GIS and BIM as data sources for sustainable Heritage building retrofit in Basrah City-Iraq

Dr. Ammar Jasim Dakhil
Assistant professor, Civil Engineering Department- College of Engineering, University of Basrah
Basrah, Iraq
ammar.dakhil@uobasrah.edu.iq

Dr Hamed H. Samir
Assistant professor, Architect Engineering Department- College of Engineering, University of BasrahBasrah, Iraq
hamed.samir@uobasrah.edu.iq

Dr Wisam Alawadi
Lecturer, Civil Engineering Department- College of Engineering, University of Basrah
Basrah, Iraq
wisam.abd-ali@uobasrah.edu.iq

Dr. Ayman Alak Hassan
Assistant professor, Civil Engineering Department- College of Engineering, University of Basrah
Basrah, Iraq
ayman.alk@uobasrah.edu.iq

***Abstract*— The integration of multidisciplinary data inside an information system is widely recognized as a crucial aspect in the context of rehabilitation programs. A comprehensive understanding of the condition of preservation and the decision-making process is essential for the sustainable restoration of a given entity. Furthermore, preserving structural integrity in a historic building, particularly one that has undergone multiple construction phases and restoration interventions, necessitates a comprehensive approach incorporating the analysis of diverse disciplines such as history, architecture, building materials, and geometric data. This study describes the elaboration of data within 2D and 3D information systems. This study presents an approach that collects, classifies, and manages diverse multisensory data, which is subsequently implemented within a geographic information system (GIS). In addition, the process of multidisciplinary documentation, along with surveying products, creates a three-dimensional heritage building information model (HBIM). This model encompasses many details pertaining to the construction stages, pathophysiology, and present condition of a structure, contributing to the overall preservation efforts. The objective of this study is to analyze the fundamental characteristics of GIS and BIM that can effectively facilitate the retrofitting of historic buildings. Furthermore, the present study aims to elucidate the primary obstacles associated with the modification of heritage buildings by analyzing various case studies documented in the existing literature. This study presents a proposed retrofit methodology that aims to streamline the retrofit process, with a particular focus on Shanashel, a building of historical significance situated in Basrah City, Iraq.**

Keywords—BIM, GIS, Heritage, Building, Retrofit

I. INTRODUCTION

Neglect of heritage buildings can have profound and far-reaching effects on the buildings themselves and the communities they are a part of [1]. These effects can include physical deterioration, loss of historical identity, aesthetic decline, safety hazards, decreased livability, and missed adaptive reuse opportunities [1,2]. To mitigate the effects of heritage building neglect, proactive preservation efforts, community engagement, awareness campaigns, and policies incentivizing restoration and adaptive reuse are crucial. It's important to recognize the value of heritage buildings as cultural and historical assets that contribute to the vitality of communities [3]. Heritage building retrofitting encompasses enhancing and refurbishing historical or heritage structures to enhance their structural soundness, energy efficiency, safety, and overall usefulness while safeguarding their historical and architectural significance [4]. The retrofitting process is necessary to ensure that these structures can effectively fulfill their original functions while adhering to contemporary norms and demands. Meanwhile, retrofitting heritage buildings presents a unique set of challenges due to balancing modernization with preserving historical and cultural value [4,5]. These challenges require careful consideration and specialized approaches. Some key challenges are preserving historical character, materials and techniques, structural integrity, energy efficiency, long-term maintenance, accessibility, and time and cost [6]. Successfully retrofitting heritage buildings requires a multidisciplinary approach that involves architects, engineers, historians, preservationists, and community members. Building Information Modelling (BIM) and Geographic Information Systems (GIS) are software tools and methodologies that can address these difficulties [7,8].

Building Information Modelling (BIM) is a digital process that involves creating and managing a 3D model of a building's physical and functional characteristics [9]. While BIM is often associated with modern construction projects, it can also be utilized for heritage or historic buildings to aid in their preservation, restoration, and maintenance. It's important to note that applying BIM to heritage buildings requires careful consideration of the building's unique characteristics, historical significance, and the expertise of heritage conservation professionals. The goal should be to balance modern technology's benefits with preserving the building's historical integrity [10].

