



Improving Sustainability Concept in Developing Countries

Integrating HBIM (Heritage Building Information Modeling) Tools in the Application of Sustainable Retrofitting of Heritage Buildings in Egypt

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Abstract

Heritage buildings are crucial to the human perception of culture. Sustainable retrofitting of such buildings represents an opportunity for their reuse while considering sustainability. HBIM tools (Historic building Information Modeling) can be used as a comprehensive data set of information, related particularly to the restoration of buildings. The aim of this paper is to integrate HBIM tools in the application of sustainable retrofitting of heritage buildings through a conservation framework. The paper provides a literature review and a qualitative analysis of worldwide examples. Findings of this paper provide useful framework for sustainable retrofitting of heritage buildings in the Egyptian context.

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1. Introduction

Heritage buildings are crucial to the human perception of culture and identity through time. These valuable resources according to the Egyptian law no. 119 of 2008 require protection and restoration. They form an important side of a place memory and the experiences of people who lived in them. Although being a part of history, some of

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these buildings are still used till today. However, some other buildings suffer from degradation problems, even so they have a wide potential of reuse. In order to enhance the performance of existing heritage buildings, or plan for the conservation of an unused building, high consideration of the special nature of heritage buildings is required. The Egyptian context is rich with a variety of built heritage that suffer from many problems. New and innovative tools and strategies are required for the protection of these valuable resources.

The approach of sustainable retrofitting of heritage buildings represents one of the biggest opportunities for the conservation of these buildings, while considering all aspects of sustainability. Sustainable retrofits consider increasing energy efficiency, optimizing building performance, increasing tenants' satisfaction and enhancing economic return without compromising heritage values. On the other hand, HBIM tools (Historic building Information Modeling) can be used as a comprehensive data set of information about all disciplines, related particularly to the conservation of valuable buildings. Moreover, the geometric accuracy of the models produced by HBIM will ensure reliable visualization outputs that can enhance retrofitting.

The aim of this paper is to integrate the HBIM tools in the application of sustainable retrofitting of heritage buildings, through designing a framework for the conservation of heritage buildings. The proposed framework considers the sensitive nature of heritage buildings and the values embedded in them.

In order to achieve the objective of this paper, the authors applied three main approaches: literature review of theoretical background, analysis of examples and design of a framework of heritage buildings conservation. The paper provides a literature review of built heritage values, generic building refurbishment tools, retrofit process and the potential of utilizing HBIM (Historic building Information Modeling) tools for conservation and management of built heritage. A qualitative analysis of some examples is discussed to give a comprehensive understanding of the topic as well as of the different attempts that have been made by researchers & practitioners. An integrated framework for heritage buildings conservation is intended at the end of this paper. This framework will merge sustainable retrofit as a design technique, HBIM as a computational tool and heritage values as guiding principles.

2. The Distinctive Nature of Heritage Buildings

Along different historical periods, humans introduced a variety of cultural heritage that kept their historical legacy through different times. Cultural heritage is defined by the Council of Europe's Framework Convention as "a group of resources inherited from the past which people identify, independently of ownership, as a reflection and expression of their constantly evolving values, beliefs, knowledge and traditions. It includes all aspects of the environment resulting from the interaction between people and places through time, [1]". Built heritage is an important type of cultural heritage. It can highly represent different aspects of a society and its development among history, [1].

From the cultural perception, heritage buildings provide local character and a very tangible connection to the past, with aesthetic and community benefits. They reach further back into the past and have greater links to locality and history; something which cannot be easily replaced, and thus they require an approach which is specific to their context. They are constructed from different materials and in different structural forms compared with modern buildings and, consequently, they perform differently, [2].

2.1. Value of Built Heritage

The presence of heritage buildings carries many values for people. Several approaches have been produced in order to classify "value". Among them is the Welsh government's historic service, Cadw, which defined five types of values of built heritage. These values are evidential, historical, aesthetic, comparative and communal values. Evidential value of buildings is related to evidence about a certain important activity that took place within the building in a certain period of time, [3]. For example, Islamic schools "*Madrasa*" represent a special form of educational activities related to Mameluke period in Cairo. Historical value is a wider perspective of evidential value. It informs about wider remarkable historical matters, not the particularity of a specific building that the evidential value may indicate, [3].

Moreover, the visual characteristics of a heritage building carry aesthetic values. A built heritage may define a specific period's architectural style, construction methods and advances in architecture and construction. Comparative value is about how rare and how unique the building is, compared to other similar buildings. Finally communal values are related to benefits the built heritage carries for people. They include economic, social and cultural values, [3].

Economic values include enhancing tourism and jobs provision. On the other hand, social and cultural values include identity expression, increasing sense of community attachment and social cohesion, [1].

Another considerable approach to classify the value of heritage buildings is that of Alois Riegl (1858-1905), who first published his work in German in 1903. His article was entitled "*The Modern Cult of the Monument: Its Character and Its Origin*". In this work, he outlined the competing values that should be taken into consideration when applying conservation of historic structures, [4]. In addition, he classified the value of a heritage entity into main categories: age value, historical value, deliberate commemorative value and use value.

In his classification, Riegl concluded that age value is represented in the monument's outdated appearance and is revealed in "imperfection, a lack of completeness, a tendency to dissolve shape and color, characteristics that are in complete contrast with those of modern". His clarification was based on the notion that man of the twentieth century enjoys the "**purely natural cycle of growth and decay**". From this perception of age value which appreciates the past for its own sake, restoring heritage buildings or renovating them should sustain a distinct trace of the original form of the building, [4].

