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Chapter 17

The Realm of Digitization for Conservation and Reconversion, Case of the Historical Hospital Adrar Medina - Algeria

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Introduction

The rapid urbanisation in the last century has incited a real pressure on the strong urban heritage. Several models were proposed to explain this phenomenon of plunder neglect and justification for rebuilding, where, through the valorization of the old and historical areas of a city, on their reanimation and their good recovery, we avoided the loss of precious parts of the collective memory of the different human groups which dominated the place (Ashrafi et al., 2021, Munasinghe, M. 2022). It is a question of searching to reflect equity between the task of conservation, renewal, and construction for the historical heritage. We also pointed out that historical buildings had historical, architectural, and cultural values that testified to the importance of the relation between man and the place in which it evolved (Pagés Madrigal, J. M. 2021). It is this commitment to the value of these buildings that prompted different countries in the world to adopt international conventions focused on the protection of the tangible and intangible cultural heritage. Any operation for the safeguarding, restoration and rehabilitation of these buildings must anticipate the requirement of an accurate knowledge of the building through a combined approach that brings together the collection, analysis, transversal reading, and representation of the survey data (Labadi et al.2021, Petti et al., 2020).

The digital revolution generated a crucial shift in the world from an industrial economy to an economy of knowledge and information. In fact, the new global economic trends favoured those nations and individuals that are able to generate, access, and release knowledge (Song, H., Selim, G. 2022). Moreover, following the path of Moore's law, the capabilities of digital tools keep increasing at an accelerating pace. The arena of cultural heritage does not fall apart from this digital burst. Its cultural assets have amassed vast amounts of information that come in diverse forms, which can be readily converted to digital data. In fact, many initiatives have used the latest advances in digital technology to develop a variety of tools for the documentation, visualisation, and analysis of the rich information embedded in tangible heritage assets. Data captured by digital tools can be processed to create a legacy of knowledge, capable of nurturing the heritage for future generations (Champion, E., Rahaman, H., 2020).

In recent years, digitization in the field of conservation and restructuring of monuments in historical towns has made significant progress in various scientific and technical fields. These advancements offer endless possibilities for documenting historic buildings, exploring them, and gaining a better understanding of them. As a result, applications for the development of historical buildings using 3D modelling and visualisation software are currently being used in several projects worldwide (Mohammed 2020, Bhatti et al., 2021, Caciora et al. 2023).

Conservation is the work of preventing damage or destruction and repairing buildings that are old and have been damaged so that they can continue to exist. The role of the conservation is to ensure that the building is used in a responsible way that is consistent with its physical and historical reality. In fact, the new technologies provide effective tools for improved building documentation for better understanding and interpretation. The new media and digital techniques, such as 3D photo survey, photogrammetry, lasergrammetry, and virtual reality, are deeply influencing and altering existing conservation approaches, enabling unique and powerful new possibilities for documenting the built heritage (Masciotta et al. 2021, Boboc et al.2022). Digital reconversion is closely related to

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the field of architecture and urbanism, which has not been left untouched by the digital revolution (Chiacchiera, F., Mondaini, G. 2023). In these areas, there have been changes in conceptions, designs, realisations, and especially representations, thanks to the application of various scientific and technological tools derived from digital technologies. This has also affected the materials used and has resulted in a diverse range of applications, which have promising implications for reflection and development, particularly in developing countries (Ocón, 2021)(Lourenço et al. 2022).

This research paper is to present the work that has been initiated to develop a digital image as an understanding tool for the survey of historical monuments. The paper summarises the methodological approach and presents a prototype Desktop GIS and CAD that showcases modelling and georeferencing results related to the case study of the Historical hospital of Adrar Medina in Algeria.

Historical Context of the Hospital of Adrar Medina

Adrar, a city in southern Algeria, showcases a rich blend of architectural styles that reflect its diverse cultural influences and historical depth. The Arab-Berber style in Adrar is a testament to the region's indigenous heritage, marked by the use of locally sourced materials like adobe and stone. These materials are used to create sturdy, heat-resistant structures designed to withstand the desert climate. This style often features intricate geometric patterns and traditional arches that not only provide structural integrity but also add aesthetic appeal and cultural significance. The interiors are typically adorned with decorative plasterwork and wooden beams, reflecting the skilled craftsmanship of local artisans.

