HBIM- A Sustainable Approach for Heritage Buildings Restoration in Egypt

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Abstract. In fact, restoration field is considered the most difficult and complicated process in dealing with heritage buildings due to, the large number of several disciplines, restricted standards, exhausted efforts, large cost and limited & non diverse resources. The research analyses this new practice of using HBIM in the restoration field, then it introduces a suitable sustainable approach to be used in the upcoming restoration projects in Egypt. The author believes that using HBIM tools have a great advantage in getting sustainable heritage restoration actions. The research analyses the Baron Empain Palace in Heliopolis, Egypt as a case study in this context.

1. Introduction
Recently, HBIM has become a topic of great interest. On the other hand, sustainability is strongly given a significant emphasis within the global society. Historical buildings have already performed large percentage in the building industry sector, which; in turn; have an effective contribution on the sustainability standards. In some countries such as Egypt, heritage buildings present large number of unique masterpieces in the historical building context. It is believed that applying the recent potentials as well as the forthcoming applications of HBIM technology will play an important role in all heritage building conservation actions. The research concentrates on restoration as it is the most common action used in Egypt and is still rarely sustainably handled whether in Egypt or worldwide/ theoretically or practically.

In this field, the research discusses the sustainable restoration concept and Heritage Building Information Modelling (HBIM) potentials. Then, it traces the recent contributions and the ambitious participation of HBIM in enhancing sustainability in restoration actions. For the same purpose, the research chooses the Baron Empain Palace to analyze its trial in using HBIM in the ongoing restoration project. Besides, the research through its analytical study aims to find out the missing potentials of HBIM in achieving sustainable restoration actions.

Finally, the research proposes a sustainable approach to integrate the HBIM potentials in the whole process of the restoration action; beginning from surveying stage till operating and maintaining the heritage building. This approach not only targets the core aims of sustainability while restoring heritage buildings in Egypt, but also provides an approach to idealize sustainability returns for all similar cases all over the world.
2. Heritage Buildings Restoration and HBIM

Among the conservation actions “such as: refurbishment, rehabilitation, renovation, retrofitting, reuse and others” that preserve and deal with heritage buildings, Restoration is known as the most strict and difficult action. Extracting from its meaning, Oxford Dictionary explained that restoration in heritage buildings field means the action of returning the building to its original condition as well as preserving its former state [1]. Restoration process is also significantly identified by the very short sentence of (THE VENICE CHARTER, 1964), “Restoration process must stop at the point where conjectures begins” [2]. Practically, actions applied in restoration process must respect the significance, materials and techniques that already exist in such buildings [3]. In Egypt, restoration actions refer to the Egyptian law and authorities’ approvals and are applied under the restricted international classification.

2.1. BIM and HBIM

As mentioned before BIM receives worldwide acceptance. Its core that depend on diverse active sets, make it useful in many fields. It is also described and defined from different points of view, which implicitly reflect its benefits.

ARUP described Building Information Modelling (BIM) as an integrated model, that all its architectural, structural, and M&E components use the same database, and work interactively with each other [4]. Jankovic added that BIM not only plays an important role in the design stages till optimizing the design, but also has promising potentials at construction sites and managing buildings during their operation life as well [5]. According to Succar and Kassem BIM is considered a methodology that manages all the building information throughout its whole lifecycle in a digital format through four main sets (Human- Technology- Process- Policy) [6]. Also, from Issa point of view, BIM is a method to create, share, exchange and manage facility information throughout its lifecycle with the collaboration of all stakeholders [7].

Subsequent to this rising reputation and potentials of BIM - especially in the AEC industry field, HBIM evolves as a new BIM dimension targeting historical buildings. It is also meaningful to say that HBIM is the result of the significant development and wide spread of the new advanced digital surveying techniques [8]. HBIM synonyms namely refer to Heritage BIM, Historical BIM, BIM for Heritage, or BIM for Historical Buildings [9].

Several studies expect that BIM dimensions are going to multiply depending on the development of digital information systems. These multiple dimensions will be used for more operations within HBIM to enlarge its potentials [8]. Anyway, the basic potential that allows the input and collaboration of professionals with different skillsets within HBIM multi-disciplinary process, is still the most considerable potential, especially when it deals with unique masterpieces [9].

