Developing a HBIM Shared Library for the Conservation of Jordan’s Heritage in the World Heritage City As-Salt and Capital City Amman

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Research Article

Keywords: BIM, shared library, heritage dissemination, parametric objects, digital technologies, Jordan

Posted Date: July 8th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1795201/v1

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Abstract

Jordan’s architectural heritage has gone through a long period of evolution and development: the result is a mixture of influences and traditions, from both Europe and the Middle East characterised by an optimal integration with the surrounding landscapes, making a great stride to conserve its buildings and historical heritage but has never adopted advanced technologies such as BIM. This is attributable to the lack of specialist training for the professionals within the sector, who remain unaware of the benefits that this methodology can offer.

This paper aims to optimise the management process to remedy the natural loss and misplaced historical documentation of heritage over time by creating a 3D library of BIM objects related to typical elements of Jordanian and Arabic architecture, specifically the House of Art in Amman and the Qaqish House in the World Heritage City of As-Salt.

This object database, represented through parametric BIM families (easily adaptable to any project of similar elements), will store information related to the geometry of individual objects, but also on the materials and their properties. By creating a library of 3D models of elements typical of the traditional Jordanian architecture, Jordan can acquire attractiveness on the part of tourists and art lovers, starting a chain reaction to get even more digital documentation and heritage conservation of the most historic cities in Jordan and, in general, in the Arabic world.

1 Introduction

Jordan is a MENA - Middle East/North Africa - country, characterised by serious problems regarding the conservation of built heritage, both archaeological and historical [1]. Culture and heritage in Jordan are no longer the domain of specialised experts in archaeology. In this context, the role of digital technologies has evolved in heritage conservation evolving into a medium for cultural identity and cross-cultural communication as well as a resource for tourism, economic and social development of local communities and regions in Jordan [1]. Architectural documentation has a fundamental role in conserving the built heritage since it is supportive of conservation interventions. The significance of this methodology lies in the fact that, over time, there is the possibility that the physical documentation may be fragmented and, therefore, be lost.

Introducing digital technologies, such as Heritage Building Information Modelling (HBIM), in the documentation of the built heritage leads to the possibility of creating 3D models that can be used as efficient communication tools, enclosing historical information, conservation status, data on the materials and construction techniques used [2]. Indeed, HBIM offers the possibility to integrate multiple layers of information and to link across industry, community and higher education with a flexibility and timeliness that traditional techniques such as paper-based drawings may not allow [3]. The connection between these layers allows for fewer discrepancies and errors that may occur when works are not completed in an integrated way, creating an integral base in which to access all the different data
Information about a particular heritage asset is also complex and interconnected with other actors. To achieve this, it is required to have multidisciplinary knowledge which leads to the process management of the lifecycle of the built heritage. Multidisciplinary knowledge is only reached through multidisciplinary teams, composed of engineers, architects, economists, historians, and more, who work in a more collaborative and shared approach, cooperating with a common purpose. BIM’s application is not limited to the drawing of the built heritage and its features, but it is much wider since it can be applied to everything concerning the existing building. This is especially significant when it comes to the built heritage when it is needed to integrate its conservation and its 2D representation, its historical (non-tangible information), technical, and architectural documentation (tangible information).

BIM is a recent technology in the construction industry of Jordan, even though it has already been considerably used in the rest of the world, as a matter of fact, it has not been carried out yet a study investigating the current situation of HBIM adopted in the heritage and construction industry in Jordan, since the majority of Jordanian construction and conservation relies mostly on 2D representation [4].

Currently, a shared library for historical Jordanian elements does not exist, hence why HBIM can help to create a library of objects related to the traditional architectural heritage in Jordan, objects that can be used by every entity involved in the intervention on the built heritage [5]. HBIM’s most important feature is the integration of data allowing for interdisciplinary decisions to be made based on models created and shared using BIM tools [6]. This paper is based on the project Herit-IT Conservation in Jordan [7], funded by the Royal Academy of Engineering, 2019–2022, and consisting of a tri-national research team from Jordan, United Kingdom and Italy. Therefore, this paper aims to discuss the methodology used in the Herit-IT Jordan project aimed at applying digital technologies for heritage documentation and promotion in Jordan, culminating in the release of a web-based, open access platform.