The Sudanese style, prominent in Adrar, is characterised by its tall, narrow buildings with thick, tapering walls made from sun-dried mud bricks. These structures are designed to keep interiors cool and minimise the impact of the harsh sun, demonstrating a deep understanding of the desert environment. This style includes minimal openings to reduce heat penetration, flat roofs that facilitate rainwater collection, and occasionally, elaborately decorated facades with intricate motifs and patterns.

The Neo-Sudanese style represents a modern adaptation of traditional Sudanese architecture, incorporating new materials such as concrete while preserving key elements like decorative facades and grand, imposing gateways. This style bridges the gap between the old and the new, maintaining the aesthetic and cultural essence of traditional designs while embracing contemporary construction techniques.

During the French colonial period, Adrar saw the introduction of Colonial architecture, which brought European influences such as symmetrical layouts, colonnades, and ornate details. These elements were often merged with local architectural features, resulting in a unique hybrid style. Colonial buildings typically feature large, open courtyards, arched windows, and expansive verandas, providing a blend of European elegance and local practicality.

In recent years, Modern architecture in Adrar has emerged, focusing on functionality, simplicity, and the use of contemporary materials and construction techniques. Modern buildings often emphasize clean lines, open spaces, and innovative design solutions to address the challenges of the desert environment. However, even modern structures often integrate traditional elements to maintain harmony with the region's cultural and architectural heritage. This blend of old and new creates a unique and vibrant urban landscape that encapsulates the historical and cultural evolution of Adrar, offering a visual narrative of the city’s journey through time. The resulting architectural mosaic not only provides a sense of continuity and identity but also showcases the adaptability and resilience of the local community (Figure 1).

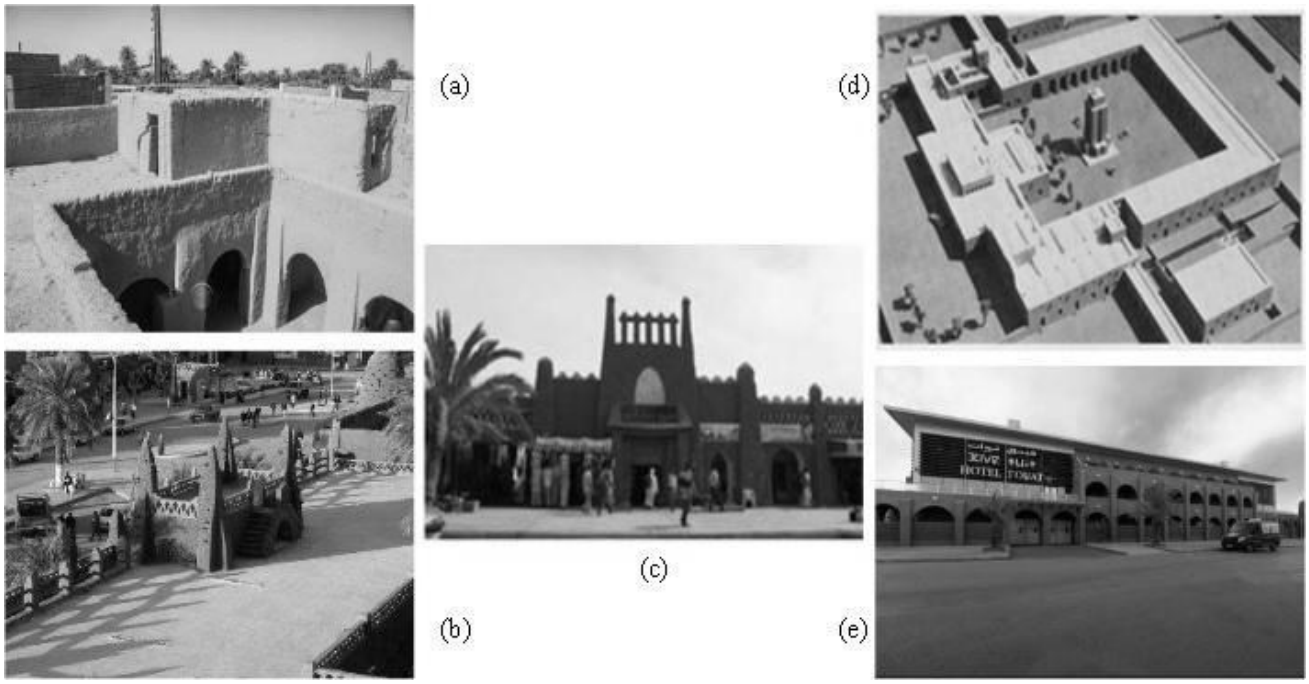

Figure 1: Development of the architectural styles of Adrar: (a) Arab-berbere (ksar), (b) sudanese (oasis rouge hotel), (c) neo-sudanese (souk Dinar Tayeb), (d) colonial (historical hospital), (e) modern (Touat hotel)