2.2. LOD in HBIM

Contradictory to the common “Level of Details” in building new object which ended by a full detailed object (LOD6) or “Level of Development” that represent the actual object graphically and non-graphically (LOD 500), LOD in HBIM depends on a real existing asset [10], [11]. Therefore, four hierarchical levels are developed to describe modeling improvement in HBIM. The first level represents the building as a solid object without any architectural details (Level 1). The following two levels represent the solid object with its principle and architectural features. The last level represents the building precisely with its architectural and services details (Level 4) [12]. In restoration projects, it is essential to scan the heritage building with all its components, architecture and services accurately. In some cases, intermediate levels may satisfy the intended restoration process. So, it is important to regard type, scope and objectives of restoration to avoid over-modelling.

2.3. Sustainable Restoration concept

From sustainable rating systems point of view, there is no specific rating system that assists, guides or evaluates the sustainable performance of the restoration projects practices. On the other hand, some well-known rating systems, integrate relevant heritage actions within their common systems’ frameworks.
Green Building Council (GBC) Italia; in this context; published “GBC Historic Building TM rating system, 2014” for underlining the historical value of the building as well as the performance of heritage in the restoration & rehabilitation process. This modified system - which is already based on LEEDR principles-dedicates 18% to the historical value of the building from the total related points [13]& [14].

BREEAM Refurbishment 2014, is also concerning the sustainable refurbishing of heritage buildings -whether they are listed buildings or included within conservation areas. Some limited adjustments have been done within this version concerning heritage preservation. These modifications include 5 categories- Management, transport, energy, materials and “health& wellbeing” category- out of the ten categories of the basic BREEAM system [15].

Meaningly, Heritage building itself is a valuable resource within its urban context. Globally, protecting heritage is considered from the valuable socio-economic driving forces in communities’ development [16]. moreover, heritage buildings restoration action- from the research point of view-meets the three pillars of sustainability [17]. part of these sustainable meaningful points can be clarified within the following 3 main dimensions of sustainability perspectives:

- Environmentally: Restoration keeps assets with their valuable non-renewable resources, preserves original materials & fabrics and their embodied energy, supports assets long lasting and reduces areas of landfill. furthermore, restoration gets real sustainable samples back to life as almost heritage buildings were considering passive design criteria from the beginning.
- Economically: Restoration avoids new buildings as well as demolishing the existing ones which in turn reduces expenses. It also increases money returns by means of enhancing heritage tourism nationally and internationally.
- Socially: preserving heritage links societies with their culture, identity and history as well as keeping the “social capital” of these communities. Internationally, it gathers communities together through sharing different and unique cultural identities.

Finally, by regarding the famous LEED quote; “the most sustainable building is the existing building” and relying on the above-mentioned contribution of restoration in sustainability, the author believes that the efficient practice of restoration process can add further sustainable contributions and achieve sustainable restoration as well.

2.4. HBIM Sustainable restoration Approach
By means of BIM new tools and techniques -that are widely distinguished and rapidly used- new potentials are explored and more dimensions are added.
In the last few years, BIM expanded its dimension from just a 3D model targeting: visualization, animation and clash analyses; to 4D that represents Time, then to the 5D model adding cost, afterwards the 6D that deals with sustainability analysis, and lately the 7D which manages and maintains building during operation stage. Undoubtedly, it is expected to get more and more dimensions in the forthcoming years as BIM is still having the capacity to integrate new techniques [8].

