(H-BIM IA) Historic Building Information Modelling and Artificial Intelligence as a methodology for the conservation of architectural heritage on land, the case of Khenguet Sidi Nadji city

(H-BIM IA) Modelação de Informação de Edifícios Históricos e Inteligência Artificial como metodologia para a conservação do património arquitectónico terrestre, o caso da cidade de Khenguet Sidi Nadji

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ABSTRACT
The architectural heritage built on land in Algeria extends over a large part of its territory and is one of its greatest assets, both locally and internationally. The conservation of this heritage is a highly complex civic and political challenge. The research carried out experiments with an unprecedented methodology, (H-BIM IA) Historic Building Information Modeling and Artificial Intelligence on a specific case study, the city of Khenget sidi Nadji founded in 1602, which over time has given us a capital city rich in architectural value, social relations, and an example of religious and cultural links. For a year, the authorities carried out a programme to improve
the rural habitat in a territory far from the old fabric, EL BORDJ, and organised a population displacement. This programme has revolutionised all the architectural, social, and typological values of the old fabric. The aim of the research has been to document the state of conservation of the city and to establish a medotology that allows the incorporation of extensive and rigorous information for its enhancement and subsequent analysis. The project carried out with BIM is enriched with historical, architectural, sociological, and material data, as well as data on the state of conservation and compliance with the Sustainable Development Goals (SDGs). This reliable information is used by the AI for political and citizen management of cultural heritage.

**Keywords:** earthen architecture, sustainability, reuse, restoration, conservation policies, vernacular heritage, BIM.

### 1 INTRODUCTION

Khenget Sidi Nadji, a town founded in 1602 in the Algerian hinterland, is a capital rich in architectural value, in social relations and an example of religious and cultural links. A high place of Makhtout and jasmine production, the inhabited territory was a continuation of the palm grove, a place of agricultural production and survival in this mountainous country.
What are the forms of intervention for safeguarding? How is the adequacy between the policy of responsibility and reality constituted? Finally, how is the future of the site being constructed today, considering the different tools for appropriate public intervention.

This complex and rich heritage has been the subject of special attention by the public authorities over the last ten years, with operations of classification and subsequent rehabilitation of the main buildings.

For a year, a rural habitat improvement programme was carried out on a site far from the old EL BORDJ fabric and a population displacement was organized. This programme has revolutionised all the architectural, social, and typological values of the old fabric. Unfortunately, this phenomenon occurs throughout Algeria, but in the case of El Khenguet it is accompanied de facto by the pure and simple abandonment of the old site.

The architectural heritage built on the ground in Algeria extends over a large part of its territory and is one of its greatest assets, both locally and internationally. The conservation of this heritage is a highly complex civic and political challenge. The research has been carried out with an unprecedented methodology, (H-BIM IA) Historical Building Information Modelling and Artificial Intelligence on a specific case study, the city of Khenguet Sidi Nadji founded in 1602, which over time has provided us with a city rich in architectural value, social relations, and an example of religious and cultural links. The BIM project is enriched with historical, architectural, sociological, and material data, as well as data on the state of conservation and compliance with the Sustainable Development Goals (SDGs). This reliable information is used by the AI for political and citizen management of cultural heritage.

The rural support project is seen as a turning point in the abandonment of the khenguet Sidi Nadji – the old city – and the real cause of the demographic transition to the new city. In 2005, the authorities launched a development project that aimed to support citizens wishing to build rural housing by providing land in the area known as La Torre (the military airport during the colonial era), located 1.5 km from the old town, on national route 83, which links the wilaya of Biskra with the wilaya of Khenshla. This displacement, however, entailed a total abandonment of the old settlement and the formation of a settlement inhabited according to urban
planning criteria and norms that were alien to local customs and traditions. This is what we have been able to verify during our field trips and to observe the way of life, as well as the attempts to adapt the new dwellings to the needs of the inhabitants' daily life.

Taking Khenguet Sidi Nadji as a field of observation, study and experimentation, the aim of this work is to document and highlight the potential of an architectural heritage on the ground that is complex in its evolution, particularly in the face of the different forms of intervention by the public authorities.

