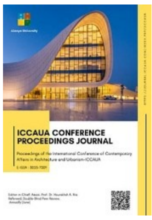

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Valorization of Cultural Heritage through the Scan-to-BIM Process – The Berber Oil Mill as a Materiality of a Total Social Fact

[1]* MSc. **Rawen Chetouane** and [2]* Assoc. Prof. **Faten Hussein**
[1] Master Degree ERASMUS+ CUDIMHA, National School of Architecture and Urbanism, University of Carthage, Tunisia
[2] ERA, LarPAA, EDSIA, National School of Architecture and Urbanism, University of Carthage, Tunisia
*Both authors have equally participated to this paper
E-mail [1]: rawenchetouane@gmail.com , E-mail [2]: faten.hussein@enau.ucar.tn

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Abstract

In the context of increasing digitalization in the construction sector, the emergence of innovative IT paradigms contributing to the virtual valorization of historic buildings enables the optimization of traditional approaches to preserving cultural heritage. In line with pedagogical experiences that rethink past objects and architectural facts by considering their overall complexity, we present a didactic approach for the regeneration of a traditional Berber oil mill located in southern Tunisia, based on the Scan-to-BIM process. This process involves acquiring historical, graphic, and geometric data to model the building in 3D, using a reverse design method. It integrates data from anthropology, history, archaeology, computer science, energetics, and architectural rehabilitation. This model can be refined and incorporated into an HBIM approach, fostering collaboration in heritage valorization while preserving authenticity and the specific context of the region, positioning it as a catalyst for sustainable development.
Keywords: Heritage, regeneration, Scan-to-BIM, point cloud, modeling.

1. Introduction

In the context of intelligent, adaptive, shared, and collaborative Industry 4.0 production, the way each society uses new technologies to convey information is crucial in determining its various economic, political, human, cultural, and artistic directions (Picon, 2010). Within the framework of practices aimed at regenerating the memory of places and enhancing architectural objects and features, we are witnessing a trend of massive digitization of these elements (Benghozi, 2011), with the goal of preserving them in the long term and making them accessible, thereby changing the way users relate to their cultural heritage. Thus, this dialogue unfolds both in the real world and the virtual world. A wide array of technologies facilitates this connection, including augmented reality, virtual reality, artificial intelligence, digital twins, and HBIM (Heritage Building Information Modeling). Several questions arise from this context: how can New Information and Communication Technologies (ICT) be integrated into the practices of cultural heritage enhancement, and what role could HBIM, an interdisciplinary field in constant evolution, play as a process in a heritage valorization strategy with its many specificities?
This research investigates the potential of HBIM and ICT in fostering sustainable cultural heritage enhancement, specifically through the lens of a transdisciplinary educational initiative in the Dahar region of southern Tunisia. Recognized internationally for its sustainable tourism practices, the Dahar region—particularly the village of Toujen—serves as a living laboratory for exploring how digital tools can be harnessed in heritage regeneration.
To address these questions, we adopted a Scan-to-BIM methodology to model a traditional Berber oil mill. Utilizing 3D laser scanning and CAD modeling, the project demonstrates how reverse design and retrodesign principles can be applied to non-parametric heritage structures for morpho-sensitive rehabilitation.
This paper contributes to the field in three key ways: first, by demonstrating the applicability of HBIM in complex heritage contexts; second, by integrating educational practices into professional heritage valorization processes; and third, by highlighting the socio-economic potential of cultural tourism as a lever for regional development.
This paper is organized into four mains sections. The first chapter introduces the study's background, providing an overview of the field and exposing key concepts. The next section details the physical context of the case study, outlines

the research methodology employed, and describes the technical workflow implemented during the study. The third chapter presents and analyzes the findings from the Toujen case study, highlighting significant observations and insights. Finally, the last section concludes the paper by summarizing the study's findings and discussing their implications for sustainable heritage management, suggesting directions for future research.