Geographic Information Systems (GIS) are powerful tools for capturing, managing, analyzing, and visualizing geographic and spatial data [11]. GIS can offer numerous benefits regarding documentation, analysis, planning, and public engagement when applied to heritage buildings and historic preservation. It's important to approach GIS for heritage buildings with a clear understanding of the building's historical value, the objectives of preservation efforts, and the ethical considerations involved in sharing sensitive data. GIS can significantly contribute to heritage buildings' documentation, analysis, and continued appreciation when used thoughtfully and with other preservation methods [12].

II. BASRAH CITY'S HISTORICAL BACKGROUND

Shanasheel heritage buildings are a distinctive architectural feature found in the Old City of Basra, Iraq, as shown in Fig. 1 [13]. These buildings are characterized by their intricately carved wooden window screens, known as "shanasheel," a hallmark of traditional Iraqi architecture [14]. The Old City of Basra contains a collection of these historic structures, which provide insights into the cultural and architectural heritage of the region. Key features of Shanasheel heritage buildings in the Old City of Basra include [14,15]:

1. Shanasheel Windows: The most notable feature of these buildings is the shanasheel, which are beautifully carved wooden window screens. These screens are often adorned with intricate geometric patterns, floral motifs, and calligraphy. Shanasheel windows are designed to allow for natural ventilation while providing privacy to the occupants.
2. Wooden Architecture: Shanasheel buildings typically use wood and mudbrick. The wood is used for the intricate window screens and structural elements such as beams and columns. The combination of wood and mudbrick construction is well-suited to the local climate.
3. Cultural Significance: Shanasheel heritage buildings reflect Basra and Iraq's cultural heritage and traditional craftsmanship. They showcase the skill of local artisans and the influence of Islamic art and design on architecture.
4. Architectural Style: The architectural style of Shanasheel heritage buildings is a blend of traditional Iraqi and Islamic architectural elements. Islamic geometric patterns and the desire for privacy in residential spaces influence the designs.
5. Urban Fabric: Shanasheel heritage buildings contribute to the unique urban fabric of the Old City of Basra. Their presence shapes the streetscape and provides a sense of continuity with the past in a rapidly changing urban environment.
6. Preservation Challenges: Like many historical areas, the Old City of Basra and its Shanasheel heritage buildings face preservation challenges due to urban development, neglect, and inadequate infrastructure. Efforts to preserve and restore these buildings are important to maintain the cultural and architectural heritage of the city.
7. Cultural Identity: Shanasheel heritage buildings are not only architectural structures but also symbols of cultural identity and historical memory for the residents of Basra. They represent a connection to the city's past and traditions.

Efforts to preserve and promote Shanasheel heritage buildings often involve a combination of architectural conservation, community engagement, and urban planning. These structures hold cultural and historical significance and offer a glimpse into earlier eras' architectural and artistic achievements. By recognizing and protecting these buildings, communities can maintain a link to their heritage while contributing to the uniqueness and diversity of urban landscapes.

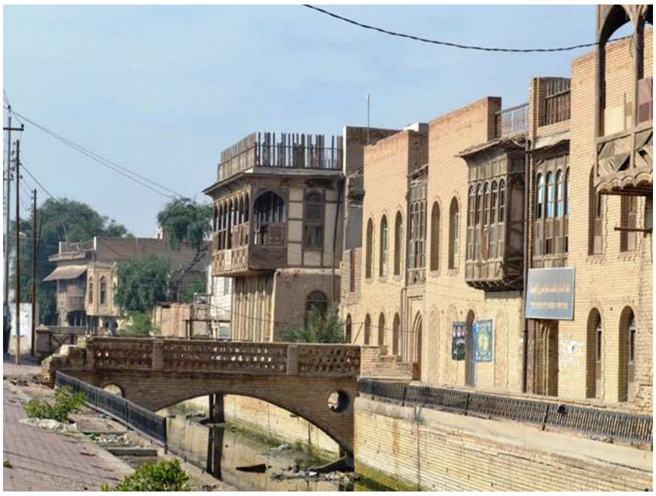

Fig. 1. Shanasheel heritage buildings in the Old City of Basra.