On the other hand, historical value is based on the analysis of the reasons of pleasure from viewing a monument or heritage building, where this pleasure is not only based on age value, but is also a product of assigning the monument to one of the stylistic categories present in the minds of viewers. Historical value is mainly concerned with the point that most people divide monuments according to general periods, such as medieval, early modern and modern. The deliberate commemorative value represents the contrast to age value. It aims at keeping a moment or heritage entity from becoming a history and to be present in the consciousness of future generations. Finally, Riegl introduced the use value, which is based on appreciating the physical value of heritage entities. Based on this concept, he considered maintaining old buildings that can still accommodate occupants a vital process. Although use value seems to be contradictory to age value, they both exist variedly in heritage buildings. Distinguishing between the degrees of applying both values is correlated with the nature of heritage building and its usage suitability, [4].

Within the Egyptian context, the National Organization of Urban Harmony in Egypt discussed values of heritage buildings in their guide about principles of urban harmony for heritage and valuable buildings and regions. Historical, architectural, symbolic, urban and social functions values are discussed. The historical value of a building is about its relation to important historical events that create cities' memory. When a building has a distinctive architectural style or represents a local architectural style, it acquires an architectural value. The value of a building can be derived from what it symbolizes. It can be related to a famous effective character or designed by an important architect. Urban value is related to the importance of a whole urban context that the building belongs to. Functions performed by the building and the services it offers to the society add a social and functional value, [5].

2.2. Classification of Values of heritage buildings

Three models of classification were studied through the previous literature review. Each model has one or more distinctive item of classification. The classification by Cadw differentiated between evidential and historical values, in which the building in itself could be an evidence of specific part of history or be a wider part of a historical period. Cultural values were classified under what was called communal value, [3]. Edward Taylor defined culture as "that complex whole which includes knowledge, belief, art, morals, law, custom and any other capabilities and habits acquired by man as a member of society, [6]". Accordingly, history is a part of culture. For the classification intended in this paper, cultural value is decided to form a more general category that includes both evidential and historical values. From the Egyptian National Organization of Urban Harmony classification, architectural and urban values are

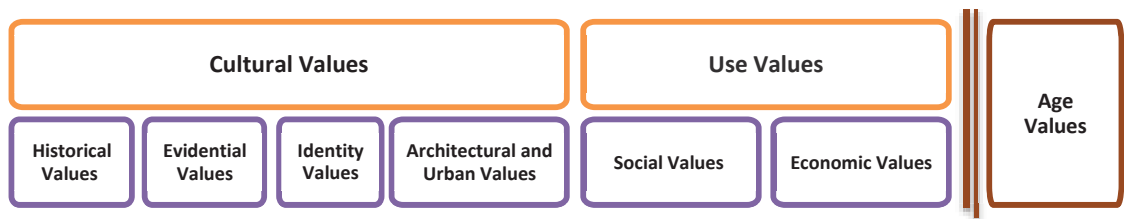


Figure 1 - Classification of Built Heritage Values, Based on ([3]; [5]; [4])

also included under the culture category. Architectural and urban values include the aesthetic values defined by Cadw. It is a wider category that includes architectural style, planning approaches, construction methods and materials used.

Another principal category in the classification is related to tangible benefits from built heritage, which is the use value defined by Alois Riegl, [4]. Use values include social and economic values defined by Cadw under the communal values category. The services that the building offers for the society and the revenue it could create form a part of its value. Finally, age value defined by Riegl is important, but not as important as other values in case of used buildings. It is important for a heritage building not to completely lose its age value. However, keeping age values has a limited extent, a building cannot be used if the effect of age on it is extreme. To sum up, the classification of built heritage includes three main categories, two of which are more concerned with used heritage buildings values, namely cultural and use values, whereas age values are less concerned with used heritage buildings. Cultural values include four main categories: historical, evidential, identity and architectural and urban values. Social and economic values are the categories of use values. Figure 1 - Classification of Built Heritage Values, Based on [3]; [5]; [4]

2.3. Categorization of Built Heritage in Egypt

Egypt is very rich with its built heritage. The variety of different time periods can be observed in the architecture of each period. The National Organization of Urban Harmony classifies built heritage into three categories as follows:

- Heritage building level 'A': the modifications allowed internally and externally are very limited.
- Heritage building level 'B': internal modifications are allowed with more flexibility.
- Heritage building level 'C': maximum flexibility is allowed, the building can be destroyed and rebuilt, but the external elevation must be kept, [5].

Heritage buildings are determined according to the Egyptian law of built heritage preservation, no. 144, 2006. Buildings determined by this law are buildings that have a distinct architectural style (architectural value), connected to national history (historical value), related to a historical character (symbolic value), represents a specific historical period (historical value), or considered as a touristic destination (social and functional value). These buildings are protected according to this law, [7].

2.4. Threats Facing Heritage Buildings in Egypt

Despite the great value of the rich and diverse Egyptian built heritage, it suffers from many problems and threats. Many buildings are subjected to partial or full destruction. For example, the city of Alexandria in Egypt suffers from rapid destruction of valuable old villas. Beside intended demolition of buildings, some other buildings suffer from partial collapse due to their deteriorated condition, [8]. The deterioration of built heritage in the Egyptian context is a result of many reasons. Low maintenance, weak management and weakness in enforcing laws and policies are some of the deterioration reasons. The effects of time and weather conditions with the low maintenance can make the problem worse, [8]; [5].