The site has been analysed, in its unity and its globality, to show the richness, the links and the coherence that exist between the different components, a global coherence that has been maintained for centuries.

Photo 1: General view on the khenguat,

Source: Author

Khenguet Sidi Nadji – throughout history – was an area of scientific affluence, known as a stronghold of culture and the spread of science throughout Algeria since the 11th century A.H., corresponding to AD 17. The foundations of this city were built by Sidi Nadji al-Mubarak and his sons after they benefited from the geographical location given to them after their displacement from the occupation tower in Tunisia.

The origins of the family of Sidi Nadji – founder of the Khenga – go back to the third caliphs well guided 'Othman Ibn Afan', they lived in Damascus (Syria), left for Egypt, then to Tripoli (Libya) and so to Tunisia. They accompanied Abderrahmane the third to Andalusia and then to Al- Dreiat in Morocco
The mosque was the first building established by Sidi Lembarek Benadji and his descendents in the region, located below the AL-ARAB valley.

Al-Khanga is derived from its geographical location (its literal translation means the furrows), referring to the narrow and confined place. In addition, it is one of the foundations and foundation forms of desert cities and castles. Their choice of location depends on water exuberance, and is in order to cover the needs of feeding the population, agricultural fields and orchards, as well as livestock breeding. Protection against natural hazards is also considered one of the main factors in the choice of location, which explains why the Khenga take refuge in the mountains and use it as protection against military attacks and tornadoes well known in the region.
In addition, a Koranic school had been built next to the mosque, after its completion, where the Islamic character was adopted as an architectural style, embodied in conquests and geometric forms, taking into account measures and sizes in accordance with the desert climate. The building was built in accordance with the possibilities and techniques available at the time. As for the structural system and pillars, a system of load-bearing walls was followed in accordance with the construction materials used and the techniques available at the time. It was used in laying the foundations and basements of the mosque and the school stones recovered from the adjacent valley and these foundations protect the building rules in case of rain or flooding, the depth of the foundations was between 70 cm and 120 cm. The height of the foundation was between 70 cm and 120 cm, and the height was the same.

We then mixed the adobe load-bearing walls with grass and dried them in the sun, and between these walls there are tree branches, for stability. As for the hollows, the arch and the dome were the predominant system, it is based on the canons of palm trees pricked in the valley for weeks to saturate them with water and then pass them to fire so that they become more cohesive and resistant to moisture and thermal range of the area in the position of the roof.

During our study of the structural system of the mosque, we were struck by the presence of the stability control system of the building, which is the same system observed in the Zeytouna Mosque in Tunisia, composed of two columns under the Mihrab (Altar), as the stability of the building can be controlled by the possibility of rotating these columns. According to manuscripts found at the site, an earthquake in 1793 AD caused the columns to stop rotating, and officials at El-Khenga installed wooden belts across the building from one end to the other to maintain the stability of the structure.
Ahmed Ben, Sidi Nagy, was the master after the death of his father and son, after which he took over the affairs of El-khenga after his death in a battle against Shabi. Sidi Mohammad Al- Tayyeb Bin Lambark worked in:

- reconstructing the area by activating construction in its designated areas, allocating agricultural areas, and investing in the agricultural field by bringing water and providing irrigation systems, creating oasis of palm trees and some types of productive trees as a flourishing agricultural activity by raising livestock along with trade. activity of the region;

- encourage the preservation and participation of teachers to publish the various sciences: memorisation of the Koran, language teaching and the origins of religion.

The urban and architectural style in the Sidi Nadjii khenga is very much aligned with the needs of the citizens and climate of the area, where we feel the
vernacular architecture, which is result of the customs and traditions of the people of the region, and for the family house, it is the result of the needs of the population. We feel the close layout, the practical space of each space and the complete separation of the private and outdoor spaces, where we see a gradual transition from the public to the private until we reach the living room, which is the place of the small family.

2 MATERIALS AND METHODS

The object of the research work is the town of Khenguet Sidi Nadji, where detailed fieldwork has been carried out during 8 expeditions over the last 3 years to collect data that has allowed us to know the state of conservation of the urban fabric and the buildings built with earth in the 17th century.