The Historical Hospital of Adrar, stands as a testament to the architectural ingenuity of the early 20th century, designed by the esteemed French architects Michel Luyckx. This architect was known for his innovative integration of local and contemporary design elements, collaborated with Auguste Perret, a pioneer in the use of reinforced concrete, to create a facility that not only served medical purposes but also symbolised colonial ambition and modernity. Michel Luyckx contributed to the aesthetic and functional aspects of the hospital by incorporating elements that reflect both European and local architectural traditions. The hospital features symmetrical layouts and colonnades, hallmark traits of French colonial architecture, providing a sense of order and elegance. Additionally, large, open courtyards within the hospital complex serve as communal spaces, reflecting the Mediterranean influence and providing relief from the intense heat.

The hospital's facade is adorned with decorative touches that showcase a fusion of styles. Arched windows with intricate lattice work draw from Islamic architectural traditions, while the use of locally sourced materials such as stone and adobe in certain sections highlights an adaptation to the regional context. The building also includes expansive verandas, designed to offer shade and reduce heat gain, thus enhancing the comfort of patients and staff (Figure 2). Moreover, the Historical Hospital of Adrar played a significant role in the social and urban development of the city. As one of the key public buildings of the colonial period, it not only provided essential medical services but also became a symbol of the modernization efforts undertaken during French rule. The hospital's design, blending robustness and elegance, has allowed it to endure as a historical landmark, representing a unique period in Adrar's architectural and cultural history.

Figure 2: (a) Adrar Medina in colonial period, (b) Architect Michel Luyckx and architectural model of the historical hospital of Adrar

Challenges in Conservation and Reconversion

In rehabilitation or restoration work, restoring a building to its original state is a task fraught with difficulties, the main objective of restoration is to remove deformations and other damage caused by weathering, pollution, or human intervention. The restoration of a historical monument must use the same base or the same techniques that were implemented during the construction of the monument. If this is not possible, one has to admit the difference between new and old materials or methods.

The high cost per person using specialised equipment in the capture process, the intricacy of getting necessary tools that capture architectural details surgically applied to match whole works, complex sites where access is extremely restricted or relatively far from main working centres, detecting remote spots abroad are examples of technological and infrastructural limitations. Overcoming these limitations is essential to ensure the triumph and enhancing extent of digitization projects for heritage buildings.

Physical Deterioration and Structural Issues

The causes of the different damages are related to environmental, human, and construction problems. The typological and mechanical strengths of traditional materials are not able to withstand the vagaries of nature. These, in addition to poor quality repair and maintenance techniques, inappropriate use, and even vandalism, make the buildings unsuitable for future use. It is essential to consider a set of factors to evaluate the capacity of earthen walls composed of different types of blocks. These variables depend mainly on the number and brick composition, the grouting method, the effect of water, the rupture of the three stages, and the compressive and tensile strength values. The junction of the blocks of a partition wall will improve the masonry resistance.

The study of the hospital showed a lot of wear to all structural components (masonry, roof, and floors) and architectural elements (doors, windows, and arches in the main courtyard). The severity and extent of the different types of damage depend mainly on the type and use of the spaces, and the strong effect of environmental and human violence. This shows the importance of decomposition and diagonal fractures related to the compression-traction force. Inside the building, the joint floors have lost their original resistance due to the collapse of the vault which led to a complete and partial collapse of the spaces used. Figure 3 gives some parts of the structure that are deteriorated. Figure 4 gives some parts of the structure that are recoverable.