During the early 1960s, the Egyptian government cancelled a system called 'Waqf', which is an Arabic word that means 'endowment'. With this system, some people used to donate a building where its revenue is used for charitable purposes and the building cannot be sold, rented or inherited, [9]. Part of the building's revenue is dedicated to the maintenance and preservation of the building to ensure the continuity of the building's provision. With the cancellation of this system, a source of maintenance fund was lost and the government was not able to provide sufficient funds for the maintenance of such buildings, [9]; [8]. Another important reason for the rapid deterioration of the built heritage in Egypt is the weak awareness of the value of these buildings and the wide potential of benefits they could provide, [5].

3. Introducing the Concept of Sustainable Retrofit

In order to have a good understanding of the term "sustainable retrofit", and since the process of updating and reusing buildings is expressed through a number of terms including: retrofit, refurbishment, restoration, and conversion, a discrimination between terms should be identified.

To start with, the broader term "Conservation" is defined according to Cen [10] as "measures and actions aimed at safeguarding Cultural Heritage while respecting its significance, including its accessibility to present and future generations, [11]". It is worth mentioning that another synonym of the word conservation is "Preservation". The second related term is "Restoration", which differs from conservation in that it includes the removal of historic materials to create an accurate depiction of a particular time period, not necessarily the original or final time periods. Restoration is defined according to Cen [10] as "actions applied to a stable or stabilized object aimed at facilitating its appreciation, understanding and/or use, while respecting its significance and the materials and techniques used, [11]".

The term "refurbishment" includes the repair, renewal and modification of a building to meet economic and/or functional criteria, [12]. It is different from the term "renovation" in that it is not specifically applied to buildings renovations, which are often focused on aesthetics and tenant facilities, but it may also include upgrades to the building's services systems and has an effect on energy and water efficiency, [13], [14]. Finally, Rehabilitation according to BPIE [12] and GDNR [13], is defined as a "process of making possible use of a property through repair, alterations, and additions, while preserving its historical, cultural or architectural values, [11]".

However, the term "Retrofitting" is commonly associated with building services, owing to the fact that the life of the building structure and fabric is considerably longer than that of the installed services. According to Douglas's [15] and Sara [16], retrofit is "any work to a building over and above maintenance to change its capacity, function or performance"; in other words, 'any intervention to adjust, reuse or upgrade a building to suit new conditions or requirements, [16]'. Whereas Riley [17] and Haeyeon [18] defined it as "fitting new and more modern systems into an existing building".

When applied on heritage buildings, sustainable retrofit has a number of positive impacts on the environmental performance, their social sustainability and their economic sustainability. Firstly, environmental performance is enhanced by extending service life and reducing energy consumption and CO₂ emissions. Secondly, social sustainability is achieved by increasing user's wellbeing, high quality indoor air and comfortable space, more natural light and cleaner air and using healthy materials. Finally, achieving economic sustainability is empowered by lowering operating costs as a result of efficient management of energy use, in addition to attracting economic return on investment, W. Sarah [16].

3.1. The Phases of Implementation of sustainable retrofit

In fact, sustainable retrofit comprises a number of phases. These phases start with setting a retrofit scope then setting up the vision for the design. Afterwards, decisions on the strategy of retrofit are settled. Finally, a number of mock-ups or alternatives are developed where the best overall comprehensive is selected, [19]. These phases are explained in more detail as follows:

- Phase 1: Evaluation of existing building: by collecting data and information; this phase is also called "problem formulation". Retrofit team analyzes the conditions and determines elements of the building which need retrofitting. In addition, condition audit is applied to determine the current condition and expected remaining life of building's components. The areas have to be examined, including the structure, external walls and roof, thermal performance, water usage, daylighting, occupant satisfaction, mechanical, electrical, materials, security and review of safety issues, [20].
- Phase 2: Setting and preparing the goals and objectives: this is based on results from the analysis by the design team. The team has to set an approach after prioritizing the goal of retrofitting to determine items to be replaced, provide a base budget for the scope and identify of the items that should be targeted for sustainability, [21]. Further on, the early goal setting is aligned with the chosen rating system that supports the objectives of retrofitting, [22].
- Phase 3: The design process and evaluation of suitable techniques and strategies that can be applied to the building, where different techniques are applied according to the existing situation of the building. These include energy efficiency retrofit (e.g. solar retrofit, lighting retrofit, passive design), indoor quality retrofit (e.g. internal shading, top level sky lights under floor supply) and water efficiency retrofit (e.g. low-flow water fittings and shower heads, low-flow plumbing equipment, water-efficient irrigation).
- Phase 4: Implementation of retrofitting strategy to the building: in this phase the retrofitting system is installed and followed by a review to make sure of meeting goals.

- Phase 5: Evaluation methods by computer simulation devices.
- Phase 6: Performance assessment: including risk assessment and performance assessment to support financial analysis and valuation of sustainable property investments. The evaluated performances include: process performance, feature performance, building performance, market performance and financial performance, [21].