The methodology used in the research followed the following steps:

- documentary research of historical data;
- fieldwork for the collection of urban, architectural and sociological data.
- use of BIM methodology to document historical heritage;
- use of BIM methodology to integrate sociological and architectural information through an extractable database;
- use of BIM methodology for the development of the Sustainable Development Goals (SDGs);
- historical record of the constructive exponent (former hotel...);
- architectural specifications, pathologies – state of conservation;
- sociological sheet;
- ods fiche.

All the information will be analysed by the AI to make decisions for the conservation and enhancement of the city and each of its constructive exponents...).

3 RESULTS

The following results of the fieldwork were obtained.

Conservation status, fieldwork If we look at the fine houses in the town with pure local materials, starting with the restored circular stone bases of the Wadi al-Arab, adjacent to El-khenga. To the load-bearing walls of the mudguards, which
are dried in the sun by the artisan hands of the fathers, mixing earth with gir to smooth the mixture and grass to give them greater stability. The mixture is soaked in water for a week, and the sky units are saturated with water, then poured into wooden blocks to give them a regular shape, and finally left to dry.

Finally, for roofing, palm and caletos are used as fiducials to carry the roofs of the house with a functional roof, or with floors. Before the application of the logs, they are also kept in the valley water until they are saturated with water, which also makes them more resistant to humidity and climatic factors.
The stability of the walls is controlled by giving them a thickness proportional to their height on the one hand and by adding branches at specific heights and distances depending on the length of the wall on the other hand.

On entering the house, we see a foyer that separates the street from the heart of the house, a room two and a half metres high, often one and a half metres wide, one of its walls has a small window that allows the parents of the home to meet the visitor without revealing the living room. At the same time, it is a place to receive guests and direct the visitor to the public guest room or living room.

After this two-door room, which in turn opens onto a Outdoor courtyard this space guarantees the natural lighting of the house as the living space and the daily breathing space of women where they will incorporate with satisfaction their daily concerns without having to wear veil. A versatile place where the family gathers to exchange modern and fragrant feasts as well as for events, it is the place where all parts of the house, the kitchen is a living room overlooking the hall and is equipped with a smoker for stewing wood. burning cookers (kannon). A place for storage of ionised (ungrounded) with a wooden deck, part of which is below ground level to maintain a suitable temperature and avoid damage to foodstuffs.

The bedrooms are also surrounded by the hallway, where all windows face this hallway because the outer walls have no windows to keep the house intact and to give the room a more airy feel with small holes above the door ensuring that the warm air that rises naturally above is released. Ensure ventilation if the door and the main window of the room are closed.

For livestock and oases, they are left in the basement or at the side of the house and local residents explain the location of the livestock on the floor.

The lower floor, ensuring that the house is heated during the winter.
Urbanism in El-khenga is a harmonious and integrated fabric with the location of a rugged terrain and in a difficult strait between two mountains with a degree of more than 20 percent of the narrow, winding streets of the city are the result of the city’s proximity to the houses to break the sun's rays and reduce their contact with the facades of the houses. The city's narrow, winding streets are the result of the proximity of the dwellings to break the sun's rays and reduce their contact with the facades of the dwellings, thus ensuring moderate temperatures inside the dwelling, and the terrain is an important part of the city's corridors, length and length. To slow the decline and facilitate the movement of people and commercial vehicles within Madya, its times are characterised by its shortening and receding, the latter linking us to various public squares and meeting places. Parallel to the mosques, the most important monuments of the city, the houses of the Qamonu and the hotels that have spread since the Ottoman civilisation, known as Dar Al Saraya.

The area of the former core was incorporated into the ordinance and classification of archaeological and natural sites according to order No. 67-281 of 20 December 1967 and was published in the Official Gazette on 23 January 1968, No. 07 these sites included in the classification are:

The village of Khenget Sidi Nagi, then Khanshla, on 30/01/1968; It also contains spaces, especially the traditional urban fabric of the Eastern Province, which is available to individuals, and has the right to use them, but maintaining its own architectural and engineering features, knowing that all its residential buildings are deserted, and this has adversely affected its nature.