2. From Traditional to Digital: Advancing Sustainable Heritage Valorization through HBIM

The integration of digital technologies into cultural heritage preservation has become an essential strategy for ensuring the sustainability and accessibility of historical sites. As traditional preservation methods face challenges due to environmental factors, resource limitations, and evolving societal needs, digital tools offer innovative solutions to document, analyze, and revitalize heritage structures.

2.1. Valorization of cultural heritage through ICT: A groundbreaking educational experience

An innovative educational experience provides a response to these questions in the context of the valorization of the cultural heritage of the Dahar region in southern Tunisia. Recognized internationally by the "Green Destination" organization in its "Story Awards 2021" as the top sustainable tourism destination in the "Culture & Communities" category, the Dahar region, particularly the village of Toujen, serves as the focus of an Erasmus+ transdisciplinary project titled "Curriculum Development: An Innovative Master in History and Archaeology – CUDIMHA 2020/2022" (*"cudimha", 2020).* This project aims to develop a professional training pathway that brings together several partners from both Mediterranean shores and involves various disciplines in a collaborative and synergistic approach. This allows learners to undertake cultural mediation projects using ICT. With the objective of opening the region to its socio-economic environment, this educational experience highlighted the sustainable valorization of Dahar's heritage by integrating innovative digital tools and involving the user of the space in a logic of recreating significant places from the past. This process encompasses human activity in the present while enhancing the genius loci— the unique entity of physical, biological, social, and historical forces that, together, define the distinctiveness of any region (Norberg-Schulz, 1981).

2.2. "Reverse engineering" and the HBIM approach

In the context of the growing commodification of culture and the "digital everything" trend, working with cultural heritage in a sustainable way is not a simple process. Indeed, current digital and energy challenges significantly influence the construction sector in general, pushing it to adapt to these changes. To address these challenges, Building Information Modeling (BIM) presents itself as a solution, serving as a collaborative working process centered around a digital model that involves all construction stakeholders and optimizes their actions throughout the entire lifecycle of the building. This working method, applied to modern buildings, becomes particularly significant when dealing with heritage structures. Considering the modeling of non-parametric heritage structures for the purpose of sustainable valorization is a difficult and imprecise task when conventional modeling strategies are applied (Arayici and al., 2017). Thus, Heritage Building Information Modeling (HBIM) emerges as a new system for modeling historical data (Murphy and al., 2009) based on the acquisition of existing data. This approach is of paramount importance, as the impact of the sustainability of the resources mobilized during various heritage valorization operations should be anticipated, tested, and discussed prior to any intervention in the field. Modeling a design process that spans from project conception to construction, the HBIM approach involves a dynamic treatment of the building's complex data, extrapolating the principles of reverse engineering to the domain of architectural retrodesign (Chikofsky & Cross, 1990). Analogous to the method of analyzing an existing object to uncover the techniques used to construct it, retrodesign is defined as an operation that simulates informational relationships within a building from a past space-time interval, initiated from a pre-existing knowledge state, oriented toward a specific projective goal according to the desired heritage operation, and resulting in new knowledge production (Claeys & Naifer, 2022). Going beyond simple morpho-technical and static modeling, retrodesign aims to regenerate and redesign a given heritage by restoring the knowledge inherent to its creation. The interweaving of these forms of knowledge—spanning anthropology, history, archaeology, computer science, energy systems, environmental design, modeling technologies, and spatial and architectural rehabilitation—shapes the complexity of the project to be regenerated and reveals its unique poetic-sensory imprint and authenticity.
By examining this case study, we aim to highlight the transformative potential of HBIM in bridging traditional conservation practices with modern technological advancements, fostering a more sustainable and inclusive approach to heritage valorization.

