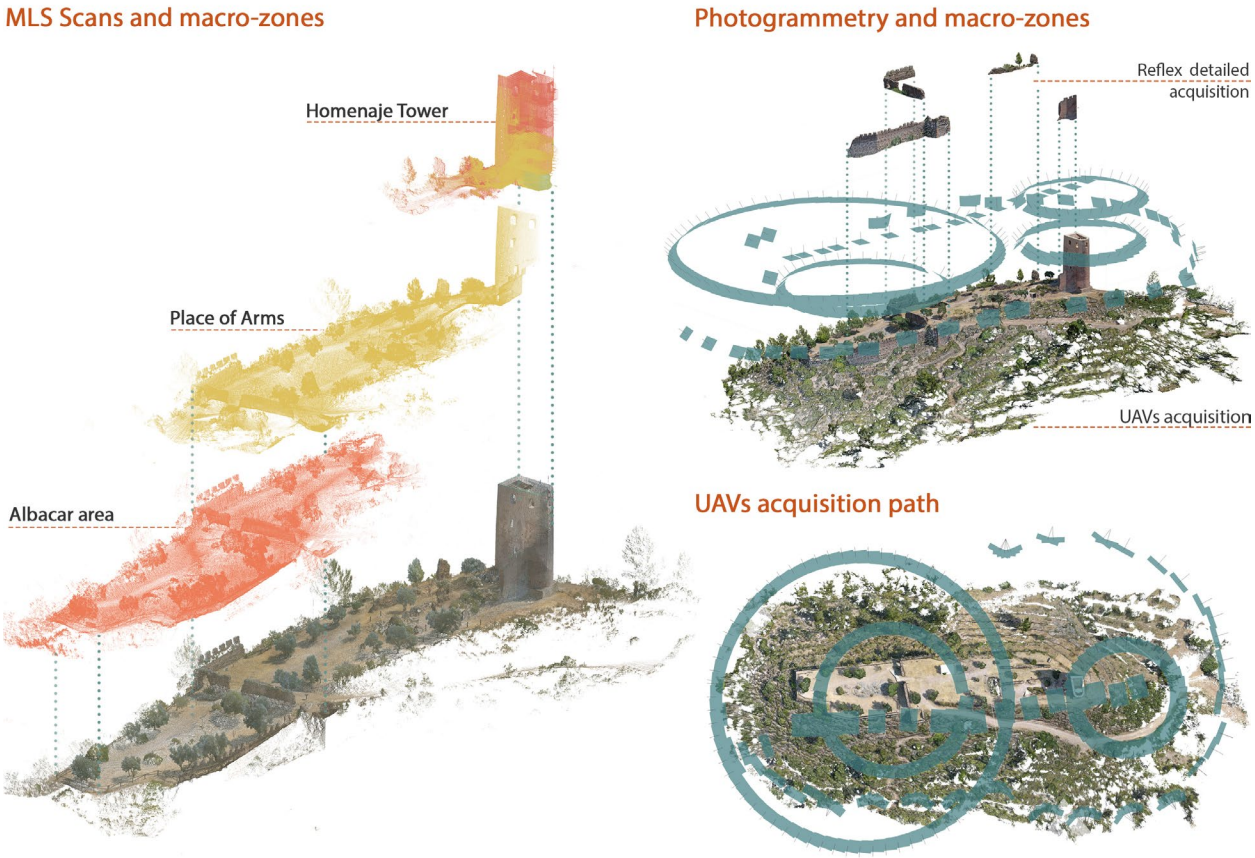

Fig.2-3, Scan overview using MLS instrumentation (BLK2GO), and Point cloud from photogrammetry. It is possible to see the frame sequences from drone survey.