III. EXISTING TECHNOLOGY TOOLS

A. BIM

The process of BIM entails the creation and management of a three-dimensional model that encompasses both the physical and functional attributes of a building. BIM surpasses conventional 2D architectural drawings by integrating comprehensive information about a structure's various components, materials, and systems, along with their intricate interactions and interdependencies. BIM has significantly transformed the construction and design sectors by implementing a collaborative platform that effectively improves efficiency, accuracy, and communication across the building lifecycle. Several key components of BIM encompass [9,10]:

1. The process of 3D modeling involves the utilization of BIM to generate a comprehensive and precise digital representation of a structure. This model effectively captures the building's geometry, layout, and many components. The presented model functions as a visual depiction of the tangible structure.
2. The data integration process in BIM involves incorporating many data types into the model, encompassing architectural, structural, mechanical, electrical, and plumbing information. The data is structured into various components, each possessing features including dimensions, materials, pricing, and maintenance schedules.
3. Collaboration is a key aspect facilitated by BIM in the context of construction projects. BIM enables effective coordination and cooperation among stakeholders involved in the project, such as architects, engineers, contractors, facility managers, and owners. The shared approach allows for universal access and participation

from all stakeholders, enhancing communication and facilitating more effective decision-making processes.

4. Utilizing a three-dimensional model allows stakeholders to visually see the design and arrangement of the building, hence facilitating the design evaluation, analysis, and presentation to clients or regulatory authorities.

5. BIM software facilitates the execution of simulations and analyses, encompassing evaluations of structural integrity, assessments of energy performance, and detecting clashes between distinct systems, such as Heating, Ventilation, and Air Conditioning (HVAC) and electrical systems.

6. Efficiency is enhanced by implementing BIM since it simplifies design and construction processes. This results in a reduction of errors, rework, and delays. Modifications implemented in a particular model facet are automatically reflected in associated components, maintaining coherence.

7. Cost Estimation: BIM can effectively estimate precise costs by directly correlating costs and components such as materials, labor, and additional resources inside the model.

8. Utilizing BIM technologies can benefit project scheduling and sequencing. These tools facilitate the visualization of the construction process, enabling the identification of potential conflicts and the optimization of construction timetables.

9. The utilization of BIM extends to the operational stage of a building's life cycle in the field of facility management. The tool is a great asset for facility managers, as it strategically plans maintenance activities, repairs, and upgrades.

10. The adaptability of BIM models allows for convenient modifications to accommodate design changes, adjustments, and upgrades over the lifespan of a building.

11. The application of BIM enables the examination and enhancement of the ecological aspects of a structure, encompassing energy consumption, carbon emissions, and natural illumination.

12. The utilization of BIM can effectively facilitate regulatory compliance by ensuring that the design and construction processes adhere to the prescribed building codes, standards, and regulations, hence meeting the necessary specifications.

BIM finds application in several sectors, encompassing design, engineering, construction, and facility management. Implementing this technology has resulted in enhanced operational effectiveness, less project expenditure, enhanced cooperation, and superior architectural planning, construction, and upkeep results.

B. GIS

Geographic Information Systems (GIS) are powerful tools to capture, manage, analyze, and visualize geographic and spatial data. GIS technology combines geographical information with attributes and data related to specific locations, enabling users to make informed decisions, understand patterns, and gain insights from spatial relationships. Here are some key aspects of GIS [11,12]:

1. Spatial Data: GIS primarily deals with spatial data, including information on specific geographic locations. This can range from simple coordinates to complex data layers like topography, land use, and population density.

2. Layers and Attributes: GIS allows you to create, manage, and overlay multiple spatial data layers. Each layer can have associated attributes, which provide additional information about the features on the map.

3. Data Collection: GIS can collect data from various sources, including satellite imagery, aerial photography, field surveys, sensors, and existing databases.

4. Data Management: GIS provides tools for storing, organizing, and managing spatial data in databases. This ensures that data is easily accessible and can be efficiently updated.

5. Spatial Analysis: GIS enables complex spatial analysis and modeling. It allows users to perform tasks like buffering, proximity analysis, spatial querying, and suitability analysis to understand spatial patterns and relationships.

6. Visualization: GIS allows you to create understandable maps and visualizations representing geographic data. These maps can display a wide range of information, from land features to demographic data.

7. Decision-Making: GIS helps make informed decisions by visualizing patterns and relationships in data. It aids in scenario planning, resource allocation, and risk assessment.

8. Environmental Management: GIS is widely used in environmental management for tasks like mapping ecosystems, monitoring wildlife habitats, tracking deforestation, and managing natural resources.