4. Historic Building Information Modelling (HBIM)

Recently, recording cultural heritage sites became state of the art as a result of the widespread usage of laser scanning and photogrammetry. HBIM (Historic Building Information Modeling) became a well-known tool that helps in conversation of historic buildings. Historic Building Information modeling, as plug-in for BIM, is defined as a system for modeling historic structures from laser scan and photogrammetric data. In general, the process of implementing HBIM involves a reverse engineering solution whereby parametric objects representing architectural elements are mapped onto laser scan or photogrammetric survey data. This process includes a number of stages to get the final product, starting with collecting and processing of laser/image survey data, identifying historic details from architectural pattern books, building parametric historic components/objects, and finally correlation and mapping of parametric objects onto scan data and the final production of engineering survey drawings and documentation, [23]. The product is the creation of full 3D models including details behind the object's surface concerning its methods of construction and material makeup. The HBIM automatically produces full engineering drawings for the conservation of historic structure and environments, this includes 3D documentation, orthographic projections, sections, details and schedules, [23]; [24].

4.1. Implementation of HBIM in Conservation and Sustainable Retrofitting

In addition to the common advantages of Building Information Modelling in achieving prototyping, visualization, collaboration, energy simulation, comparing different design options, solar study and energy demand prediction, HBIM is specially tailored to the application on heritage buildings. The reasons beyond the adoption of HBIM in the conservation of heritage buildings in general, and in sustainable retrofitting of such buildings in particular, are evident in the advantages of HBIM which outweigh other modelling approaches, as it provides automated documentation in the form of engineering drawings for precise conservation of architectural heritage. It helps in developing the details behind the object's surface concerning its methods of construction by using images to understand texture, massing and form, and it can be considered as a dataset of information about the disciplines, [24]; [25]. In addition, HBIM provides review of the building's exterior and interior. It also eases the availability to survey renovations and changes that took place through different time periods prior to committing to a strategy and produce full-construction documents, [26], [27].

4.2. Examples of the Application of HBIM in Heritage Buildings

The use of computation methods in works related to heritage buildings is not widely used in Egypt. Very limited application using laser scanning for the purpose of documentation was applied in Egypt. Examples included a pilot project for laser scanning of old Cairo, [28], laser scanning of Red Monastery church in Upper Egypt to document the final state of the church after a restoration project, [29], laser scanning for a virtual reality documentation of the monuments of Tutankhamun, [30], and laser scanning of the Northern wall of Old Cairo as part of a restoration project. The following part of this paper will analyze the example of Jeddah Historical Building Information Modelling (JHBIM) as limited data is available on examples that used HBIM in the Egyptian context. (Available data about most Egyptian projects includes the application of laser scanners and making as-built models only).

4.2.1. Jeddah Historical Building Information Modelling (JHBIM)

Jeddah Historical Building Information Modelling (JHBIM) is an initiative aiming to introduce BIM tools for the documentation of existing historical buildings in Jeddah. Traditional surveying methods are currently being used to create report data about existing buildings. These tools have high costs, consume much time and are sometimes not

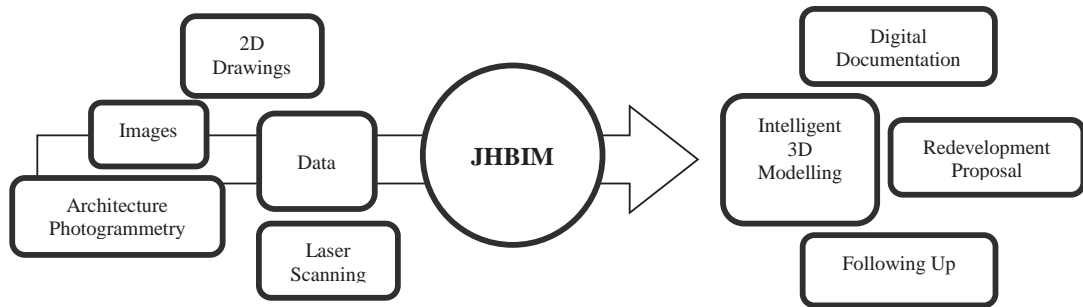


Figure 2- JHBIM Approach from Baik et al [31]

accurate or reliable. JHBIM initiated a test project to create a model for one of the historical buildings in Jeddah, Farsi House. It recommends to be expanded later to form a complete database about the current conditions of historical buildings in the region of Old Jeddah. The importance of having such a database will help in the determination of their conditions and decision making related to management, reuse and maintenance of these buildings. The project used image survey, laser scanning, creation of 3D points clouds models and creating of the 3D model using Autodesk Revit, Figure 2- JHBIM Approach from Baik et al[31]. When expanding the project JHBIM will be a set of data about the buildings, for example, new parametric models of architectural features can be added as prototype libraries, different architectural drawings and construction and materials information, [31].

A number of challenges faced the implementation of this project, including, [31]:

- Constrained Resources and equipment availability challenges, as only one laser-scanner device was available to serve all projects at King Abdul-Aziz University in Jeddah city.
- Climatic condition challenges: where the weather was hot (35°) and max Humidity was (89%) in the 15th of Apr., 2013.
- Time-related Challenges: concerning the time needed to produce a professional 3D model for each building with sufficient level of detailing, where almost each building needed one month for modelling.

5. Analysis of Examples of the Application of Sustainable Retrofit in Heritage Buildings

The following part of the paper provides examples of retrofit of heritage buildings. Two examples were selected, one from the Egyptian context and the other from the Chinese context. The Egyptian example was selected from one of the most culturally rich cities in Egypt, the city of Alexandria. The city has suffered a rapid loss of its built heritage over the recent years through a sort of systematic destruction that highly caught the attention of people concerned with the protection of culture heritage, [32]. The retrofit of Bassili Pasha Villa in the National Museum of Alexandria is an evident example of the wide potentials retrofit can provide for the conservation of built heritage. The example might not be accurately applicable to the concept of sustainable retrofit and does not follow all its principles, but still it is a good example of well-adapted buildings of new projects that gained acceptance of both professional and laypersons with different degrees, [33].