Figure 3: Deteriorated parts of the historical hospital of Adrar

Figure 4: Recoverable parts of the historical hospital of Adrar

Material and Methods

Digital heritage building conservation entails a host of methods to save, and document ancient structures for generations. 3D survey is a key tool that allows for the production of precise digital models of buildings, right down to an impressive level of detail including sizes. Another important method is Photogrammetry, to generate precise 3D models of cultural heritage sites by photographs (Murtiyoso, A., Grussenmeyer, P. 2019). HBIM (Historical Building Information Modeling), Agi Soft Meta Shape and Sketch Lab are used for measuring and managing all data referring to the construction and maintenance of a structure (Khan et al. 2022, Croce et al. 2021). Also, Virtual Reality (VR) and Augmented Reality (AR) technologies (Gaugne R., Barreau J. B. 2022) are used to create an immersive exploration with buildings and digital techniques to let users manually touch the heritage (Figure 5). Utilising those techniques is of the essence when it comes to saving, and promoting our heritage, that future generations are able to witness all architectural treasure built over centuries. Integrating the building into a navigable application implies adding some display and interaction tools in the model to allow the visitor to observe the main parts behind a transparent surface, read and listen to some attached stories, and take some objects as pictures. To reach these final objectives, it is mandatory to choose the optimal equipment and technologies, sort and process the acquired data until obtaining the final navigable application. The digitization process implies mainly a 3D scanning stage followed by a 3D model creation stage. However, when a detailed reconstruction is needed, other stages of processing and adding of some components are implied.

Figure 5: Lasergrammetry, photogrammetry, drones and VR tools of digitization

Data collection phase is crucial and extremely important, since it provides the basis for the other steps in the study. Data such as buildings' shape, geometry, measurements are necessary for the conservation and conversion project. In this step, the whole physical details of the existing hospital building such as storey height, plan and so on need to be collected for the documentation and conservation for later analysis, as the data can be utilised for the following stages such as surveying, monitoring, modelling, and visualisation. Information should include architectural and historical relevant data; i.e. floorplan, elevations, sections, doors, windows, railings, floors, stairs, etc. It is also necessary to review old documents such as past research and conservation archives. This research has

collected a large amount of data in relation to the historical hospital of Adrar Medina. These data need to be digitised, cataloged, and organised in order to provide for the documentation and conservation needs. It is also needed to visualise the old site maps, drawings, architectural sketching, historical photographs, restoration archives, and research reports from the National Archives. Its collection and recording is a prerequisite activity for the design of the digital application.

The visualisations allowed illustrating the work and facilitating the process of presenting it. Digitization serves to keep safely the original values of architectural elements, reconstructing them where these are deteriorated or absent from previous compositions. On the other hand, in the configuration and representation of the architectural space, it involves the reconstruction of the spaces in plan, elevation, and volume through digital modelling. In general, the walls of the hospital are old and intend to collapse over time if the necessary interventions are not carried out.

Results and discussion

The aim of the study is to present the case of the Historical hospital of Adrar Medina, and emphasise the importance of digitised architectural documentation, high-resolution 3D modelling, and its role in restoration. Firstly, the hospital building is explored and surveyed using a photo survey of the hospital's current state. The main facades of the Hospital were selected for a rectified image supplied by drawing. The obtained geometrical documentation created a three-dimensional model that respected the architectural elements through detailed manual editing, carefully fitted to the stacked image supplied by the draft. In a further CAD program, the texture obtained from the stacked draft image was fixed according to the coordinate system obtained from the facades using ArcGIS.

According to the AutoCAD plans, the hospital's layout includes a grand main entrance featuring arched doorways leading to a spacious reception area. Patient wards are designed with windows and high ceilings to ensure proper ventilation and natural light, essential for comfort in the desert climate. Administrative offices are strategically positioned near the main entrance for operational efficiency. Service areas, including kitchens, laundries, and storage spaces, are typically situated at the rear or in the basement, optimising functional workflows (Figure 6a).

The hospital's verandas and colonnades, characteristic of colonial architecture, provide shaded walkways and outdoor spaces for patients and staff, enhancing the building's usability and aesthetic appeal. Structural details in the AutoCAD plans highlight the extensive use of wall coverings with waterproof materials such as lime and tafza, ensuring the building's durability and longevity. Decorative elements such as intricate lattice work on arched windows, detailed moldings around doors and windows, and ornate facades reflect a blend of Islamic and European influences, showcasing the cultural integration in the design. This shows the architectural mix of Sudanese, Arab-Berber and colonial styles. It examines the architectural and potential elements (bordj, arkiza, benches, chorrifat, sunshades, awnings, arcades, rahba, zkak, skifa, entrances, doors, enclosures) and the potentialities (Fogarra, seguia, oases, mausoleums, mosques, zaouïas). It opens up prospects for the 3D digitization of this Saharan built heritage, requiring public-private partnerships and strengthening local capacities, while respecting cultures. This digital heritage approach could be extended to other regions. Figure 6b shows the original plan (left) and the current plan (right) with some parts that have collapsed over time.