9. Urban Planning: Urban planners use GIS to analyze land use, transportation networks, infrastructure development, and population growth to make informed decisions about city development.

10. Emergency Management: GIS is crucial in emergency response and disaster management. It helps locate affected areas, coordinate resources, and assess the impact of natural disasters.

GIS has applications across numerous industries and disciplines, contributing to informed decision-making, efficient resource management, and a deeper understanding of spatial relationships. It has become an essential tool for professionals working with geographic data.

This research explores using GIS and BIM to support the sustainable Shanasheel heritage buildings retrofit process.

IV. RESEARCH METHODOLOGY

The present study is structured into two primary sections. The initial section of the study examines prior case studies that have effectively utilized BIM and GIS in the context of retrofitting heritage buildings. This portion also provides a detailed analysis of the essential prerequisites for such implementations. The subsequent section presents a set of criteria for the effective deployment of BIM and GIS in the context of preserving Shanasheel heritage buildings.

V. RECENT INITIATIVES

The study analyzed several case studies within the framework of incorporating BIM and GIS technologies to improve the effectiveness of retrofitting historical structures. Thorough investigations have been conducted on each case study to meticulously identify the requisites and obstacles associated with successfully integrating BIM and GIS, as shown in Table 1.

TABLE I. CASE STUDIES DETAILS

Ref.	Case study specifications		
	Case study	***Software***	***Challenges***
Göçer et al (2016)	Campus building	BIM & GIS	Capturing an accurate as-is building model
Gigliarelli et al (2017)	Four case studies buildings	BIM	Existing data
Wahed et al (2023)	Four case studies	BIM and GIS	Integration Between BIM and GIS
Pepe et al(2021)	A rock church	BIM and GIS	Limitations present in the management of information in BIM software
Congiu et al (2023)	Public building in Carbonia (Italy)	Special GIS platform with BIM	Optimizing the existing procedure
Diana et al (2022)	Three case studies	GIS and BIM	Data sources

The critical challenges and factors that contribute to the effective integration of BIM and GIS for the purpose of preserving historical buildings can be classified into three primary categories.

A- TECHNICAL FACTORS

These factors are mainly related to data management, starting from gathering existing structure data to modeling it to the data flow between GIS and BIM. Most of the previous case studies pointed out that the available standard data classification will prevent old elements from being classified automatically. In addition, the accuracy of gathering existing information is also considered as a considerable challenge.

B- Current procedures

Numerous methodologies documented in scholarly literature primarily concentrate on the collection of data pertaining exclusively to the energy consumption of historical buildings. The assessment of structural integrity is of utmost importance, particularly in light of the significant shift in seismic zoning that recognizes the susceptibility of these types of structures. Furthermore, the perspective of the surrounding society holds significance when considering any proposed alterations to heritage buildings. Due to the factors as mentioned above, the complexity of data collection procedures necessitates further simplification.

C- Data sources

Gathering data for heritage buildings can be challenging due to various factors, including the age of the structures, limited access, historical significance, preservation ethical dilemmas, inadequate documentation, and preservation concerns.

The retrofit of the Shanasheel heritage building encounters similar challenges as those previously mentioned. Furthermore, the local market is currently experiencing a shortage of professionals proficient in BIM and GIS, which will have a detrimental impact on the advancement of the retrofitting process.

This research paper introduces a systematic approach for initiating the retrofitting process of Shanasheel, as clarified in the subsequent section.

VI. RETROFIT METHODOLOGY

Based on the previous stage of this research, a retrofit methodology proposed which is divided in three stages as follows:

1- The first stage is also referred to as the conceptual stage. During this stage, both national and local authorities must establish strategic objectives pertaining to the modification of heritage buildings. These proposals necessitate evaluation and endorsement from both academic and industry experts, as well as the local community through their designated representatives. A sequence of deliberations and consultations aimed at formulating a practical approach for retrofitting heritage buildings in a manner that satisfies the requirements of all involved parties. Enrolling in a project fund is of paramount significance at this juncture, as it will have a significant impact on the retrofit strategy and the extent of implementation. A comprehensive execution plan will be formulated to address various modification scenarios for historical buildings, taking into consideration their unique circumstances. The diagram illustrating the conceptual progression of this stage is depicted in Fig. 2.