Then, the photogrammetric data from Drone acquisition was integrated through a photogrammetric ground campaign using a reflex camera. The photogrammetric processing phase - aimed at obtaining a reliable point cloud such that it can be integrated with the point cloud from MLS - was managed using two different software: Agisoft Metashape and RealityCapture. The use of two software, which are based on different operating algorithms, made it possible to compare the generated point clouds and to choose the best data from a morphometric point of view[Fig.4]. The point clouds from the three different sources (Laser Scanner, Photogrammetry processed by Metashape and Reality Capture) were combined to obtain a single database from

Materials Research Proceedings 40 (2024) 350-357 https://doi.org/10.21741/9781644903117-36

integrated datasets. This made it possible to perform a morphometric comparison operation on the basis of the MLS point cloud [Fig.5]. The three point clouds were then integrated into a single global database from which the most suitable combination of integrations could be selected for subsequent import into the parametric modeling software. The final database consists of the data from the mobile laser scanner and the photogrammetric cloud processed in RealityCapture. In general, the discriminating factor for the choice was the best geometric quality against a nearly comparable accuracy and average deviation from the laser scanner cloud.

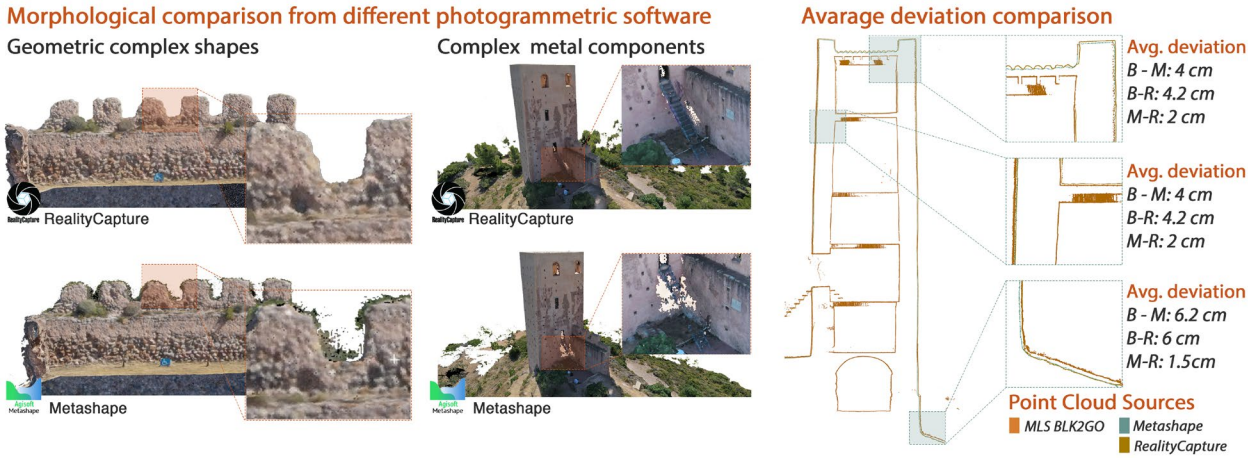

Fig.4-5, Processing results and morphometric data comparison from the different sources

Structuring the HBIM project from data survey

The methodological application of Scan-to-BIM to the Cultural Heritage field opens up a potential range of applications, allowing the integration and management data of different natures, from architectural to territorial scale. These potential applications allow the realization of tools ranging from architectural and historical analysis to urban planning and design [13]. In the architectural information models, each represented element becomes “smart” because it can contain different levels of relevant information. This research considers the application of the scan-to-BIM process in order to obtain an informative model of the castle, useful for its management, maintenance and enhancement over time. To develop this methodology, the global point cloud was treated through a cleaning process and then exported in a format compatible with the BIM platform Revit. The modeling of the castle was structured according to a dual principle: the chronological division of the construction phases, and the typological subdivision of the individual elements on an architectural and territorial scale. To this purpose were used preset parametric families already present in the software while for some specific components, it was necessary to implement the default abacus with new elements. Before proceeding to the typological modeling of the elements, were set up 'work phases' where historical evolution models were prepared based on historical considerations. The first modeling step was the topographical surface on which the architectural structures were subsequently placed. For the realization of the terrain surface it has been used the UAVs photogrammetric data: the DTM (Digital Terrain Model) was exported from the Agisoft Metashape software. Before the exportation, the model was cleaned from the anthropic elements.