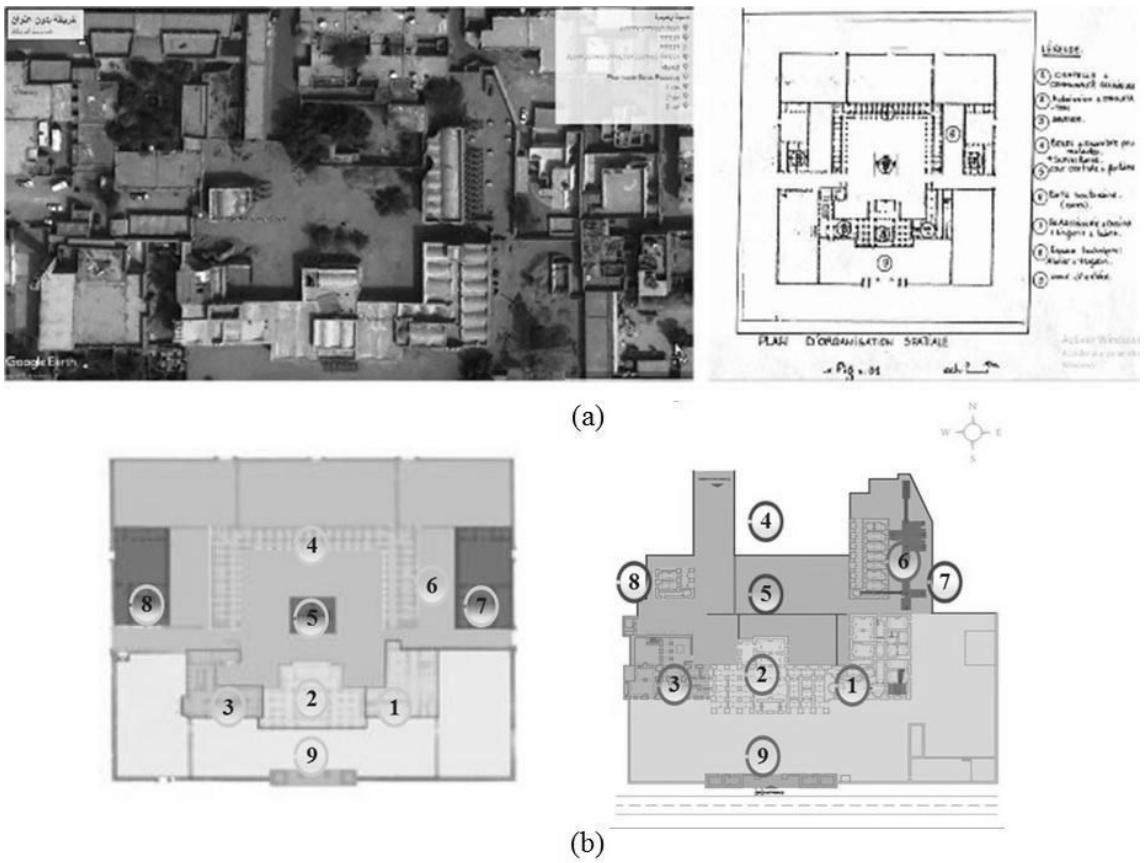

Figure 6: (a) Initial plan and (b) Current plan with different parts:
1-Chappelle and Religious Community 2-Admission 3-Emergency 4-Sick Room and Surveillance 5-Central Court and Fountain 6-Basement (caves) 7-Service areas 8-Technical premises 9-Entrance Courtyard

The plans also identify areas of deterioration, including weathered roofing, spalling concrete, and eroded decorative elements due to the harsh desert environment. Proposed restoration methods include modern techniques to repair and reinforce the roof, treat and protect concrete structures, and meticulously restore decorative features using traditional craftsmanship combined with contemporary materials. These restoration efforts aim to preserve the hospital's original aesthetics and functionality, ensuring it continues to serve as a cultural and historical landmark in Adrar.

The restoration of the Historical Hospital of Adrar into a manuscripts museum is a transformative endeavour that has meticulously preserved its architectural grandeur while repurposing it for a new cultural role. The restoration process involved a comprehensive approach, addressing both structural integrity and historical authenticity. Structural elements such as the roof, walls, and foundations underwent thorough repairs and reinforcements to ensure stability and longevity. Architectural features, including the characteristic arched windows, intricate lattice work, and ornamental facades, were restored to their original splendour, preserving the building's colonial charm.