2 Methodology

Investigation and documentation of the built heritage are essential for its conservation and subsequent dissemination [8]. To reach this goal, several and constant interventions are conducted under an organisational management process, which requires a specialised methodological basis to address the complexity characterising historic buildings. Herit-IT Jordan, aimed to bridge the divide in Jordan by applying digital technologies to support heritage conservation plans. Co-production and collaboration with diverse stakeholders were central to the development of the methodology and design of the research. The tri-national team engaged early-on with national and local stakeholders in two main cities: (1) Capital City, Amman and (2) World Heritage City of As-Salt.

Despite the focus on the application of digital technologies to heritage, the fundamental goal was to influence and promote social cohesion, economic and technological development, tourism, and awareness of Jordanian cultural heritage. Early discussions with local stakeholders in the cities led to the co-identification of local vernacular architectural houses in each city that served as ideal for digitisation and application of HBIM. In the city of Amman, the research team in collaboration with Greater Amman
Municipality selected the Jordanian House of Art. In the city of As-Salt, the As-Salt Municipality and the research team selected the Qaqish House. National stakeholders such as the Jordanian Tourism Board and the National Heritage Council played key roles throughout the research project.

The developed methodological process is based on the problem of the fragmentation and inaccessibility of the information by all the entities of the interdisciplinary management process. The process is divided into six steps: a first presentation of the case study, a description of the survey conducted, a third step with the 3D modelling description, implementation of texture, creation of shared parameters and finally the online BIM library oriented to heritage dissemination.

3 Digitising Jordan's Historic Houses: Case Study Of House Of Art, Amman And Qaqish House, As-salt

3.1 Jordanian House of Art, Amman

The Jordanian House of Art (Fig. 1) - in Arabic “Beit Al-Fann” - is an original Ammani architectural building, characterising the social, cultural, and political timeline of the city, holding historical, artistic, and cultural value [9]. This building is one of the first buildings that started the gradual transformation of Amman from a village to a city [10].

The house is owned by a rich and military figure family, the Al Sukhun family. It is located on the outskirts of Downtown Amman, in the neighbourhood of Al Rjoum, in one of the oldest and most bustling streets of the capital, Prince Muhammad Street [11]. Anciently, this street was among Amman's first commercial areas, representing a commercial valley between residential hills [9]. It is a house where privacy is present since its entrance is set back from street level. The orientation of the house did not follow the street line but was built dynamically oriented towards a different angle, in such a way to ensure privacy and to have a wider entrance preceding the construction. At the end of the stairs, the visitor arrives at a large entrance in which stone arches of beautiful design rise [12].

The “Beit Al-Fann” has not always been in the form it can be seen today. It was designed by the Palestinian architect Fawwaz Al-Muhanna consisting of two storeys. The work was split into two stages, the first one included the construction of the ground floor, which took around three years between 1923 and 1926; the first floor was added in 1937. The house is built with an area of 1,300 square meters, and the construction area is 400 square meters built of stones brought from Palestine representing a mix of eastern and western influences [13].

Originally, the house has been the property of the first Jordanian to hold the position of commander of the Jordanian Badia Force, Ahed Al-Sukhun, from 1934 to 1938 [14]. When he left Amman to become mayor of Ma'an, a city 218 kilometres southwest of Amman, he started renting out the building to the Ministry of Education, which transformed it into Al-Zahraa School for girls, which operated until 1995 [9].
In 1995, the Greater Amman Municipality started renovating works on the building that lasted until 2002, year in which the house opened to the public with the new and current name of “The Jordanian House of Art”, enclosing an art museum, a theatre, and a cultural centre that preserves the memory of past generations and shows the authentic Jordanian heritage. The House (Fig. 2) was inaugurated on the 20th of May of 2002 by Queen Rania Al Abdullah, on the nomination of Amman as Arab Culture Capital for the year 2002 [14].

Over the years the house has held different roles, as the home of the first commander of the Jordanian Desert Force, Ahed Al-Sukhun; Al-Zahraa School for girls; it finally opened in 2002, after 7 years of restoration, with the new and current name of “The Jordanian House of Art”, enclosing an art museum, a theatre, and a cultural centre that preserves the memory of past generations and shows the authentic Jordanian heritage [14].