In addition to the various monuments of history that exist and are affected by the radiation and civilisation of the inhabitants of the region, there are:

The Sidi Lembarek Mosque on the western side has been restored in the same position and form, retained its characteristics, and continues to play its religious and educational role.
The Sidi Abdul Hafiz Al-Khenegui Mosque, which was covered by the same operation as the Lambark Mosque.

Take, for example, the Hasbies Palace on the west side, parallel to the Sidi Mubarak Mosque, which suffers from deterioration and is a radiant feature of the area.

The colonial prison that bears witness to colonial brutality has become an abhorrent place and parts of it have been destroyed

3.1 RESULTS OF BIM APPLIED TO KHENGUET SIDI NADJI
"BIM is a digital representation of the physical and functional characteristics of a building. As such, it serves as a shared knowledge resource for information about a building, forming a reliable basis for decisions during its life cycle from inception onward"

The key principal is that BIM is not any single act or process. It is not creating a 3D model in isolation from others or utilising computer-based fabrication. It is being aware of the information needs of others as you undertake your part of the process.

A BIM model can contain information/data on design, construction, logistics, operation, maintenance, budgets, schedules and much more. The information contained within BIM enables richer analysis than traditional processes. Information created in one phase can be passed to the next for further development and reuse.


More generally, the idea that we want to implement and that we believe is already essential, is that BIM is already a recurrent practice in all architecture and urban planning projects for the integration of parametric information within the
same architectural model, so that a complex and interoperable database is created between different professional figures.

The objective of a project with H-BIM methodology – Historic Building information modelling goes beyond the simple parameterisation in architecture, if it does not carry out a recovery of historical, sociological and pathological information on the building, so that it never loses value and can be analysed and facilitated in the future for future recovery interventions.

The term HBIM (acronym for Heritage or Historic Building History) refers to a new approach to the modelling of historic buildings, which aims to develop BIM models from remote data through photogrammetry or laser scanning.

The aim of the project "BIM methodology and surveying at the service of traditional architectures" carried out between the Polytechnic of Bari (Italy) and the University of Alicante has been to demonstrate that, with few technological means such as a camera and a laptop, it is possible to carry out a modelling with photogrammetric methodology to analyse and develop an intervention project on a historic building.

One of the virtues of platforms based on the BIM methodology is that all this information can be available in a single file (parametric model), regardless of the type it belongs to. The main source of geometric-descriptive information for H-BIM modelling, or Historic Building Information Modelling, is photogrammetric modelling.

At the same time it has to be taken into account that the modelling and parameterisation of the model must be based on two fully interrelated components, assuming CAD information as a principle and the transmission of this information to BIM information as a goal.

Our case study aims to reproduce heritage architecture by means of informative geometric (parametric) digital modelling, in which traditional information (traditional direct survey) and digital information (indirect survey) can and must be added.

The architectural survey campaign will certainly change over time, becoming more and more an indirect data collection campaign. In many cases, in fact, it is actually dangerous to carry out surveys because of the deterioration of the property, and in others it is equally cramped and uncomfortable where there are places that are almost inaccessible or with little room for manoeuvre.
The Medina of Khenguet Sidi Nadji is an emblematic case in this respect because difficulties of manoeuvre, problems of excessive degradation of the building (for example, our study in the Medersa) and inaccessibility in some particular cases can be encountered.

Characterised by narrow streets and poorly lit premises, we have been able to appreciate that the hybrid workflow is still necessary to carry out a quality survey, with the possibility of being able to use the photogrammetric point cloud over the following months and in fully featured environments in Khenguet Sidi Nadji. This is one of the added values of this new methodology: being able to take advantage of a realistic photographic model in all its measurements without having to rework the site. All of this allows for improved collaboration and interoperability between people, countries and work teams that are physically and temporarily disconnected from each other.

The idea of implementing a BIM model for such a specific and rigorous fieldwork was born out of the necessity that Khenguet Sidi Nadji does not present any written or audiovisual infographic information. A city of such historical value and which preserves so much constructive information cannot be left in a state of cultural abandonment, without anyone trying to trace its history, its construction techniques, and its main characteristics.

BIM modelling therefore offers a concrete option to summarise all the information that, as architects, we want to ensure that it is not lost over time, and that it can be improved and updated throughout its life.