Furthermore, many theoretical and practical studies dedicate BIM as a considerable practical approach to enhance and support sustainability throughout the whole building lifecycle stages (design-construction-operation); and HBIM as a current growing sustainable necessity in administering heritage projects [7], [16]& [9]. In addition, it is also proved that HBIM can influence each stage of the heritage building lifecycle. Moreover, providing single model, depending on parametric objects, integrating tangible and intangible data, having the capacity to host advanced programs, and allowing all partners to share and supply simultaneously data, information and documents - even from distance places, makes HBIM an efficient solution in planning & executing preservation processes, as well as managing the operation and maintenance of the heritage building after fulfilling the preservation works [8].
Thereby, it is important to clarify that HBIM-Sustainable Approach main aim is to enhance sustainability along all restoration process stages and beyond. The “6D” mentioned above with its tools and energy performance targets is not the scope of the research. The research focuses on how to make benefit of HBIM potentials [fig.1] in restoration process. The sustainability goals - from research point of view - are to achieve efficient preparation, seamless implementation, cost reduction, optimal practice, long-term data management, and operation & maintenance support. However, the sustainable approach for restoration projects is not only vital in assuring sustainable project process and the long-lasting manner of the restored building, but also a signal in nowadays global great issue and concern.

2.5. HBIM platforms & Interoperability

In addition to its recognition as the most popular system for developing and storing the project integrated data throughout the project’s different stages, BIM is known as a multi-dimensional (nD) platform in which many professional practitioners can apply it in different ways along the project lifecycle [18]. HBIM possesses the same properties: it extracts and accumulates heritage building sets of data and metadata and it offers the chance for all specialized collaborators to use different related programs in one common platform along and after conservation actions [fig.2].
3. Methodology of Getting an efficient HBIM

It is important to clarify that establishing functional model for heritage building is distant from the one targeting new building. New building ordinary sequence begins with: the “conceptual, performance, then final” Design model; then “preparation& documentation, pre-work simulation, monitoring implementation, adjustment and modification” construction model; and finally ends with the owner “as-built” model for managing and maintaining during operation [18]. Contradictory to this typical flow, Heritage Building Information Modeling begins with the surveying action and the as-exist model. The Heritage building is physically existing. Its geometric form, elements, data and more are still stand completely or even partially on ground. So, it has been dictated to establish the heritage building model through reasonable successive phases/stages.

After studying and analyzing several academic researches and different practical case-studies, the research concluded that the most common sequence in getting an efficient model for heritage building must pass through the following:

3.1. Data Acquisition and Documentation

UNESCO defined heritage documentation process as: “the act of acquiring, processing, presenting and recording the necessary data for the determination of the position and the actual existing form, shape and size of a monument in the 3D space at a particular given moment in time” [20]

It is commonly agreed that data acquisition is the most important and difficult stage in restoration process. This stage is considered the bedrock of a successful and sustainable restoration project [21], [20].

3.1.1. Capturing geometric data techniques

Capturing geometric form and data for heritage building is indicated by “a big and colossal challenge”. A great number of heritage buildings have complex and non-standard design as well as unique and missed elements. Despite this, an accurate metric survey should be carried out to document, position, size and dimension all visible surfaces, components and context of the heritage asset as- exist before any restoration process [9]. Anyway, surveying and data capturing tools proof a great development in this field. They upgraded their conventional core to the revolutionary 3D digital based devices. In fact, issues such as saving time, ensuring accuracy, dealing with complex architecture, consuming limited resources and more, became grantee of this great development.

Furthermore, theoretical analysis and practical experiments proved that depending on Electronic distance Measurements (EDM) are more efficient than conventional methods, and the 3D digital survey techniques are much more qualified and sustainable [18], [9]. Countries which are deep rooted in heritage restoration such as England, prompt depending on 3D laser scanning, photogrammetry (terrestrial or airborne), LiDAR (Light Detection and ranging technology with great intensity), close range3D scanning, mobile mapping or two or more of these methods to obtain accurate, fast, reliable results [9].

Certainly, using advanced techniques don’t eliminate conventional ones. Almost case studies that have been reviewed by the research use variety of tools and methods such as: geometric measurements, hand sketches, theodolite, total station, traditional traverse method and other conventional& electronic methods side by side with the 3D digital surveying techniques [9]. Sometimes these traditional methods have a supporting role to check the model output accuracy. Other times, they stand alone and completely capture the geometric data for simple and small HBIM [9].

Standing on what mentioned above, it is agreeable that using 3D digital surveying techniques in addition to the conventional methods is the most efficient and sustainable capturing technique.