3. Regenerative Scan-to-BIM method of a berber oil mill

Experimenting with the application of the HBIM process through the inverse modeling of conceptual knowledge with the aim of a morpho-sensitive enhancement of past architecture, we will detail the regenerative approach adopted to rehabilitate a traditional Berber oil mill located in the village of Toujen in the Dahar region of Tunisia. This approach aims at the sustainable redevelopment of the region and its integrated urban reorganization based on the driving activity of authentic cultural tourism as a sector with high employability potential and an attractive, competitive economic lever for the Dahar.
Thus, we considered the implementation of a Scan-to-BIM approach as a crucial step in the HBIM process, employing the reverse design of the oil mill by acquiring the existing data of the building in its current state through 3D laser scanning technology. This data, which is presented as a point cloud, is post-processed and integrated into CAD software to create a 3D model that regenerates our building. This model is subject to evolution by incorporating the necessary

level of detail to integrate an HBIM process and ICT applications, leading to the rehabilitation of the oil mill (Macher, 2017).

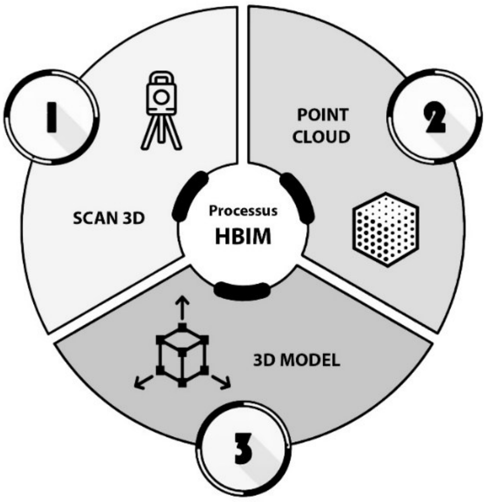

Figure 1. Scan-to-BIM Process in the HBIM Approach (Source: Authors).

3.1. From the Toujen village to the oil mill, a holarchic approach

2.1.1. Study area

The context of this study is situated between the ridges of Toujen. Located 670 km from Tunis, this village with stone houses is nestled on the edge of the Dahar plateau, hidden within its natural setting as if it were born from the mountainous relief of the area. The traditional Berber oil mill, the subject of our intervention, is located at the foot of the village's highest mountain. It directly faces a dirt road and opens up to a neighborhood of houses descending towards the valley, which has allowed for a visual opening onto the panoramic landscapes of the village.

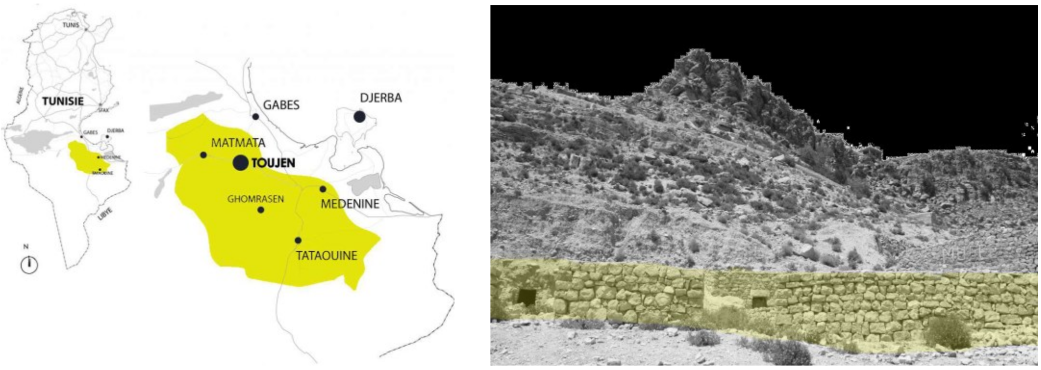

Figure 2. Dahar Region – Toujen Village (a) and General View of the Oil Mill (b) and the Mountain (Source: (Chetouane, 2022)).

2.1.2. The oil mill, fragment of a total social fact

Prior to the morpho-digital survey of the existing state of the oil mill, a process of regenerating the social facts produced within this space took place, based on precise documentation and fieldwork aimed at updating the olive oil extraction process in the region, along with the entire spiritual and cosmogonic universe it generates, which itself regenerates the spirit of the place. Thus, we adopted a holarchic approach that considers every element of a system as a whole part of a larger ensemble (Ryle, 1949). The regenerative potential of any hierarchical system is manifested in this openness, fluctuating from the highest level of integration and moving towards the creation of new structures. Each regenerated social fact related to the activity of olive oil extraction is a dynamic manifestation of its totality as a phenomenon in itself, with an assertive tendency that integrates at another level, depending on the entire social holarchy to which it connects and dissolves, thus expressing its partiality and regenerating its poetic potential (Koestler, 1979).