Internally, the hospital's spacious rooms and corridors were thoughtfully adapted to house the museum's extensive collection of manuscripts and historical documents (khizanat of the ksours of Touat). The manuscripts of the Touat region represent more than half of the manuscripts of the entire country. Each exhibit space was carefully curated to showcase the region's rich literary and scholarly heritage, providing visitors with immersive experiences that illuminate the cultural significance of the artifacts on display. Interactive displays, multimedia presentations, and educational programs further enrich the visitor experience, fostering a deeper understanding and appreciation of the manuscripts' historical context and cultural significance. Figure 7 gives the 2D/3D drawings for the reconversion project into a manuscript museum (Merabti et al. 2011).

The museum's transformation extends beyond its physical space, serving as a dynamic hub for cultural exchange and community engagement. It hosts a diverse range of events, including lectures, workshops, and performances, that bring together scholars, artists, and the public to explore and celebrate the region's cultural heritage. The museum's serene courtyards and landscaped gardens offer inviting spaces for relaxation and contemplation, enhancing the overall visitor experience and fostering a sense of connection to the past. In essence, the restoration of the Historical Hospital of Adrar into a manuscripts museum represents a harmonious blend of

architectural preservation and cultural revitalization. It honours the building's storied history while re-imagining its future as a vibrant centre for cultural discovery and exploration.