3.1.2. Collecting Data and Meta Data

The second step is to collect all the related non-geometric Data and Metadata. In restoration work, it is essential to establish a complete reference data about the current state of the building as well as authentic information about the building as it was in its historical period. In this type of conservation actions, current building is going to be recover to its original state and of course it is particularly worth to depend on reference data and information [5].
In this step, corresponding datasets whether Tangible & Intangible / physical& nonphysical must be collected, listed, and described. It is fundamental to obtain all details behind surfaces before any restoration action. Some of data sets are used in practical action; such as material types and composition, construction components and methods, components condition, and alike [8]. Others are used in legacy way to strengthen the heritage significance; such as cultural and historical memories, events occurred throughout the building lifecycle, famous characters’ personal visits and observations [16].

Available manuscripts and historical documentations are also having a reliable role in recognizing the asset original data. On the other hand, advanced experimental techniques as well as surveying & capturing data tools have extended and sustainable role in both obtaining existed data and enhancing restoration process. To clarify, using on-site and off-site new experimental techniques (such as hammer & core tests) can report the asset strength and the component composition un-destructively; 3D intensive laser scanners (such as; LiDAR) & infrared based tools can automatically -and in relatively no time- “detect, register and document” hidden “defects, cracks and humidity level” for all building components. moreover, embedded installation (such as; electrical and plumbing paths, pips and ducts) behind surfaces can be easily inspected in a visual way.

If adding that, some of these techniques and tools can be integrated automatically, or even report their results in diverse files formats that can be attached to BIM, this make restoration work gain considerable sustainable issues such as: avoid destructive inspection; save money, time and keep the identity& originality of the asset; as well as allow precis& qualified repair and treatment; etc. finally, by the end of this step complete data and metadata sets are being established for the heritage asset.

3.2. As-Exist Model (Geometric & Non-Geometric Modelling)
Regularly, as-exist model points to the near start of restoration work. all the building objects data geometric and non-geometric are included in it in a digital parametric form. The model is used in documenting the state of the asset before any action as well as planning the upcoming restoration project.

3.2.1. The Heritage 3D Graphical Model
Results of the 3D digital survey almost have the form of point cloud and mesh surface outputs. photogrammetry techniques also offer stereo images for the scanned parts of the building. These two techniques by means of conventional or automatic calibration, and sometimes third parties of software can collaborate and generate the 3D geometric model of the heritage building. Initially, sets of raw point cloud from different positions outside and inside the building are obtained in the main BIM drawing program. successfully, most of recent BIM software import point cloud datasets directly [9]. Afterward, diverse segments of point clouds are merged. The visible parts of the building surface and its complementary objects are determined within the BIM platform. Then, color, texture and real view are aligned by merging photogrammetry digital photos. later, unique& complicated objects are precisely mapped relying on point cloud and image& render based techniques. At the end, they are positioned and referenced to their real places within the model. In this way, the geometrical model of the heritage building is established in its primary 3D visual manner [16].

3.2.2. 3D parametric model
Parametric model starts upon point clouds and ends with complete and integrated sets of data into HBIM platform. In the most fortunate scenario, point clouds are automatically detected in BIM platform programs. Scan-to-BIM technology allows managing and adjustment point clouds depending on algorithmic detection. By this type of point detection, walls and simple objects surfaces are automatically created as parametric objects [16]. Although this technology lately integrated in most BIM programs, point clouds fully automated conversion to a virtual modeling is still distant. The relevant algorithms need to be more intelligent, especially when dealing with the complicated and irregular forms of the heritage buildings. As a result: some conversion solutions depend on the manual method to draw the parametric objects with the help of point clouds; Others apply semi-automatic methods and use BIM & GIS tools with the aid of third-party software to get the geometric parametric model from point clouds.
However, HBIM is strongly expected to work under “Building SMART open platform managed server” soon [8]. Web services integration in addition to data interoperability, are going to make it more efficient to build heritage parametric models. Historical elements are parametrically constructed in a separate and distant way then shared within the Historical International Foundation Dictionaries (HIFD). By this HBIM open archive existence: diverse vocabularies can be shared; new families are imported; native objects are established; and HBIM libraries are enriched. Thereby, building heritage parametric model- within this predicted frame- becomes easier, faster and more accurate.