The other example was chosen from a non-Egyptian context, as an attempt to provide a different perspective of retrofit. It is the Lui Seng Chun in China, which dates back to the same period of the Bassili Pasha Villa. Yet, it presents a different usage, which is useful in providing more suggestions about reuse strategies. The examples include different features that considered all aspects of sustainability in the process of retrofit. It is a good example of how features of retrofit can be implemented inconsistent with its goals, [34]. The examples were analyzed in accordance with the literature discussed about heritage values and elements of retrofit. Different values these buildings offer for the society are determined, in addition to how the goals of reuse address these values. The analysis also includes the comparison between reuse goals and the elements that were added to meet these goals. The goal of the analysis is to give an illustrative example of how adding new elements can serve in the conservation of values.

5.1. Lui Seng Chun – Hong Kong – China

Lui Seng Chun represents a type of Chinese buildings called “Tong – Lau”, which is a term used locally to refer to a shop house. In 2000, the Lui’s family donated the building to the government. In 2012, the building was reopened with a new use that reflects its original historical use, [35] . “Lui Seng Chun not only bears witness to the history of a well-known family in Hong Kong, but also illustrates the past community life, economic activities and architecture of the territory, Conserve and Revitalise Hong Kong Heritage Buildings, [34] ”.

Lui Seng Chun – Hong Kong – China, ([36]; [34]; [35])

Background	Date	1930s
	Original Owner	Lui’s Family, famous Chinese business family
	Original Use	Shop house, ground floor: Chinese bone-setting medicine shop Upper floors: family residence
Cultural Values	Social Evidential	Represents a typical living style of Chinese business families during the time to which the building belongs
	Economic Evidential	Represents a typical economic activity during the time to which the building belongs
	Architectural	A distinctive architectural design compared to the standard design of other shop houses belonging to that period
		One of the few remaining till now
Current Use	The Hong Kong Baptist University, Chinese Medicine and Health Care Centre	
Goals of Reuse	Enhancing the building’s heritage value by the preservation of its original fabric with minimum intervention	
	Bring social and community benefits, provide education and raise awareness	
	Add some modifications to adapt the building to the current building regulations and codes in China	
	Examples of Added Elements for the Reuse	Glass panels for terrace enclosure
New staircase and fire safety measurements		Safety requirements
New elevator		Facilitates the use of the disabled
New mechanical and electrical installation Solar panels		Consideration of power saving and production
Restriction on number of visitors for the upper floors		Management strategies to structure safety
Low cost medical services for the neighbourhood residents		Community Benefits; Use Value

5.2. Alexandria National Museum – Alexandria – Egypt

The city of Alexandria is one of the most culturally rich cities in Egypt. It witnessed the presence of different successive cultures that affected its heritage. Its built heritage reflects a multi-cultural value, which is a distinguishing feature of Alexandria. The presence of many foreigners who lived in the city for many years introduced a variety of

architectural styles, [37] . However, Alexandria has recently suffered a continuous loss of its built heritage. The unsettled period following the 2011 revolution led to the destruction of many heritage buildings which extended till present. Many other buildings are under the threat of destruction and suffer from deteriorated conditions, [32].

Protection of the built heritage requires more attention. The reuse of one of the old villas in Alexandria as a national museum is an example of built heritage protection. The villa originally owned by Al-Saad Bassili Pasha was then owned by the United States government that used it as a consulate. The Egyptian Ministry of Culture bought the building in order to reuse it as a national museum. The plan of the reuse ensures the importance of keeping the architectural features of the villa regarding both the interior spaces and the external elevations. New feature required for the museum use was added, [33].

Alexandria National Museum – Alexandria – Egypt ([33])

<i>Background</i>	Date	1931
	Original Owner	Al-Saad Bassili Pasha
	Original Use	Residential
<i>Cultural Values</i>	Social Evidential	A representative place of social life of upper class families who lived in Alexandria. It was an upper-class meeting place
	Architectural	Represents the multi-cultural value in Alexandria
		Neo-Renaissance style with classical decorative elements
<i>Current Use</i>	Alexandria National Museum	
<i>Goals of Reuse</i>	Preservation of the main villa and redesigning the garden around it	
	Enhancing the circulation system inside the villa to accommodate the new use as a museum	
<i>Examples of Added Elements for the Reuse</i>	New glass showcases designed in diagonal orientation for the display of the artefacts	The original setting and decoration kept without interfering Criticized by users Seen as an efficient use of space providing more show areas by professionals
	Fire safety measurements	Safety requirements
	New mechanical, electrical and acoustic installation	Performance enhancement
	Provided the residents with sense of neighbourhood history and memory	Use Values and Cultural Values

6. Findings

Findings of this paper were based on both extant literature review and analysis of examples. They provide useful framework for the conservation of heritage buildings in general and in the Egyptian context in particular. This framework merges sustainable retrofit as a conservation approach, HBIM as a computational tool and heritage values as guiding principles. Figure (3): Shows the suggested framework, divided into five main phases: initiation, planning, implementation, monitoring and assessment.