The building has not been built with the same material all around: some stones were brought from Palestine, which gave the building diversity, beauty, and distinction. The stones needed to complete the construction were collected directly from quarries in the areas near the capital. As for the roof of the house, the sand for its construction was brought on camels by the stream of Oman. Furthermore, the tiles arranged in the interior of the building differ from one room to the other in pattern and colour (Ali, 2021).

The construction's most eminent attribute is the interesting relationship it creates between the vegetation and the rising building elements, through which the landscape does not feel forced or artificial, but part of the spatial identity distinctive of the territory.

3.2 Qaqish House, World Heritage City, As-Salt

The Qaqish House (Fig. 3) - or Beit Qaqish, Arabic for “The House of the Qaqish” - is located in the Al Wal’a area, in Downtown As-Salt [15], and it is connected to the north of Al-Khader Street through a main stairway. The house is one of the oldest notable residences of As-Salt City, in west-central Jordan: it was built during the urbanisation period that characterized the city during the Ottoman empire, when elite merchants took As-Salt as a safe city for trade expansion to the east [16].

Its construction started in 1866 to end 39 years later, in 1905, upon request of the Qaqish family. It can be described as an extended “peasant” family house, then transformed into a merchant house, with a cross-vaulted iwan (Fig. 4) and a double terrace decorated by a false front wall with openings.

The building has a floor area of 300 square meters. It is orientated to the east, characteristic of the old cathedrals. It is composed of two floors: the entrance consists of three halls big enough to accommodate pilgrims and religious leaders who used to visit the house from the nearby churches. In the hall closer to the entrance, it can be found a fountain that was used to bring water to the horses that were placed in two halls to the right of the entrance – the walls of these halls are smooth and curved to allow horses to move freely and reduce obstacles. This led to having the rooms divided into two floors, in order to have privacy and segregation between public and private, between men and guests in the common area on the ground floor, and women and family on the first floor in the back. In order to increase privacy, on the first
floor there is an outdoor terrace backed up from street level, in such a way to have a buffer zone between the exterior and the interior of the house.

In 1989 the house underwent restoration, addressed to secure the house and improve its aesthetics (Fig. 5). Starting from 2006, the house has been donated to As-Salt Municipality, which converted it into the office of the As-Salt City Development Project.

4 Developing An Open-access Hbim Shared Library

4.1 Digital survey

The instrumentation used to carry out the survey consist of a laser scanner from Leica GeoSystems, the Leica RTC360 [17], which gathered a total of 47 internal and external scans from the House of Art and 56 from the Qaqish House (Fig. 6), due the geometrical complexity. This scanner by Leica (Table 1) is the smallest and lightest imaging laser scanner available on the market.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Height: 165 mm / Diameter: 100 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>1 kg</td>
</tr>
<tr>
<td>Laser class</td>
<td>Class 1 (in accordance with IEC 60825-1:2014)</td>
</tr>
<tr>
<td>Scanning range</td>
<td>min. 0.6 - up to 60 m</td>
</tr>
<tr>
<td>Point measurement rate</td>
<td>Up to 360'000 pts / sec</td>
</tr>
<tr>
<td>Measurement speed</td>
<td>&lt; 3 min for complete full-dome scan, spherical image &amp; thermal image</td>
</tr>
</tbody>
</table>

The data processing has been done with the Leica Cyclone software: what Cyclone does, using the Iterative Closest Point algorithm, is to look for all the possible overlaps between the scans; for each overlap, the program chooses the best matching point pairs between the two scans. As the last thing, the program runs a minimization among these matching point pairs of all the connections, minimizing the global error [19]. From Cyclone Register 360 it is easy to export the data into an LGS or RCP file: these files will be manipulated on Autodesk.

The point cloud thus obtained, in this case from both houses, must then be uploaded on the software Recap by Autodesk, in order to cancel the noise in the scan: noise includes furniture, interference of people, and vegetation. This RCP file, once saved, can be opened with the software Revit to generate the three-dimensional model.

On the other hand, also from the digital survey is possible to acquire the 360° spherical photos and videos that will used on the development of the virtual tour and to appreciate the quality of the materials
and geometry (Fig. 7). In fact, the real dimensions of the modelled objects will match exactly the information derived from the Virtual Tour and the Point Cloud.

### 4.2 Generation of the BIM objects

Since the Jordanian Architecture has a peculiar morphology, the project does not present standard components that may already be found in the Revit families’ catalogue. These elements need to be modelled from scratch with aim of configuring the corresponding parameters.