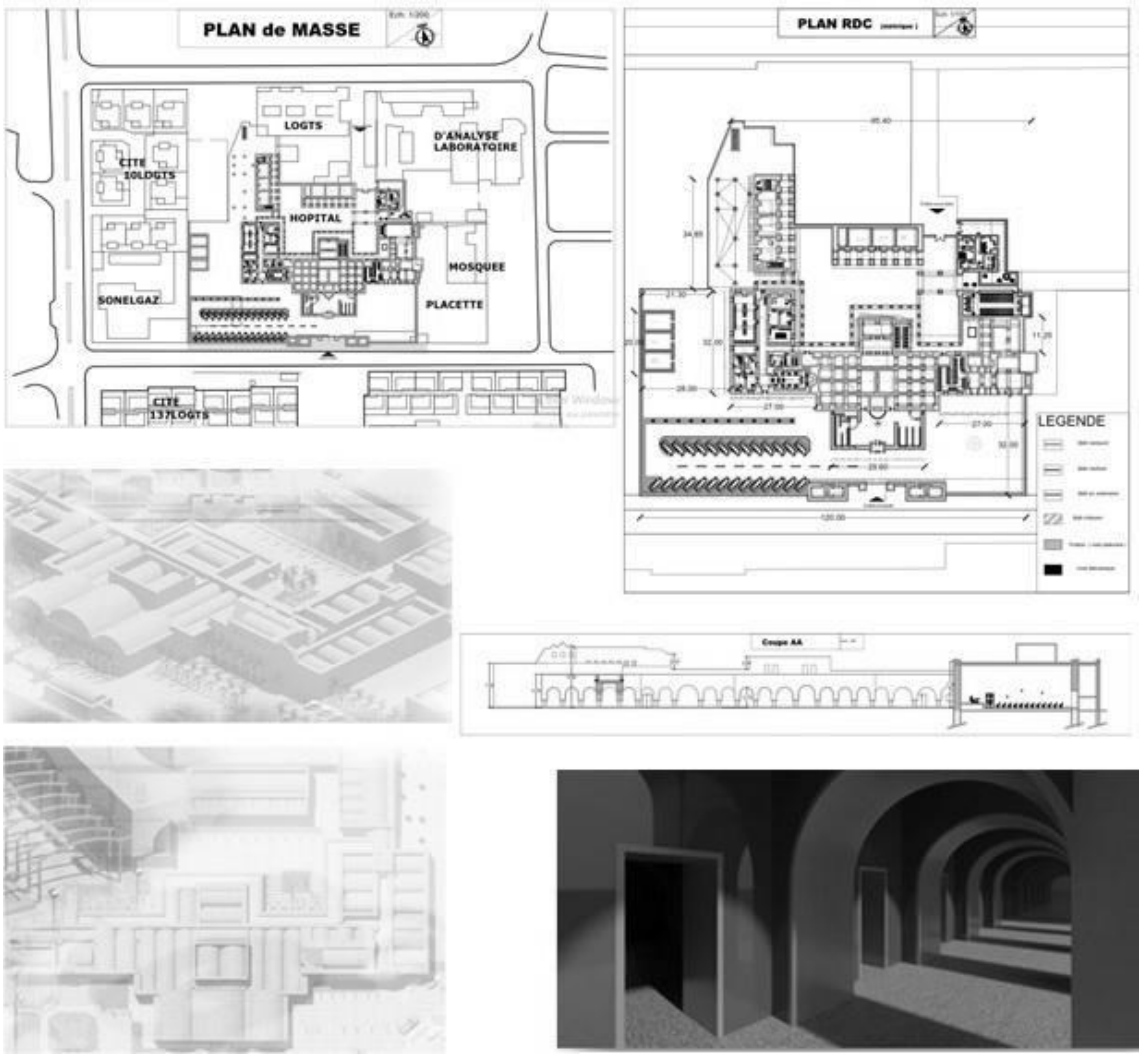

Figure 7: 2D/3D drawings for the reconversion project into a manuscript museum

The Historical Hospital of Adrar, nestled within its historical environment, is surrounded by a landscape rich in cultural heritage and natural beauty. Situated amidst the arid desert terrain of southern Algeria, the hospital is characterised by its tranquil setting and panoramic vistas toward the ksours and the oasis. The main routes around the hospital lead through streets lined with traditional adobe dwellings, offering glimpses of everyday life in the vibrant local community with an easy accessibility from the placeta of Adrar. These routes serve as arteries connecting the hospital to the heart of the city, bustling with activity and the rhythmic pulse of daily routines.

Beyond the immediate vicinity, the hospital is enveloped by the vast expanse of the desert, where rolling dunes and rugged terrain stretch as far as the eye can see. The harsh yet mesmerising landscape provides a dramatic backdrop to the hospital's historical significance, serving as a constant reminder of the challenges faced by early settlers and the resilience of the local population. Travellers along these routes are treated to an inspiring vistas of endless horizons, where the boundless sky meets the undulating sands in a timeless embrace.

Figure 8 shows maps of Adrar Medina development using ArcGIS. Maps 2 and 5 show the location of the historical hospital in the centre of Adrar Medina and its urban development, starting from Ksours to the current state of the city in the new urban neighbourhoods of Tililan and Sidi Mohamed Belkabir. We note that the historical hospital has an important location with a high proportion of the population, which poses a danger to it from theft and vandalism. On the other hand, it can become a centre for incoming visitors if it is restored, revived, and resurrected with a sustainable function for future generations. Maps 3 and 4 show the roads of the city of Adrar and the Foqara paths as a main landmark.