Phase one: Initiation: includes setting a vision for the conservation project. It comprises two sub-phases: value determination and problem formulation. In value determination, the decision about the building value is determined

according to the defined law. Once a building is classified as a heritage or valuable building, it becomes protected under the law. The law also regulates the whole process of conservation related to the building. If the building was decided to be reused, then many requirements from both sides of retrofit and heritage values need to be considered.

On the other hand, the phase of problem formulation starts with studying current situation in order to detect problems and analyse needs. This is done by collecting data using laser/image survey data and identifying historic details from architectural pattern books. The later process is performed in order to present a 3d model with detailed information and data, such as: drawings, structural elements, mechanical systems, material measurements, data suppliers, scheduling and financial data identifying the existing situation of the building.

In addition to collecting technical data, value-related data are also gathered. Determination of values is important; it can be taken into consideration and even enhanced throughout the conservation processes. Retrofitting for better energy performance should not overlook other important values. Goals and strategies of conservation should balance between requirements of retrofit and ensuring the building heritage value, to provide more benefits for the community. Built modelling requires information about all features of the building and the degree of allowed interventions.

Phase 2: Planning: It includes the design process. This phase starts by setting goals and strategies that can identify the building elements which need retrofitting and applying the suitable technique on the building on the detailed 3D model and the automated documentation in the form of engineering drawings that help in applying the main aim of retrofit. Planning and design provide different alternatives for the conservation of the building. The input of heritage value will be one important side of evaluation of this alternative, which forms phase 3 (Evaluation).

Phase 3: Evaluation of executed alternatives: It includes selecting the alternative that has both minimum effects on heritage values and is most efficient in sustainable retrofit. This is done by using simulation tools embedded in HBIM as a testing tool that can help to compare different design options and make decisions about the solutions that will be applied further on the project. Achieving community cooperation and participation, as well as a good communication among the professionals responsible for this process, are crucial in this phase. At the end of this phase, the best alternative should be selected and is further implemented in Phase 4, based on a number of factors:

- Maximizing the benefits of the building;
- Enhancing the building performance;
- Highlighting the heritage values of the building;
- Achieving sustainable design goals, including reducing energy use, costs and environmental impacts of the property;
- Adding green improvements and optimizing financial performance.

Phase 4: Implementation phase represents the actual application of the best selected sustainable retrofitting design solution. It follows the evaluation of executed alternatives phase and is followed by the final Assessment phase.

Phase 5: Performance assessment: it aims to making sure of achieving high building performance. Different methods of assessment can be applied here, including:

- Mock-ups assessment to provide a visual sense of what the final version might look like.
- Risk assessment through understanding the specific risks of different features and avoiding untested features or strategies with unclear track records.
- Sustainable performance assessment of the building which includes process performance (e.g. integrated design, energy modeling, contracts, etc.), feature or system performance (e.g. energy/water, indoor environment quality, materials and resources, etc.), building performance (e.g. public benefits, sustainability compliance, flexibility and adaptability, etc.), market performance (e.g. operating costs, investor demand, space user demand, etc.) and financial performance (e.g. return on investment, risk and value).