This holarchic approach to the oil mill as a fragment of a total social fact (Mauss, 2007), connected to the spiritual phenomena surrounding the olive tree as a blessed tree in the regional Berber collective imagination (Laporte and al., 2013), aims to enrich the technicist approach induced by the digital survey work of the oil mill for a regenerative morpho-poetic modeling of the genius loci of the oil mill. In this context, we cataloged various fragments and social facts directly related to the oil mill and its operation based on the documentation work conducted. A model of the olive oil extraction activity within the oil mill was thus created, considering both the technical and material details as well as the social and spiritual aspects of this phenomenon, with the goal of integrating it into the regenerative process of rehabilitating the oil mill space following the Scan-to-BIM process.

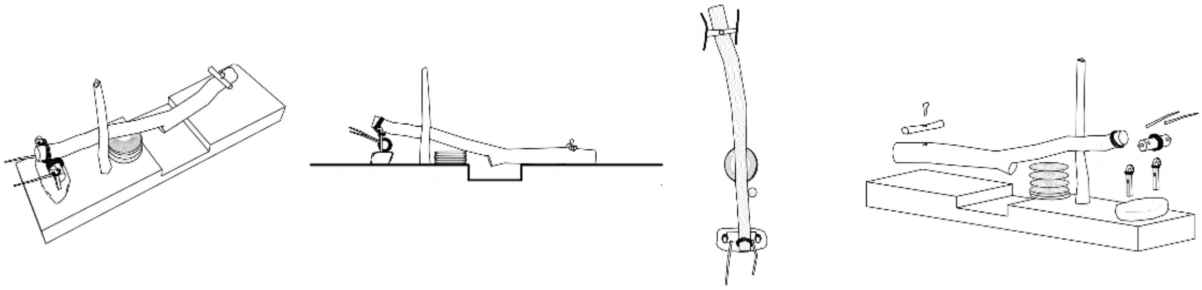

Figure 3. Modeling the Olive Oil Extraction Process in the Studied Oil Mill Based on Documentary Sources and In-Situ Surveys (Source: (Chetouane, 2022)).

3.2. Survey of the existing conditions, 3D laser scan campaign

The acquisition of the existing conditions is the step that initiates the Scan-to-BIM process. This operation is crucial as it provides the necessary information to create an accurate digital model. It involves performing a detailed survey of the historical building using digitization technologies such as photogrammetry or 3D laser scanning, combined with traditional architectural and urban survey techniques. In our case, we used a 3D laser scanner (FARO Laser Scanner Focus3D X 30) to capture high-precision 3D point clouds of the oil mill and its surroundings. The scanner emits laser beams that measure the distance between the device and the building's surfaces, thus creating a detailed digital representation of its internal and external geometry. It is essential to properly position the device at different points within the oil mill, specifying reference points (targets) so that the system can link the different scans together, ultimately resulting in a digital reconstruction of the oil mill that faithfully represents the existing structure. The 3D laser scanner is capable of capturing data with high resolution and precision, allowing for the capture of even the finest and most complex details of the building (Golparvar-Fard and al., 2011). Moreover, this technique is not limited by the ambient conditions during the acquisition. This precise digital recording of the oil mill, containing a large number of unconnected points that cover its external surfaces (whether the recording is made inside or outside the oil mill), is referred to as a point cloud. These points have defined positions and colors, which makes point clouds easy to edit, display, and filter.

Figure 4. 3D Scan Campaign of the Studied Oil Mill in Toujen and the 3D Laser Scanner Used (Source: Authors).