In order to achieve an adequate level of information, it was essential to decide at what level of detail (LOD – Level Of Development) to work.
LODs have been introduced in order to define what and how much knowledge should be included in the project in relation to life cycle, planning, construction and future maintenance activities. Therefore, they are intended to be a measure of the reliability of the project information on the individual element, which can then be used by different professionals. In the case of restoration and renovation, the information of the current state model (as is) has to respect certain parameters which, in the case of the Khenguet Sidi Nadji project, have been set as standard LOD350 according to the Building Smart Spain table.

LOD350 – Model elements with this level of development differ from the previous LOD350 in that they can also be integrated with Relationship Parameters with other sets of project elements. The real digital revolution, given by the "I" of Information, is given by the quality of the data entered and modelled, and not by the quantity of data.

To date, there is no pre-existing BIM projects in Algeria, which does not allow us to use a national standard or a standard that would be consistent with the place where we propose this project. However, we believe that the Building Smart classification can be applied worldwide in the absence of local standards.

We will then start working on BIM with reference to existing case studies, which are implemented on the basis of a remotely sensed database, i.e. based on a point cloud. Both solutions, both focomo laser scanner, are valid to be able to carry out a field work of the current state relief to then be able to import it into a BIM model.

In this specific case the work has been carried out by laser scanner due to the specific condition of the hotel under study, which has been restored a few years ago with a construction technique totally different from the original one.

The idea of being able to analyse all its pathologies and the stratigraphy of the architectural and constructive interventions is an important basis to be able to carry out a HBIM work with certain results, especially in the field of conservation of the immovable heritage.

"The restoration constitutes the methodological moment of the recognition of the work of art, in its physical consistency and in its double aesthetic and historical polarity, in view of its transmission to the future. [...] The physical consistency of the work must necessarily take precedence, because it represents
the very place of the manifestation of the image, ensures the transmission of the image to the future, and therefore guarantees its reception in human consciousness". (Brandi, 1977)

As Cesare Brandi rightly explains, the transmission of an architecture to the future comes from the combination of historical and aesthetic conservation, which puts us in a condition of wanting to pass on to future generations all the information that the building itself can contain and tell us.

Very important for an architect are the physical characteristics and the state of preservation of the building, which without much mystery can show us all its battles and transformations over time.

So that this information is not lost and above all so that it can be analysed without too many complications in the future, it has been decided to make a decoding and subsequent study of the pathologies present in the building, based on physical tastings, visual and tactile analysis and conversations with local people.

Being able to model everything in a single parameter file, it has been decided to create different shared parameters in which all the information previously studied on each single pathology is summarised and schematised.

Thanks to these tools that BIM offers, we can affirm that creating a database in which all the information about the building under study is present is the key and the path to follow if we want to digitise and safeguard everything that respects traditional architecture and its construction techniques.

In addition to the introduction of the various parameters in the model, and in order to create a methodological database for a search of the pathologies present in the individual elements, a mapping of the degradation of the façade surfaces is carried out with the ultimate aim of identifying effective intervention proposals for the case under study and with respect to the traditional techniques that have been implemented over the centuries.

This condition whereby we can check the BIM model and change or update the information at any time during the life cycle of the building allows us to work on it by phases of life, which simplifies the study and the consequent extraction of data.

This also allows us to analyse in a historical-pathological context the specific development of the materials and gives us the opportunity to confront the diagnostic pathological picture in different historical epochs and with different technical.
With the idea of digitalization and the preservation of a database of historic buildings, a much broader study of the entire Medina of Khenguet Sidi Nadji can be carried out.

The creation of a DNI for the identification of a historic building has to be a starting point to leave more complete and complex information to future architects, and thus can be of great importance for all the buildings that we are interested in protecting, creating a digital BIM catalogue.

3.2 BIM IN THE MEDINA OF KHENGUET SIDI NADJI

Despite the socio-cultural difficulties and logistical problems that one can encounter when carrying out this type of work, it is very useful, from the point of view of preserving assets of high cultural value and that have a historical-constructive traceability, to convert current knowledge (printed, visual, orally transmitted) into digital knowledge, through the H-BIM methodology.