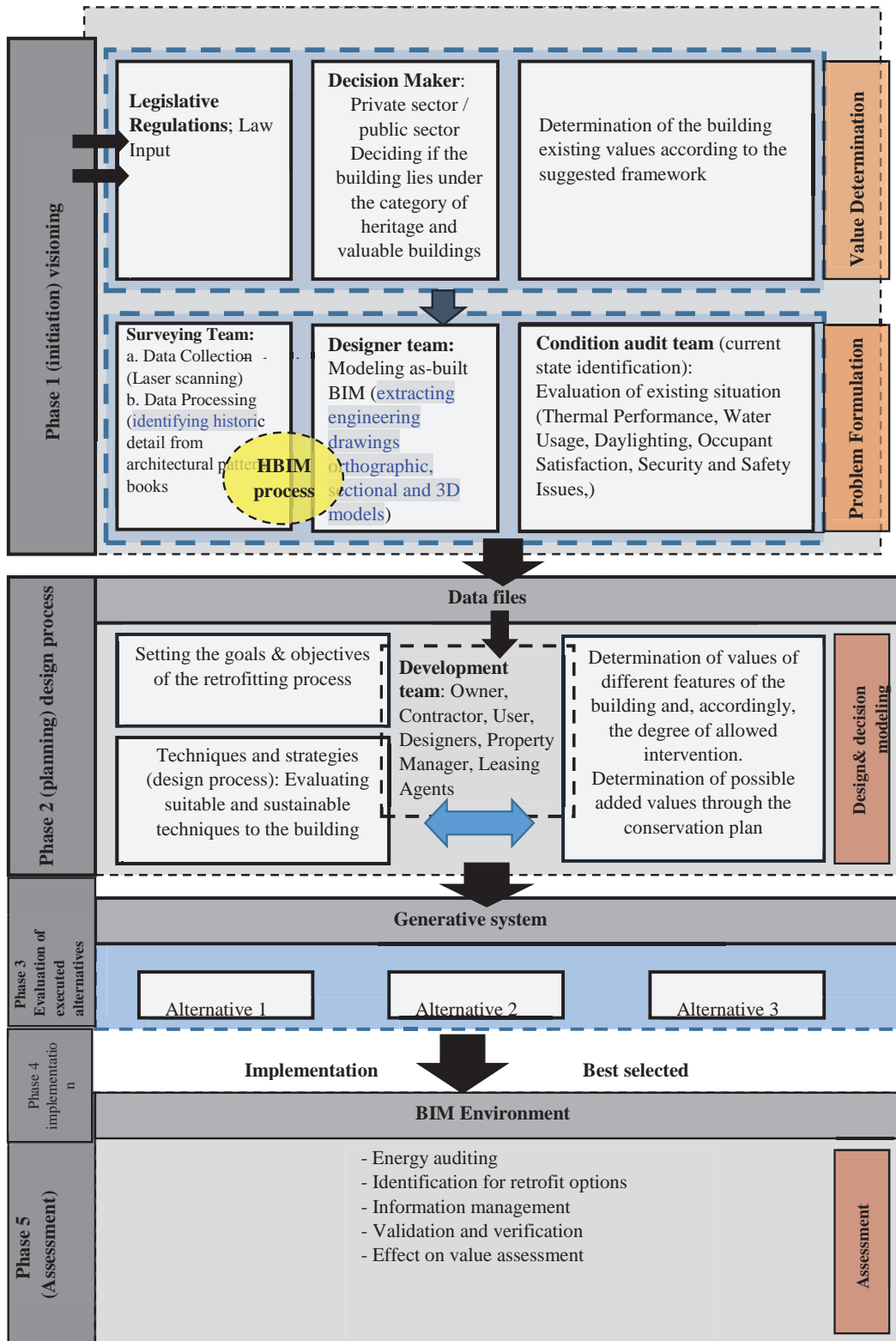


Figure (3): Suggested framework

Conclusions

Based upon the analysis of examples presented in this paper, it is obvious that applying both HBIM and sustainable retrofit on heritage buildings in Egypt is still limited and faces a number of challenges. Among these challenges are the unavailability of equipment, limited availability of professionals, and funding and financial-related challenges. This calls for the need of inviting different international entities that are concerned with conserving worldwide heritage to share in training of expertise and funding such projects.

It is worth mentioning that the suggested framework presented in this paper is still a theoretical outline, it has not been applied yet. The goal was to integrate different sides of conservation in one framework that depends on a scientific background. This framework needs further evaluation and feedback from the operational perspective.

Conservation of heritage buildings in Egypt requires stronger legislative support. The Egyptian law which forms the first key entry for the suggested framework, with its current form, allows for manipulation. The ability to manipulate made it easier for building owners to skip listing their buildings among valuable and heritage buildings. It requires stronger clarification to be more obligatory.

Spreading awareness of the value of built heritage is another important issue. Built heritage conservation is not contradictory to providing owners with economic benefits. The building can be reused for different purposes without demolition and rebuilt. In fact, the National Organization for Urban Harmony in Egypt should provide help in spreading awareness, guidelines and rules that facilitate the application of sustainable retrofit and in setting rules for the collaboration of community members into this process.

The cost of applying both HBIM tools and sustainable retrofit processes on heritage buildings is the primary determinant in selecting acceptable risk for evaluation standards and for selecting the minimum performance objective for retrofit public policy. Energy efficiency retrofits have shown attractive returns on investment when applied in countries like the UK and China, since such measures do not only generate direct cost savings, but they also show positive impacts on the overall value of buildings. However this issue is highly debatable within the Egyptian context, as demolishing an old building and building a new multi-storey one can be more beneficial for the owner of the building. In conclusion, this paper calls for a more detailed study of the short-term benefits versus long term benefits and the return on investment from applying both HBIM and sustainable retrofit on heritage buildings in Egypt.

References

- [1] C. Dümcke and M. Gnedovsky, "The Social and Economic Value of Cultural Heritage: Literature Review," *Eur. Expert Netw. Cult.*, 2013.
- [2] May N, Griffiths N. Planning responsible retrofit of traditional buildings. Sustainable Traditional Building Alliance; 2015.
- [3] Cadw, "Criteria for Assessing Historic Buildings for the Purposes of Grant Assistance." Llywodraeth Cymru Welsh Government, 2011.
- [4] A. Riegl, "The Modern Cult of Monuments: Its Essence and its Development," *Hist. Philos. Issues Conserv. Cult. Herit.*, pp. 69–83, 1996.
- [5] National Organization of Urban Harmony, Principles and Standards of Urban Harmony for Heritage and Special Value Buildings and Areas: Reference Guide, 1st ed. Cairo: National Organization of Urban Harmony - Egyptian Ministry of Culture, 2010.
- [6] J. D. Moore, *Visions of Culture: An Introduction to Anthropological Theories and Theorists*, 4th ed. Rowman Altamira, 2012.
- [7] Ministry of Housing, Utilities and Urban Development, "Implementation Regulations of the Law no. 144, Year 2006 about the Regulation of the Demolition of Structurally Safe Buildings and Architectural History Protection," *The Official Egyptian Journal*, 04-Nov-2006.
- [8] Cairoserver, "11 Recent Cultural Disasters in Egypt," Cairoserver, 2014. [Online]. Available: <http://cairoserver.com/post/75403717693/11-recent-cultural-disasters-in-egypt#.VfB43dJViko>. [Accessed: 09-Sep-2015].
- [9] D. Bakhom, "The Waqf System and the Maintenance Cairo's Historic Buildings," Cairoserver, 2014. [Online]. Available: <http://cairoserver.com/post/73345721523/the-waqf-system-and-the-maintenance-of-cairos#.VfB5bNJViko>. [Accessed: 09-Sep-2015].
- [10] CEN, EN 15898-Conservation of Cultural Property - Main General Terms and Definitions, European Committee for Standardization, Brussels, 2011.
- [11] Mazzarella L. Energy retrofit of historic and existing buildings. The legislative and regulatory point of view, Italy; *Energy Buildings* (2014).
- [12] BPIE, Europe's Buildings under the Microscope, Buildings Performance Institute, Europe, 2011.
- [13] Georgia Department of Natural Resources – Historic Preservation Division, What makes a property "historic?", 2014, Retrieved from <http://www.georgiashpo.org/register>.
- [14] European Parliament, Directive 2002/91/EC of The European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, Official Journal of the European Union. L 1/65,2003 04.1.
- [15] Douglas J. (2006). *Building Retrofit* Butterworth Heinemann.
- [16] Wilkinson S. Sustainable Retrofit Potential in Lower Quality Office Stock in The Central Business District. Management and Innovation for a Sustainable Built Environment conference, Australia; 2011.