permanently, parametric model must integrate tangible& non-tangible data sets. unintegrated information of heritage building components must be linked in files to the model. The 3D model by the end of this stage must fulfill the latest Level of Development

3.3. HBIM and Beyond

Beyond getting a 3D model with full integrated data and Meta data for each object of the heritage building, HBIM also offers great potentials in the rest of the restoration project processes. HBIM potentials in this stage can be summarized in the following:

3.3.1. Restoration Action Phase

By getting the previous produced model (As-Exist model), the philosophy and plan of restoration action can be suggested. Intervention limits are determined. A virtual model that expresses visually the final appearance of the intended restoration is established. As a matter of fact, these actions satisfy the authorities’ approval. In general, a restoration action model is built to simulate the project implementation stages and represent in visual and documental way the successive actions. Repairing, treatments, instructions, standards, specifications, quantities, experiments, budget, project schedules, timeline schemes and all implementation requirements are estimated in this model. This model concludes finite decisions about cost, time and specification. A restoration plan model at the end of this stage is adjusted to the accepted technical and practical plan.

Afterward, all the pre-restoration actions can be prepared and completed within HBIM platforms. 2D drawings are automatically extracted from the geometric model. Final project specifications, criteria, standards, procurements, quantities, schedules, time duration& rate of execution, and more are all integrated in the accepted plan model. At that moment, the effective collaboration between project participants begins in the HBIM wide platform. The owner, consultant, contractor and their responsible actors integrate efforts to insure seamless project delivery. Each partner can revise and manage his section to insure its validity. It is really worth in this phase to end with a simulation construction model. This model shows the ideal sequence of the project implementation stages due to the contract. The model represents virtually: the motility of workers, resources, equipment as well as the continuous progress of the implemented work. The model benefits in insuring the concurrence of the real workflow during implementation comparable to the certified work sequence [18].

Next step is to manage and monitor the implementation process. The pre-prepared HBIM model initiates the project management requirements. Work organization begins proceeding from the model given charts. Actual progress is monitored and compared with the pre-installed plan. In this stage, it is crucial to update the model according to any certain changes. Model optimization -in this implementation stage- is also predictable to improve efficiency or meet specific goals [18].

HBIM- Cyber Physical Systems (CPS) integration is considered a promising technique in construction management field. In this technique, Radio frequency Identification (RFID) works with the Real Time Location Sensing (RTLS) to monitor implementation progress. Within this system an easy visual comparison can be performed between actual and planned progress. Briefly, HBIM outcomes in restoration implementation stage are monitoring and tracking work progress, eliminating field conflicts, putting quick solutions, overcoming delay, managing changes and more. However, by the end of this execution stage all changes must be documented and updated in the HBIM working model.

After finishing restoration action as-restored model is produced. This model describes the state of the heritage building after fulfilling all restoration works. All the stages – from data acquisition stage till
execution model – are transferred in integrated model/ models. The owner final delivered model must contain the complete history and full information of the project.

3.3.2. Operating and maintenance Phase
Considering the extremely large data transferred to the as-restored model and the big size of files. It is accepted to divide this compact model into two linked models: Project Information Model (PIM) and Asset Information Model (AIM). PIM is the responsible partner of archiving and storing all the restoration actions, details, editable elements and even minute treatment along heritage building long life. If it is approved, any innovative ideas must be simulated, examined and included within this PIM frame [8].

On the other hand, AIM concentrates on the asset itself. This model main aim is to operate and maintain the restored antiquity. The model is equipped by operation and maintenance manuals. Recent and upcoming inspection and maintenance dates are identified in it. Repair and maintenance instructions in addition to maintenance type are also included. The complete details and information needed for both operating and maintaining the building component must be provided in the model.

4. Case-study overview
For its historical legacy and unique architecture “Baron Palace” became one of the worldwide master pieces. The Egyptian Government decided to restore this listed heritage “Baron Empain Palace” within a great recent restoration plan for eight heritage sites and buildings. A budget of LE113.738 million was set apart to the “Baron Palace” of total LE 1,270 billion provided by government for the whole project. Restoration work is currently undertaken during writing this research [fig.3].