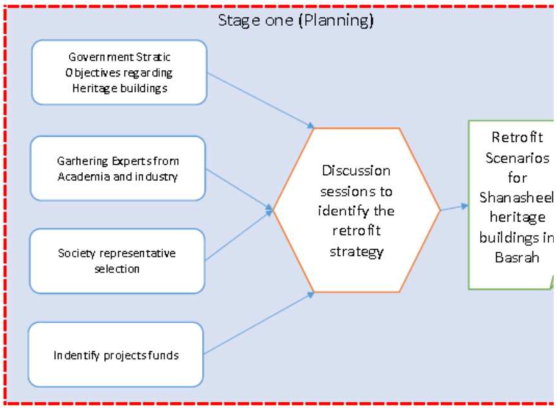

Fig. 2. Conceptual stage of retrofit strategy

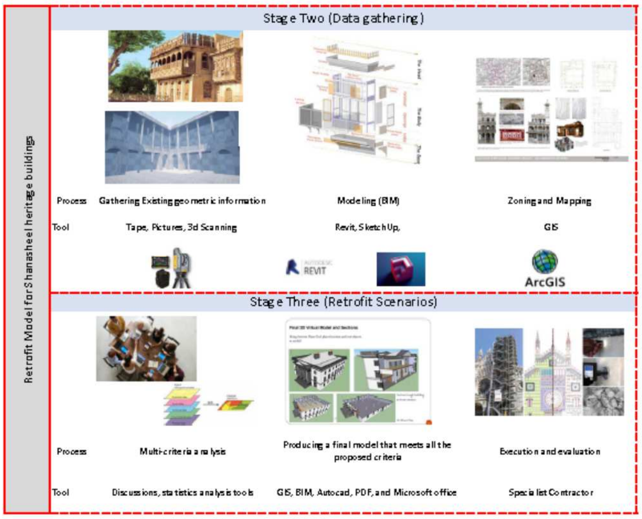

Fig. 3. Stages two and three phases

2- Stage two exemplifies one of the challenges outlined in the recent initiatives section. According to the consensus among experts, a significant dearth of information exists about the historical edifices in Basrah, particularly concerning shanasheel houses, which are under the ownership of various individuals. Current circumstances necessitate technology implementation to collect comprehensive data, including geometric information, material properties, modification history, structural safety, and existing limitations. Various tools will be employed, including a 3D laser scanner, measuring tape, photographs, and non-destructive testing methods. The entirety of this data will be migrated onto a BIM platform, such as Revit or Sketch-Up. The primary objective of this platform is to digitally reconstruct the model and ascertain the specific missing information required for comprehensive analysis. Consequently, there will be a continuous exchange of information between the data-gathering and modeling stages until the final model is deemed satisfactory. As previously stated, the built environment has the potential to influence and alter various types of structures, including historical buildings, as a result of the unique requirements associated with their preservation and restoration. Hence, the utilization of a GIS platform is crucial for the comprehensive collection and analysis of data concerning the surrounding environment. Additionally, a sequence of circular interactions will occur between the BIM model and GIS in order to ultimately resolve all limitations. This stage and stage three steps are represented in Fig. 3.

3- Retrofit scenarios
During this phase, various retrofit scenarios will be deliberated upon by all relevant stakeholders, with the assistance of specialized retrofit firms. The utilization of BIM and GIS as tools for data management offers a notable opportunity for optimizing the selection of retrofit scenarios.
The ultimate model will proceed to the conclusive production phase, wherein all essential documentation, including drawings and Bill of Quantities (BoQ), will be generated. Furthermore, supplementary documents encompassing safety, risks, quality, and execution plans will be formulated.
The concluding stage of this strategic approach is the execution phase, wherein all plans will be implemented to produce tangible outcomes. The significance of this stage lies in its capacity to analyze unforeseen risks and errors. This stage will offer insights gained that can aid in future planning and enhance efficiency.

VII. Conclusion

The process of retrofitting heritage buildings presents significant challenges, primarily stemming from factors such as the loss of historical information, the involvement of diverse stakeholders, and the inherent complexity of the retrofitting process. The current state of affairs in Iraq is exacerbated by a dearth of effective strategies and qualified experts. The utilization of contemporary technologies, such as Building Information Modeling (BIM) and Geographic Information Systems (GIS), has the potential to greatly streamline this particular procedure. This study conducted a comprehensive examination of prior research to ascertain the anticipated obstacles. Moreover, this study presents a viable retrofit strategy that can facilitate the retrofitting of historic buildings, specifically Al Shanasheel in Basrah City. The methodology comprises three interconnected stages, namely planning, gathering, and execution.