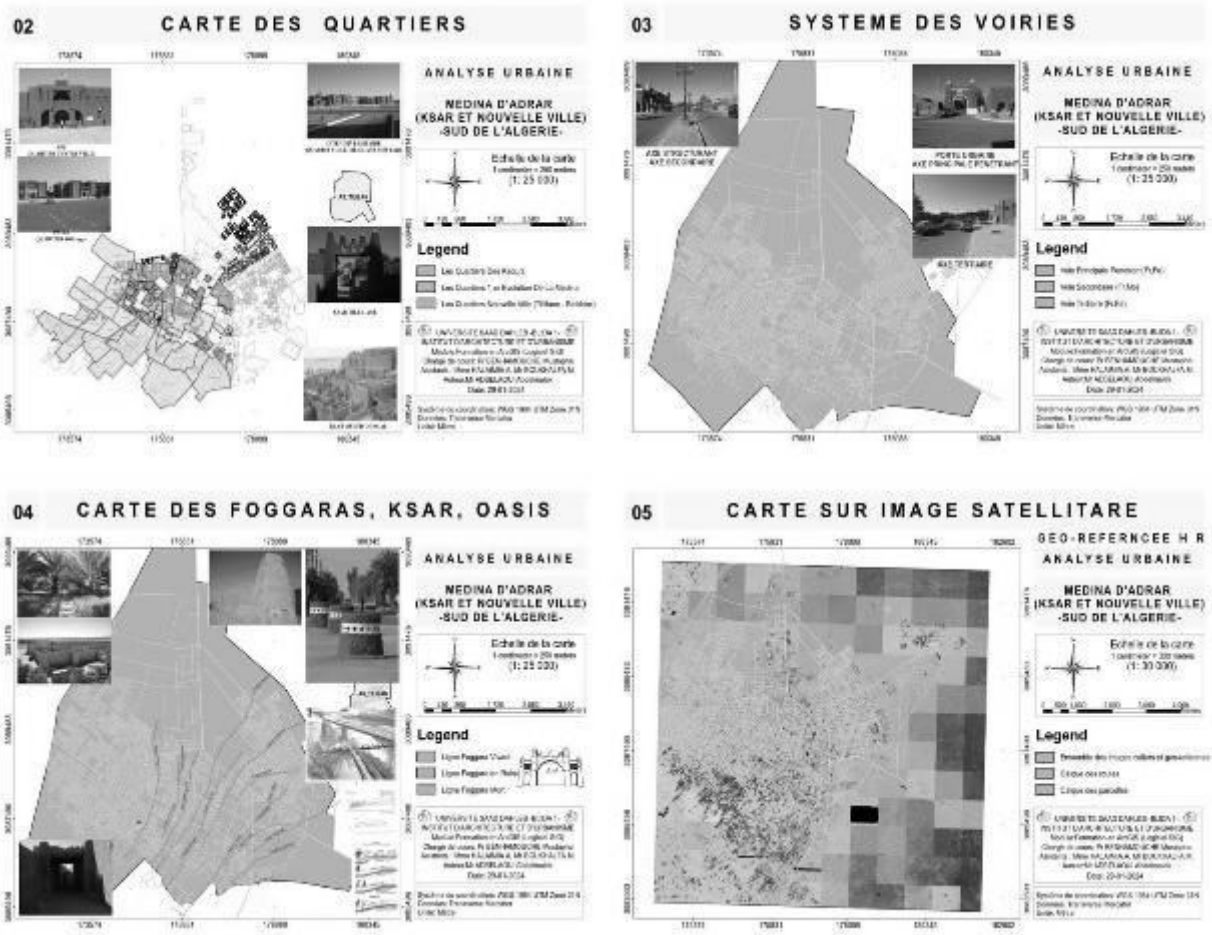

Figure 8: Maps of Adrar Medina developed by authors using ArcGIS

Conclusion

In this paper, in order to study the conservation and reconstruction of the historical hospital of Adrar, we had to study the whole architecture of the region of Adrar in terms of the different architectural styles that has influenced this architecture over time. After this step, we have done the survey of currents photos to determine endangered and recoverables parts of the building. With this data, we have draw the 2D/3D AutoCAD plans of the current state of the building, and how to convert it to a manuscript museum.

Classic methods of heritage conservation are insufficient in the face of degradation for specialists in structural diagnosis. Digitization is a solution to safeguard architectural and urban heritage. It uses various tools and software such as: 3D AutoCAD survey, lasergrammetry, photogrammetry, 3D drones, point clouds, HBIM, Agi Soft, Meta Shape or Sketch Fab. New immersive technologies such as virtual, augmented, mixed or extended reality allow the promotion of the heritage building via 360° videos, audio headsets, touch screens, smartphones, projection mapping, holograms and 3D printing. These technologies are used for documentation of the heritage buildings in museums, libraries and archives.

In the end, our paper confronts three objectives. Firstly, the mission of preserving built heritage through the dissemination and sharing of their architectural characteristics and challenges. Secondly, illustrating digitization enriches the preservation of built heritage through reproduction and restitution. Thirdly, the valorization and promotion of the heritage building in a protocol of sustainable tourism strategy in Adrar, either in-person or online.

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Conflict of Interests

The author declares no conflict of interest.

Glossary of Ancestral Words

Ksar: (architectural potential): It is the place of habitation of the Saharan people
Rahba: Collective gathering space in the Ksar
Zekak: Traffic route in the Ksar
Wast dar: Central meeting space in the Ksourien house
Rekiza: Architectural Element retaining wall of the Ksar surrounding wall
Tafza: Type of earth stronger than clay and waterproof
Jnan: (natural potential): it is the Oasis of Saharan agriculture
Khachba: Trunc of Palm
Madjen: Storage space for irrigation water
Gammon: Vegetation space in Jnan
Afreg: Enclosure surround protects Jnan
Foggara (water potential): The only water source supplying Ksar and Jnan classified by UNESCO in 2018
Hassi Nzoul: This is the main descent well for the maintenance of Foggara
Anfad: It is the passage of water underground between the Foggara wells
Aghisrou: It is the water passage on land linking the Foggara line to Kassriya
Kassriya: Foggara water distribution area towards the Seguias
Seguia: Foggara water distribution area towards Jnan

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