4.1. Historical background
The Belgian millionaire; Edouard Louis Joseph who famously known by “Baron Empain”, built this palace between 1905: 1911 to house his family. As he came to Egypt from India, he commissioned the French architect “Alexander Marcel” to design the palace on the Indian style which he was fond of. The palace was inspired from the ancient Orissa Indian temples and the famous Hindu temple of Angkor wat in Cambodia. The palace was decorative by the famous decorator ceramist and painter Georges-Louis Claude. Empain chose its place to be on the highest level of Heliopolis out-skirt as he was from the main founders of Heliopolis suburb.

4.1.1. Baron Empain Palace architecture and site
The palace consists of two floors, service basement and an open-air decorated roof where several occasions were held. There is also an accessible tower with four floors height to allow the view of the whole district all around. The palace is surrounded by a wide garden from all directions. The ascending leveled terraces with their own sets of statues and decoration attach the building with the garden. Total site area of the palace occupies 12.5 thousand meters square.

4.1.2. Palace original construction and materials
In General: bearing wall is primarily the structure system, foundations are continuous strip footings & slabs are double layer reinforced concrete with embedded beams. The main materials of foundation, retaining and basement walls are the bulky blocks of plain concrete. Sand bricks besides are the common material for walls. The reinforced Concrete with its steel smooth rods, plates and thin flat metal tie straps are used in the double roof slabs and their embedded beams.

Regarding: architecture, Ornaments and Statues materials, both local and nonlocal materials are used. Wood is used in flooring, stairs, doors, windows, and walls paneling. Marble is also used in flooring as well as palace parapets’ caps, statues and ornaments. Reinforced concrete and natural stone are used in the stepping terraces parapets and floors. Ceramic tiles are covering bathrooms’ walls. Mosaic tiles cover the roof floor. Lime, Gypsum and cement-based mortar are used in plastering, ceiling cornices and decoration purposes.
4.1.3. *Palace innovative techniques and environmental treatments*

It is noticeable that there is standard repetition in many miscellaneous components of the palace. Modular production and pre-fabrication techniques were obviously applied. Pre-cast techniques were also used in an innovative way in the fabrication of the standard decorated units for the parapets of the stepping outside terraces [fig.4]. Regarding the environmental treatments, natural ventilation and sun ray’s penetration were well and carefully planned. Further, the palace thick walls and the top 90 cm double roof slab are working via same goal. Moreover, natural light was also considered.

![Figure 3. Palace under restoration.](image1)

![Figure 4. Parapet standard units.](image2)

![Figure 5. Deterioration features.](image3)

4.1.4. *Palace condition before restoration work*

The palace suffered from neglect for a long time and several damages are visually reported. It can be simply said that deterioration reached everywhere in the palace; walls’ plastering, slabs’ floorings, doors, windows, glass, ornaments and statues [fig.5]. Over and above, the palace structure exposes that the reinforced steel in some parts of its three floors ceiling had lost their cover [22].

4.2. *The Palace Current Restoration Project*

The palace restoration project has three stations; pre-restoration phase/ station (preparation), restoration action (implementation), post restoration phase (usage suggestions)

4.2.1. *Project preparation*

Project preparation has lasted for long time. 2007 was the starting date, as the ownership of the palace moved to the Supreme Council of Antiquities, now the Ministry of Antiquities. Preparation began and stopped several times due to different reasons. In 2015, Ministry of Antiquities recalled the latest proposed restoration plan. A comparative study was carried out and a non-detailed 3D model was established depending on traditional measurements. Preparatory documents such as: 2D drawings, work descriptions, quantities calculation, cost estimation, and more were figured out. In this stage, the restoration philosophy, intervention limit and work plan are also proposed. Preparation stage ends by revision, plan approval and offering budget to begin implementation.