References

[1] Bernardi, A. (2008). Microclimate inside cultural heritage buildings. Il prato.

[2] Rebec, K. M., Deanovič, B., & Oostwegel, L. (2022). Old buildings need new ideas: Holistic integration of conservation-restoration process data using Heritage Building Information Modelling. Journal of Cultural Heritage, 55, 30-42.

[3] Rahman, M. A. A., Akasah, Z. A., Abdullah, M. S., Musa, M. K., & Sekitar, U. T. H. O. M. (2012). Issues and problems affecting the implementation and effectiveness of heritage buildings maintenance. In The International Conferences on Civil and Environmental Engineering Sustainability.

[4] Wise, F., Moncaster, A., & Jones, D. (2021). Rethinking retrofit of residential heritage buildings. Buildings and Cities, 2(1), 495-517.

[5] Nair, G., Verde, L., & Olofsson, T. (2022). A Review on Technical Challenges and Possibilities on Energy Efficient Retrofit Measures in Heritage Buildings. Energies, 15(20), 7472.

[6] Fouseki, K., & Cassar, M. (2014). Energy efficiency in heritage buildings—future challenges and research needs. The Historic Environment: Policy & Practice, 5(2), 95-100.

[7] Ma, Z., & Ren, Y. (2017). Integrated application of BIM and GIS: an overview. Procedia Engineering, 196, 1072-1079.

[8] Arayici, Y., Counsell, J., Mahdjoubi, L., Nagy, G. A., Hawas, S., & Dweidar, K. (Eds.). (2017). Heritage building information modelling. Taylor & Francis.

[9] Race, S. (2019). BIM demystified. Routledge.

[10] Teicholz, P. (Ed.). (2013). BIM for facility managers. John Wiley & Sons.

[11] Fotheringham, S., & Rogerson, P. (Eds.). (2013). Spatial analysis and GIS. Crc Press.

[12] Fabbri, K., Zuppiroli, M., & Ambrogio, K. (2012). Heritage buildings and energy performance: Mapping with GIS tools. Energy and buildings, 48, 137-145.

[13] Abd Alteef, E. G. (2022). Residents of Basra from the Companions. Journal Of Babylon Center for Humanities Studies, 12(1).

[14] Alqatrani, F. S. A. (2020). The Historical Dimension and Physical Characteristics of Al-Shanasheel Heritage Buildings in the Old City of Basra (Iraq). Journal of Basra researches for Human Sciences, 45(2).

[15] Mudhefer, M., Mutar, Q., & Magamis, S. (2022). The reality of heritage houses in the city of Basra and ways to preserve them. Adab Al-Kufa, (53).

[16] Göçer, Ö., Hua, Y. & Göçer, K. A BIM-GIS integrated pre-retrofit model for building data mapping. Build. Simul. 9, 513–527 (2016). https://doi.org/10.1007/s12273-016-0293-4

[17] Gigliarelli, E., Calcerano, F., & Cessari, L. (2017). Heritage Bim, numerical simulation and decision support systems: An integrated approach for historical buildings retrofit. Energy Procedia, 133, 135-144.

[18] Wahed, M. M. A., Mohammed, N. A. E. M., & Ismaeel, T. S. (2023). Integrating Building Information Modelling and Geographic Information System to Achieve Energy Efficiency in Buildings and Urban Areas. Green Building & Construction Economics, 63-79.

[19] Pepe, M., Costantino, D., Alfio, V. S., Restuccia, A. G., & Papalino, N. M. (2021). Scan to BIM for the digital management and representation in 3D GIS environment of cultural heritage site. Journal of Cultural Heritage, 50, 115-125.

[20] Congiu, E., Desogus, G., Frau, C., Gatto, G., & Pili, S. (2023). Web-Based Management of Public Buildings: A Workflow Based on Integration of BIM and IoT Sensors with a Web–GIS Portal. Buildings, 13(5), 1327.

[21] Diana, L., D'Auria, S., Acampa, G., & Marino, G. (2022). Assessment of Disused Public Buildings: Strategies and Tools for Reuse of Healthcare Structures. Sustainability, 14(4), 2361.