The modeling phase of architectural components of the castle was carried out by isolating the individual elements following a semantic typological decomposition. The following information components were associated with each element: creation phase, demolition phase, cross section, vertical angle, and material. Each model element was renamed according to a code describing the element type and its dimensions.

Materials Research Proceedings 40 (2024) 350-357 https://doi.org/10.21741/9781644903117-36

The model for the management and knowledge of its historical stratification

The development of the model through a BIM platform enabled and facilitated the structuring of an abacus of the castle's typological elements. Various information (metric, constructive, historical and military function) is linked to each element. This allowed the codification of the individual elements and their possible re-use for the creation of informative models of typologically related fortifications[Fig.6].

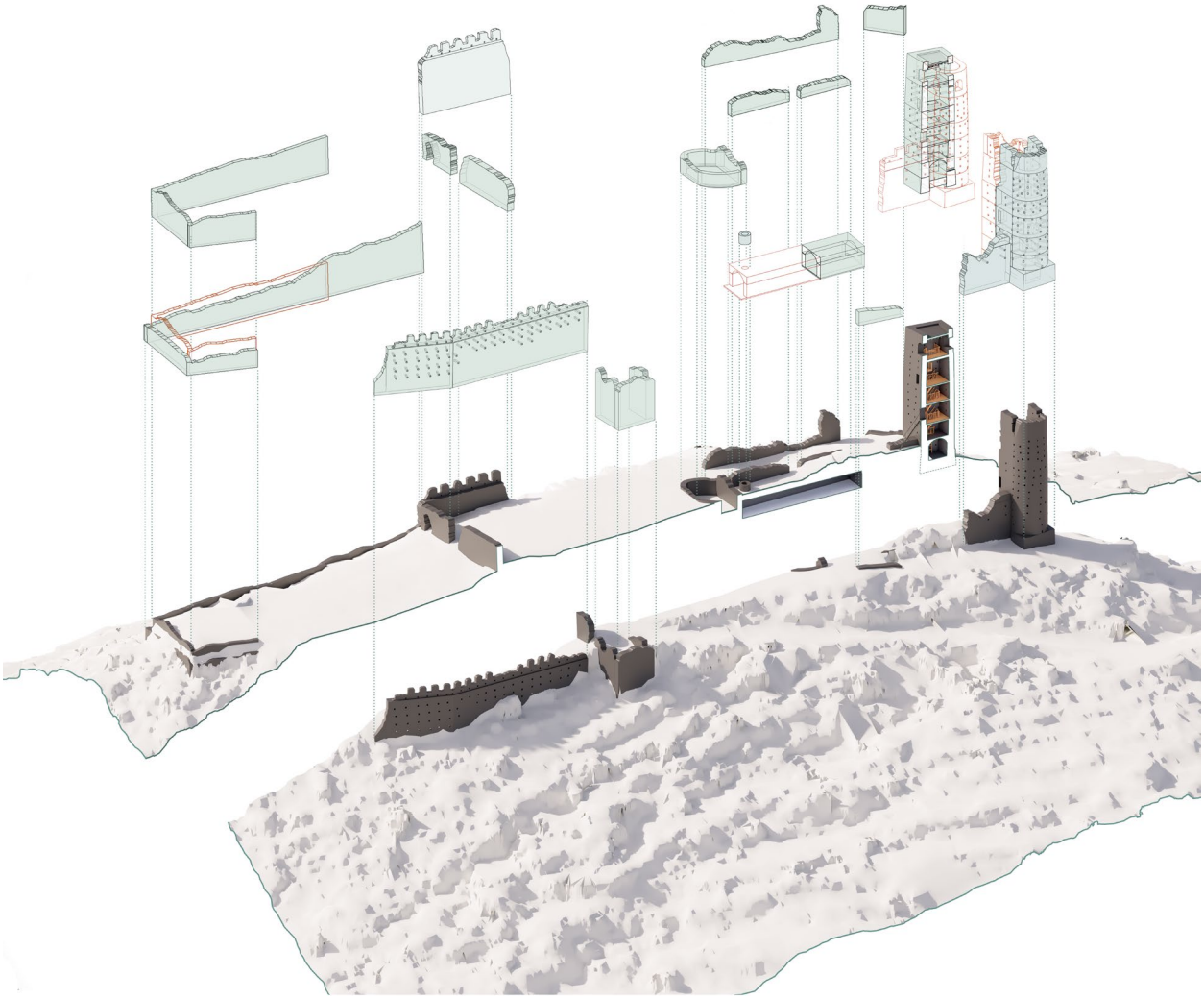

Fig. 6, Axonometric cross-section of the elements modeled in Revit. In the background the parametric model of the current state of the castle (2023), in the foreground the castle before the partial restoration work (2008).