3.3. Post-processing of the data

The data extracted from the 3D laser scan, in the form of point clouds, is post-processed: a precise control is performed on the drifts, angles, and offsets between the scans to eliminate imperfections, noise, and correct errors (reflections, mirror effects, shadows, etc.). It is also necessary to align the scans so that they fit together perfectly. The alignment of the scans involves geo-referencing them to align them within the same coordinate system, thus ensuring an accurate and consistent representation of the existing structure. This data preparation step required appropriate point cloud processing software. We used Faro SCENE software. Each 3D laser scan is recorded with specific spatial coordinates, defined by control points or targets placed around the oil mill beforehand. Once the scans are properly recorded and aligned, the isolated point clouds are merged to form a global point cloud representing the entire space of the oil mill, a true imprint of the existing state of our building (Nurunnabi, 2022).

To make the data accessible, the resulting data was exported in several formats compatible with 3D modeling software such as Autodesk Revit and Autodesk AutoCAD (*.e57, *.rcp, and *.wrl).

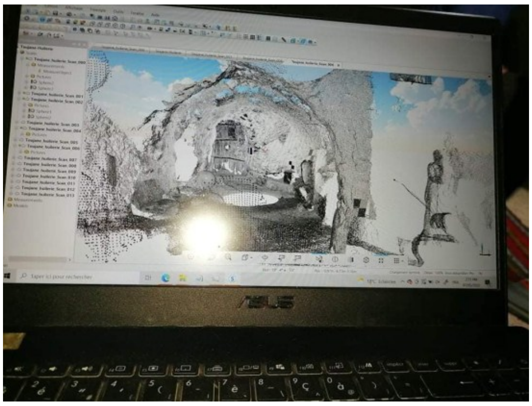

Figure 5. Post-Processing of the 3D Scan Data into a Global Point Cloud via Faro SCENE (Source: Authors).

Visualization software for the obtained scans also provides advanced tools to analyze point clouds and extract useful information such as distance measurements, volumes, cross-sections, etc. Additionally, they allow for interactive visualization of point clouds, which facilitates the inspection and navigation of the building's digital data through virtual reality (VR) views. We used SCENE 2go to assess the captured data in a VR environment before modeling it.

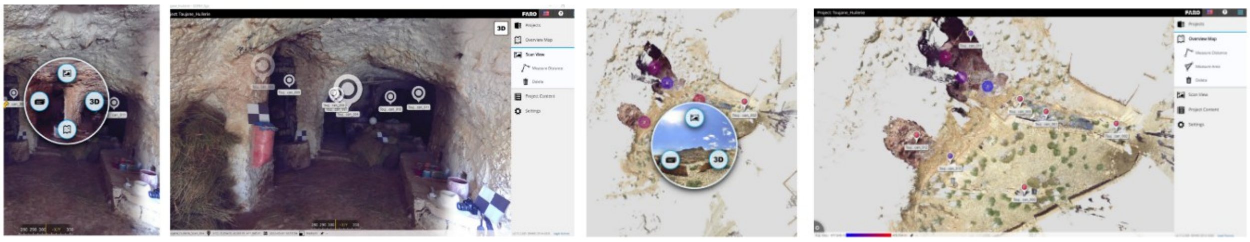

Figure 6. Virtual Tour of the Oil Mill Visualized in the SCENE 2go Application (Source: Authors).

3.4. 3D Modeling

The global point cloud is imported into a modeling software and aligned in the X, Y, and Z workspace. 3D meshes are then generated to represent the building's surfaces. Once the 3D mesh is created, it is important to verify its accuracy by comparing it to the original laser scans and reference data. Adjustments may still be necessary to correct any errors or inconsistencies and ensure that the model faithfully represents the existing structure. We chose Autodesk Revit 3D modeling software to generate the digital model of the oil mill, add the desired level of detail for our rehabilitation process, and assess the carbon footprint of our proposed building valorization project. Thus, our goal is to integrate our approach into a BIM process by making our model accessible within a collaborative work environment, which is essential for sharing information with all professionals involved in the success of our heritage conservation operation.