However, the objective of H-BIM modelling and management is not so much the realisation of an emergency intervention, but rather the actual future restoration of the artefact from the "as damaged" state to an "as build" state, with appropriate evaluations.

Therefore, in order to build the "cadastre of the future" it is necessary to start a "cultural revolution" involving the use of BIM models not as a simple graphical representation, but as a real database that can/should be used in an interoperable way between different users.

4 CONCLUSIONS

4.1 ON AI AND THE MANAGEMENT OF BUILT HERITAGE

In conclusion, the indirect survey campaign is much faster, requires less human resources and can certainly be more easily transferred to other users, and contains a much more developed amount of visual and geometric detail.

The processing and collation of the data collected and obtained by the various programmers is a very useful tool through the "point cloud" thus involves the generation of a photogrammetric model, which is followed by a parametric model, and from which tables, graphs, object libraries, energy information, sustainability studies and much more can then be extracted.
All this information makes it possible to catalogue and analyse each modelled component individually according to its real characteristics, generating an as-is model, which in the case of Heritage Building is an as-damaged model, paying special attention to the 'I' of the BIM, that is, all the diagnostic-pathological information that characterises that architecture at a specific historical moment in its life.

How does a parametric model and the restoration study that accompanies it differ from the traditional method, and what added value can it bring to the management of a historic building?

There are several ways to perform a conservative study of an architecture, and certainly each of them leads to the result of an improvement of the physical and structural conditions; however, the possibility of being able to perform the study within a single "house" and, as a consequence, being able to extrapolate all the information through a single tool, is an opportunity that a BIM designer can take advantage of.

The idea behind BIM is that any information is stored in a single file, and that this file is able to extrapolate data from projects in any of their phases, and at any time in their life cycle. In fact, the objective of an H-BIM project is not limited to the simple modelling and collection of information, but encompasses all phases of project management during all years of its life cycle, using the same virtual prototype.

This allows us to manage different phases of the same building, involving activities carried out during different years.
Here we propose a methodology and a codification of all the pathologies that can be found in a building in the Medina of Khenguet Sidi Nadji, in order to be able to manage the damage information with predefined and well-coded solutions.

It is clear that, in contexts such as Algeria, where craftsmanship and tradition are still very important in the world of construction due to the materials and construction techniques that are passed down from generation to generation, it is not enough to pigeonhole pathologies and standards. resolutions to carry out a restoration project that respects the tradition and originality of the environment.

The BIM model should be integrated with indigenous, endogenous, orally transmitted information of high historical value, reasoning in the form of direct information integrated with the geometric modelling, thus converting the mapping of façade pathologies and the informative catalogues on the state of the building into a univocal digital process.

The advantages of interacting with different actors in the construction or restoration process are in fact essential if one wants to involve tradition with innovation and any factor that characterises an architecture, and for this it is necessary to implement an interoperable process in two ways: the first concerns the possibility of exchanging data between different software and manufacturers through different digital formats (IFC-Industry Foundation Classes); the second concerns the communication between these actors, with the need to "speak the different languages" of each professional.

One of the achievements that can be obtained is to teach the modelling, and then the geometry and materiality of the houses, through virtual reality, thus being able to communicate with any professional and with anyone who is interested in learning about the project.

As a result, it is proposed to create a digital BIM catalogue of monuments and houses in the Medina of Khenguet Sidi Nadji, starting with the Sidi Nadji Mosque and the Seray Caravan in order to create a photogrammetric and photographic archive that can be integrated with the parametric BIM models and serve as a reference for future intervention projects.
In addition to the possibility of leaving a traceability of historic architecture protected by UNESCO as a World Heritage Site, it is a challenge that feeds the study of our heritage, our culture and our past.

To be carried away by the emotions and suggestions of the Medina of Khenguet Sidi Nadji is really simple, but to fall in love intimately studying its deepest part, analysing its heart of earth, stone and lime, is the added value that the White Dove leaves in everyone’s memory.

The hope of an architect, an engineer, a fireman, a student, who comes to work or simply to stroll through Khenguet Sidi Nadji, is content not to lose this historical heritage, to save the houses and streets from their inevitable physical destruction and structural deterioration; it is content to give life back to the houses, so that (social) life can continue in them.
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