The abacus of elements inside the Revit project collects in an organized manner all the elements used for the representation of the historical phases, allowing them to be searched and consulted according to an organised excel file. In order to realise coherent reconstructive hypotheses [Fig.7], were examined numerous coeval case studies inside the Valencian Community and in neighboring regions. The typological analysis was supported by the archaeological evidence, and hypotheses were made by mediating the information from the two sources. Subsequently, to support the modelling of the phases, through the setting and management of the phase filters in the Revit software, was structured a 'reliability map' in order to allow the real reliability of the hypotheses. The possibility of including, in addition to the geometric basis representative of the object, other levels of information, represents a useful tool to follow all the operational processes necessary for the conservation and management of the architectural asset. The BIM system makes it possible to

associate the various objects with a series of parameters that characterise them specifically for what they are and not only as surfaces.

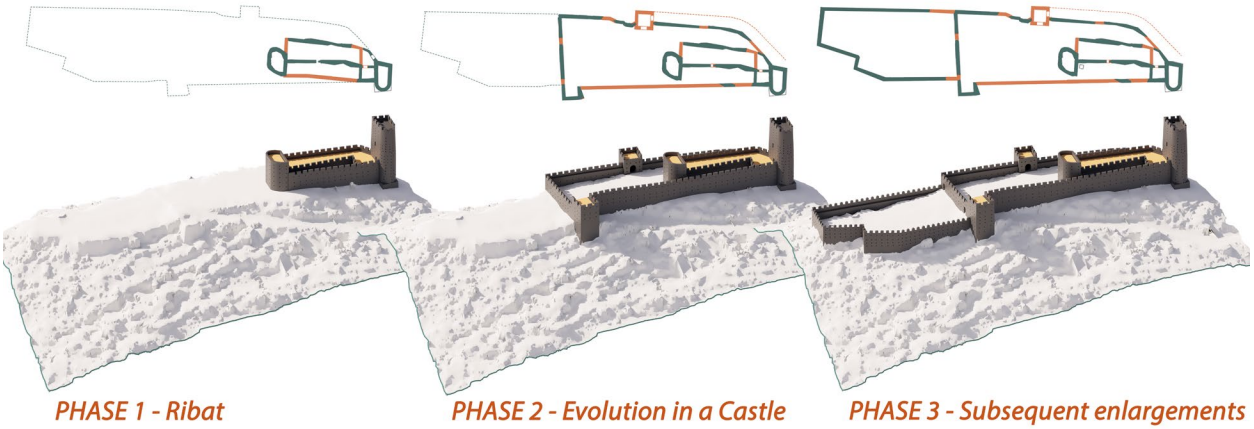

Fig. 7, Three historical developmental hypotheses for the castle, from around X to XV century.