4. Results and discussions

Due to unforeseen circumstances related to the unavailability of a sufficiently powerful workstation to support the large amount of data resulting from the post-processing of the scans, we were unable to use Autodesk Revit during this 3D modeling step. Alternatives to Autodesk Revit were considered with the primary goal of successfully completing the 3D modeling phase. We resorted to Agisoft Metashape software to perform an automatic 3D reconstruction of the oil mill from our global point cloud.

Figure 7. 3D Modeling of the Exterior of the Oil Mill Generated by Agisoft Metashape (Source: (Chetouane, 2022)).

Although the use of Agisoft Metashape software was initially considered as a solution to bypass a purely hardware issue related to the inability to access the file containing the global point cloud in Autodesk Revit due to its large size, the advantage of using Agisoft Metashape lies in the automation of 3D model construction from the post-processed global point cloud. This process would otherwise require programming and injecting plug-ins into Autodesk Revit to achieve the same result. Furthermore, Agisoft Metashape allows the generation of a realistic 3D model through the use of textures derived from the 3D Laser Scan. Thus, this alternative proved beneficial for our reverse engineering approach to the oil mill on several levels. The final result of the 3D model obtained is in the *.fbx file format, which can be exported to Autodesk Revit to generate the graphical elements (plans, sections, and elevations) essential for understanding and using the resulting 3D model. Additionally, the subsequent work in Autodesk Revit allows for the initiation of the BIM process, which is where the value of the Scan-to-BIM approach adopted for our oil mill valorization project lies.

While aiming to complete the final export of data from Agisoft Metashape to Autodesk Revit, we again encountered an issue with the availability of high-performance workstations capable of processing the large 3D data. Ultimately, manually aligning the point clouds using Autodesk AutoCAD became the final solution to bypass the hardware obstacle that was hindering our work. Despite being time-consuming, moderately precise, and not well-suited for optimal 3D model management within a BIM process, this last strategy allowed us to overcome the situation and continue the 3D modeling work aimed at rehabilitating our oil mill and assigning it new functions, while also enabling us to later assess the energy impact of this operation.

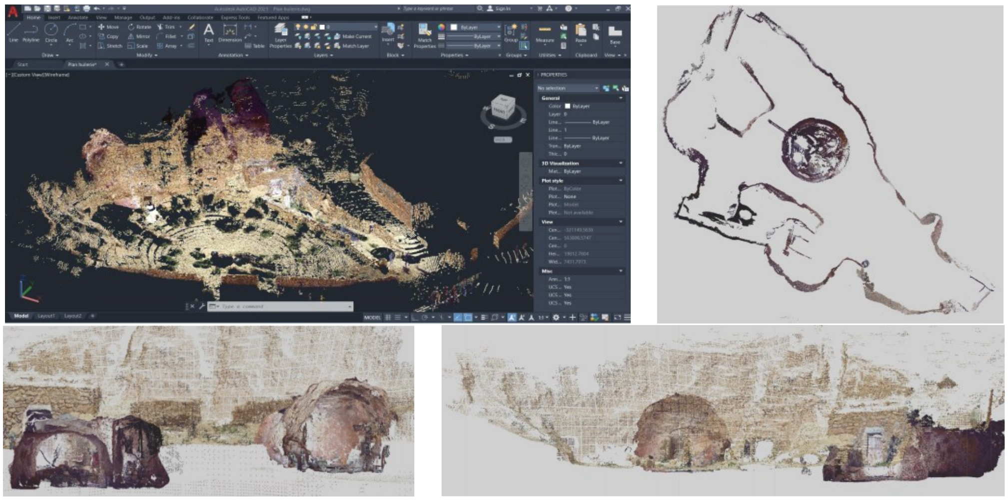

Figure 8. Point Clouds Collected in Autodesk AutoCAD (Source: (Chetouane, 2022))