- [17] Riley M, Cotgrave A. *Construction Technology 3: The Technology of Refurbishment and Maintenance*, New York, Palgrave Macmillan. ISBN-13 : 978-0-230-29014-3; 2011.
- [18] Ryu H. *Sustainable building refurbishment: Process-based approaches with the Hotel Klaus K refurbishment case*, M.Sc. degree in architecture, Aalto University; 2014.
- [19] EHS book regulation .*Green Building regulation for developments*. Under Dubai World Jurisdiction; June 2013.
- [20] BCA Building and Construction Authority. *Existing building retrofit*. Singapore; 2010.
- [21] Tobias, Leanne, and George Vavaroutsos, et al. *Retrofitting Office Buildings to Be Green and Energy-Efficient: Optimizing Building Performance, Tenant Satisfaction and Financial return*. Washington, D.C.: Urban Land Institute; 2009.
- [22] Abraham, Loren E, et al. *Sustainable Building Technical Manual: Green Building Design, Construction and Operations*. Public technology; 1996.
- [23] Murphy M, McGovern E, Pavia S. *Historic Building Information Modelling – Adding intelligence to laser and image based surveys of European classical architecture*. ISPRS Journal of Photogrammetry and Remote Sensing, Ireland; 2013, vol.76, pp. 89-102.
- [24] Dore C, Murphy M. *Integration of Historic Building Information Modeling and 3D GIS for Recording and Managing Cultural Heritage Sites*, 18th International Conference on Virtual Systems and Multimedia: "Virtual Systems in the Information Society"; 2-5 September 2012, Milan, Italy, pp. 369-376.
- [25] R. Quattrini, E. S. Malinverni, P. Clini, R. Nespeca, E. Orlietti. *From TLS to HBIM. High Quality Semantically-Aware 3D Modelling of Complex Architecture*, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-5/W4, 2015, 3D Virtual Reconstruction and Visualization of Complex Architectures; 25-27, February 2015, Avila, Spain.
- [26] Murphy M, McGovern E, Pavia S. *Historic building information modeling (HBIM) (structural Survey)*; 2009, Vol. 27 (Issue: 4.); pp. 311 – 327.
- [27] S. Logothetis, A. Delinasiou, E. Stylianidis. *Building Information Modelling For Cultural Heritage: A Review*. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume II-5/W3, 2015, 25th International CIPA Symposium 2015; 31 August – 04 September 2015, Taipei, Taiwan.
- [28] H. M. Gadou, "Use Of Airborne Laser Scanning (ALS) for 3D Modelling in Dense Urban Areas," *J. Urban Res.*
- [29] "3D Laser Scanning at the Red Monastery Church Project," *The American Research Center in Egypt*. [Online]. Available: <http://www.arce.org/expeditions/projects/u138>. [Accessed: 18-Sep-2015].
- [30] "3D Laser Scanning and Tutankhamun," *Laser Scanning Europe*, 27-Dec-2010. [Online]. Available: <http://www.laserscanning-europe.com/de/node/877>. [Accessed: 18-Sep-2015].
- [31] A. Baik, J. Boehm and S. Robson, "Jeddah Historical Building Information Modelling 'JHBIM' Old Jeddah–Saudi Arabia," 2013.
- [32] T. Rollins, "Understanding Alexandria's Embattled Urban Heritage," *Middle East Eye*, 12-Feb-2015.
- [33] D. A. Elsorady, "Assessment of the Compatibility of New Uses for Heritage Buildings: The Example of Alexandria National Museum, Alexandria, Egypt," *J. Cult. Herit.*, vol. 15, no. 5, pp. 511–521, 2014.
- [34] *Conserve and Revitalise Hong Kong Heritage Buildings*, "Revitalising Historic Buildings through Partnership Scheme: Lui Seng Chun, Resource Kit." 20-Apr-2013.
- [35] W, HO, "The Impact of Climate Change in Hong Kong on the Strategic Planning for Built Heritage – A Case Review of Lui Seng Chun," in 1st International Academic Conference on Climate Change and Sustainable Heritage 2015, Graz, Austria, 2015.
- [36] AGC Design Ltd, "Revitalisation Scheme – Conversion of Lui Seng Chun into Hong Kong Baptist University of Chinese Medicine and Healthcare Centre." LCSD, Apr-2010.
- [37] K. Heba, "Preserving Architectural Heritage in Historical Cities." Department of Architecture, Al-Azhar University.