Conclusion

In the field of Cultural Heritage, research in the implementation of BIM procedures is still open and in an experimental phase, in relation to the different possible fields and application perspectives. The adoption and consolidated use of parametric models of the built environment represents a great achievement in the management of all aspects and practices related to the existing. In this sense, it is essential to consider the application possibilities of BIM to the entire cultural heritage, in accordance with the most advanced technologies currently available, covering all stages from acquisition and survey to management for preservation. Heritage-BIM is configured as an innovative element compared to traditional methods of management, cataloguing and valorisation of architecture. Through an information modelling methodology capable of storing and visualising geometric and documentary data in a single database, it is possible to obtain querying models in which all historical and technical information, often dispersed among different sources, is brought together. This methodology allows for the preservation of information, appropriately selected by facilitating data storage management processes, minimising information redundancy and data dispersion. The application of BIM methodologies also provides the conditions for continuous updates and necessary modifications in response to the evolution of digital systems for the preservation of historical memory. These processes, aimed at promoting the territory, play a key role in the process of enhancing and preserving the historical-architectural heritage, contributing to cultural promotion of James I's territory.

References

[1] S. Parrinello, F. Picchio, R. De Marco, A. Dell'Amico, Documenting the cultural heritage routes. The creation of informative models of historical russian churces on Upper Kama region, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W15, (2019) pp. 887–894. https://doi.org/10.5194/isprs-archives-XLII-2-W15-887-2019; S. Parrinello, A. Dell'Amico, Experience of Documentation for the Accessibility of Widespread Cultural Heritage. Heritage (2019), 2, 1032-1044. https://doi.org/10.3390/heritage2010067

[2] B. M. Feilden, J. Jokilehto, Management Guidelines for world Cultural Heritage management, ICCROM, Rome 1998.

[3] A. U. Arteta, Orignes del Reino de Valencia, cuestiones cronologicas sobre su reconquista, VOL.I e II, Saragozza, 1981.

[4] H. Miranda, Historia musulmana de Valencia y su región: novedades y rectificaciones, 3 VOL., Ayuntamiento de Valencia, Valencia, 1970.

[5] A. U. Arteta, Orignes del Reino de Valencia, cuestiones cronologicas sobre su reconquista, VOL.I e II, Saragozza, 1981.

[6] A. M. Criado, V. G. Domenech, Comunitat Valenciana 2030, Síntesis de la Estrategia Territiorial, Generalitat Valenciana, Valencia, 2012.

[7] V. F. Martì, Torre y Castillos de la Sierra d'Espadan, Sociedad Castellonense de cultura obras de investigation historica LXXVII, Castellòn, 2008.

[8] J. P. Rodriguez, Historia del Castillo, in J. P. Rodriguez, (Eds.), El Castillo de Almonecir, Castellò, 2005, pp.19-35.

[9] P. Guichard, Al-Andalus: 711-1492: une histoire de l'Espagne Musulmane, Paris, 2000.

[10] J. P. Rodriguez, Historia del Castillo, in J. P. Rodriguez, (Eds.), El Castillo de Almonecir, Castellò, 2005, pp.19-35.

[11] 'Libre de Repartiment', ancient register in which King James I's accounting officer registered property donation at the conclusion of the conquest of Valencia.

[12] F. Picchio, Acquisition protocols for UAV photogrammetric data – Comparison in methodological SfM procedures from architectural till urban scale, in S. Barba, A. Dell'Amico, M. Limongello, S. Parrinello, S. (Eds.), D-SITE – Drones-Systems of Information on culTural hEritage – For a spatial and social investigation, Pavia University Press, Pavia, 2019, pp. 70-79.

[13] S. Parrinello, A. Dell'Amico, From Survey to Parametric Models: HBIM Systems for Enrichment of Cultural Heritage Management. In: c. Bolognesi, D. Villa, (Eds.), From Building Information Modelling to Mixed Reality. Springer Tracts in Civil Engineering. Springer, Cham, 2021, https://doi.org/10.1007/978-3-030-49278-6_6, A. Dell'Amico, HBIM and digital documentation for development reliable parametric models on complex systems. AIP Conference Proceedings 2021. https://doi.org/10.1063/5.0071096