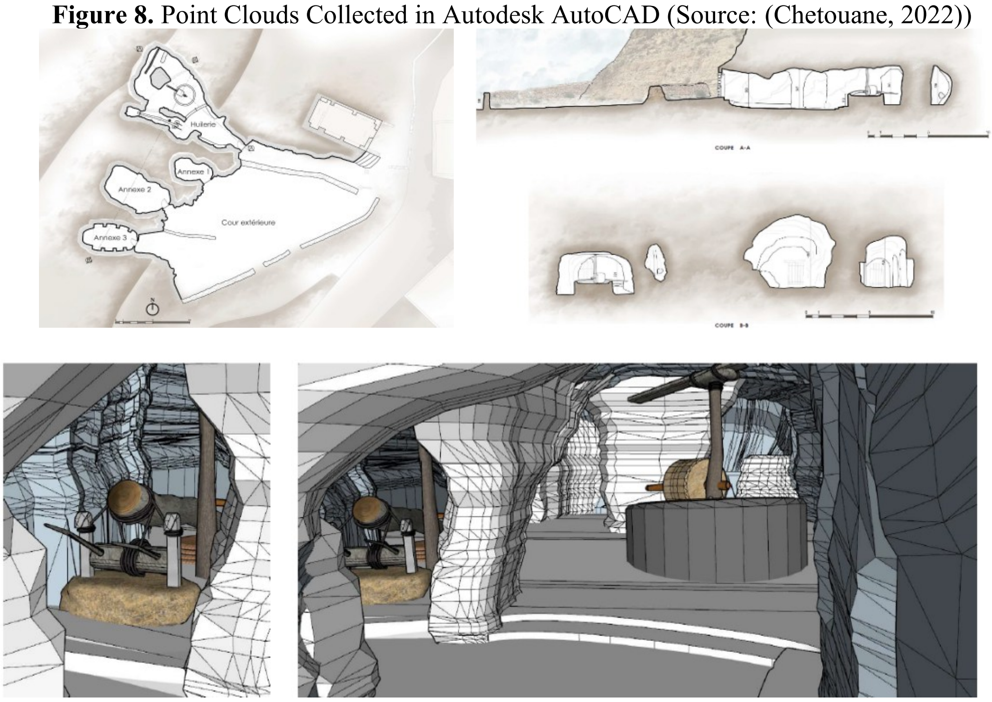

Figure 8. 2D and 3D Graphical Elements of the Existing State of the Oil Mill Obtained in Autodesk AutoCAD (Source: (Chetouane, 2022)).

Furthermore, we did not address in this experimental reflection the management of data and processes related to heritage valorization work in a BIM context for the long-term management and maintenance of this heritage building. This experience highlights the need to carefully target and plan the appropriate resources to successfully complete such projects in the future and fully leverage the benefits offered by a BIM approach applied to heritage.

5. Conclusions

In a context aimed at the sustainable redevelopment of the Dahar region in southern Tunisia and its integrated urban renewal based on the driving force of authentic cultural tourism, we have presented a didactic approach experimenting

with the valorization of a traditional Berber oil mill located in the village of Toujen by adopting a Scan-to-BIM methodology. This methodology incorporates the acquisition of existing data from the building to be regenerated via 3D scanning, which provides a digital footprint of the complex forms typical of Berber heritage architecture in Dahar. It also involves the post-processing of the isolated point clouds created and their integration into a global point cloud, which can be exported into 3D modeling software. We obtained a digital twin, ready to be manipulated and managed within an HBIM process. This management is essential, as any sustainable intervention on a given heritage should involve close collaboration among all its stakeholders to successfully carry out the heritage preservation operation, considering its technical, energy, financial, and social aspects.
The key benefit of the adopted Scan-to-BIM approach and the advantages it provides are crystallized in the standardization of heritage valorization operations, reducing uncertainties, time, costs, and efforts associated with such operations. It is worth recalling that our work is part of a transdisciplinary didactic experiment involving architects, engineers, historians, archaeologists, linguists, economists, and designers, aimed at valorizing the cultural heritage of the Dahar region. Its innovative character is expressed in the fact that it lays the groundwork for future heritage regeneration efforts within a process that fully adopts BIM and its complementary technologies, enriching the region's local sustainable economy with contributions from the new postmodern economy based on knowledge, information, data, and the creativity of new adaptive and innovative start-ups.

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