4.2.2. *Project execution sequence*

Actual restoration action began in august 2017. As any restoration project, documenting the as-exist condition of the palace was the first target in this project. Therefore, detailed and extensive structural, architectural and archeological surveys were precisely carried out. The geological survey used both mechanical and electrical geophysics analysis methods. On-site and laboratory tests advocate each other to inspect the palace foundations and structural components. Infrared techniques are used to define humidity levels and further investigate hidden installations. The structural condition was analyzed by means of dedicated software (SAP software was used in this case). Formerly, all examinations, investigation, inspections and structural situations were reported and documented.
Architecturally, HBIM was officially required. The main purpose of applying HBIM was to document the recent state of the palace. 3D laser scanning and photogrammetry techniques were operated to capture the palace architecture externally and internally [fig.6]. Fine details such as: ornaments, statususes and decorated objects are also intensively scanned. In order to assure accuracy, several pre-registration targets were coordinated using (theodolite& total station). The resulted point cloud is converted into 3D surface model by the help of ReCap software. The real imaging of the palace was blended to the 3D model by assembling the stereo photos of photogrammetry and re-rendered by 3DMAX software. As stated from the responsible team work on site, it was satisfied to get an as-exist visual 3D model that document each part and detail of the palace. Actual work has already obtained the palace drawings from the previous preparation stage. The flow of work practically continues in the most common ordinary manner of restoration projects.

![Figure 6. 3D scanning work for exterior facades.](image1)

![Figure 7. Parquet manual tracing scale 1:1](image2)

Extra conventional surveying work was carried out to verify the accuracy of the delivered drawings. Palace objects are identified, divided and coded. Identified objects are traced to scale 1:1 manually after their photographic documentation [Fig.7]. CAD drawings are included for each restored part and object in the palace [fig.8]. All the architectural related data (such as: materials, techniques, fabrication, state … etc.) are studied and attached to the objects. Each object has a code with its place, specification, state “before, through & after restoration”, and the whole necessary data [fig.9], [fig.10]. Restoration process is digitally documented and printed out to be archived in hard copies form as well. In this context, Project & construction management apply the familiar software (Primavera). Cost, time, quantities …etc. are managed routinely.

![Figure 8. Documenting deterioration on CAD files.](image3)

![Figure 9. Each space has code.](image4)

![Figure 10. Fine parts have a code.](image5)

In the same mainstream, the archeological studies were reported and documented within the coding system and distant away from the produced 3D model [23].
4.2.3. Post restoration studies/ plan
As there were an earlier approval of reusing the palace after fulfilling restoration actions. Several suggestions are offered, and the palace 3D model comes to spot again. One of the proposed usages is to build an open-air theater in the palace backyard. It is suggested to represent the history of the palace through sound and light performances. This project analysis and studies are predicted to be submitted accompanied by visual model to get the authority approval before implementation.

4.2.4. Case study evaluation and observation
From the above analysis, it is obvious that applying HBIM in the Baron Empain case study doesn’t go beyond documenting the geometrical situation before restoration. Which is not distant away from common restoration projects that apply HBIM all over the world [17]. The ambitious scenario of using HBIM in completing the missing parts of the palace fine objects “via 3D printing” faces many challenges. Cost, material and absence of authentic prototype were major challenges in this context. In fact, Preparation and implementation of restoration action or even the suggested operation was precisely undertaken. But on the other hand, the above theoretical and analytical study drive the research to trust HBIM in achieving sustainable restoration. In case of Egypt as well as similar projects worldwide, converting practical procedures to be operated from one platform would save efforts, time and in turn cost. At the same time, it improves efficiency and enhance sustainability.

5. Conclusion
There are already some limitations facing HBIM applications, but obvious evidences and rapid development assure eliminating these problems soon. The research supposes an approach that integrate HBIM in the whole restoration stages [fig.11].

![Figure 11. Sustainable approach proposal.](image)

This approach commonly targeting a sustainable restoration action. Some applications prove their success and the rest are promising to succeed. Using HBIM in restoration projects saves time, cost and
efforts. Applying HBIM also reduces waste and resources consumption as well as eliminates re-work and landfill occupation. Regarding project efficiency, the restoration action -within HBIM platform- is fully simulated before implementation then tracked, monitored and controlled digitally during execution. HBIM has farther contribution in managing and maintaining during operation. All these HBIM potentials are addressing sustainability core. From the research point of view, this sustainable approach is suitable in restoring heritage building in Egypt. It is also nominated for similar projects worldwide.

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