With regards to both Houses, thirty elements of interest were identified (Fig. 8, Fig. 9), which were grouped according to five categories for the House of Art: windows, doors, arches, columns, and balustrades (Table 2), and three categories for Qaqish House (Table 3): windows, doors and arches. Each element of the categories has been given an identification code and a name, indicating the storey to which they refer.
Table 2
Families composing the House of Art.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Cat. Identification Code</th>
<th>Family Name</th>
<th>Storey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>3</td>
<td>Main Double Window</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Double Window</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Triple Window</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Back Window 1</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Back Window 2</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>External Window</td>
<td>2/2</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Quadruple Window</td>
<td>2/2</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Internal Window</td>
<td>2/2</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Mini Back Superior Window</td>
<td>2/2</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Mini Back Inferior Window</td>
<td>1/2</td>
</tr>
<tr>
<td>Doors</td>
<td>1</td>
<td>Main Door</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Internal Inferior Door</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Back Door</td>
<td>1/2 &amp; 2/2</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Main Superior Door</td>
<td>2/2</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Internal Superior Door</td>
<td>2/2</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>Internal X Door</td>
<td>1/2</td>
</tr>
<tr>
<td>Columns</td>
<td>2</td>
<td>External Column</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Superior Column</td>
<td>2/2</td>
</tr>
<tr>
<td>Arches</td>
<td>20</td>
<td>External Arch</td>
<td>1/2</td>
</tr>
<tr>
<td>Balustrades</td>
<td>14</td>
<td>Balustrade</td>
<td>2/2</td>
</tr>
</tbody>
</table>
### Table 3
Families composing the Qaqish House.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Cat. Identification Code</th>
<th>Family Name</th>
<th>Storey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>2</td>
<td>Internal Window</td>
<td>2/2</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Superior Window</td>
<td>2/2</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Arched Window</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Window</td>
<td>2/2</td>
</tr>
<tr>
<td>Doors</td>
<td>1</td>
<td>Internal Door</td>
<td>2/2</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Glass Superior Door</td>
<td>2/2</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>External Door</td>
<td>1/2</td>
</tr>
<tr>
<td>Arches</td>
<td>3</td>
<td>Internal Arch 2</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Internal Arch</td>
<td>1/2</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>External Arches</td>
<td>2/2</td>
</tr>
</tbody>
</table>

Since the families that have been modelled are Revit loadable families (usable in other projects through the modification of the parameters), they have been created in an external file (RFA extension), in such a way to be later loadable in the family editor and imported into any Revit project: this is only possible adding some information parameters. This means that the families that have been produced for the House of Art may also be used for other buildings that present similar morphological characteristics.

The first step consisted in studying and understanding the geometry of the building, which was possible through both the point cloud and the virtual tour generated by the Leica TrueView software. Using these two tools, it was possible to measure the true size of the elements, making their digital representation faithful to reality (Fig. 9).

The actual modelling takes place in the Revit software, where it is first chosen from the templates the one suitable for our purpose, such as "metric door", "metric window", "metric column" and so on. Each template will already bring predefined parameters, such as the width and height of the element.

The geometry of the element is broken down into its elementary parts, which are then modelled individually through commands like extrusion, revolve and sweep (Fig. 10), both in the form of solids and voids. In Revit families, this geometry in families may be composed of solid and void forms.

To create the columns, the varieties of solid and void forms used are extrusion, revolve, and sweep. The shape perimeter is bound to parameters (in the form of quotas) and to reference planes (in green), so that, when the parameters related to those given reference planes are changed, the geometry moves in the desired way. All the parts of the column will depend on instance parameters, so that, in case of scale change or modulo adjustments, the column will move as we want it to.
In the case of the windows, after modelling all its parts (including sashes, frames, casings, mullions, and eventual window bars) making sure to constrain them to the reference planes, it can be tried to flex the family by editing its parameters to check if everything has been modelled following the parameters (Fig. 11). These windows must adapt to walls with different thicknesses, passing from external to internal walls, and this is where the parameters come to help.

To make the model more easily adaptable to any other project, it was necessary to create two different Family Types: one for the window itself, and another one containing the window bars (Fig. 12). In this way, it is possible to switch the visibility of the window bars off or on in case the windows of the building in which we are loading the family do not present this feature.

Once the modelling is complete, it has been necessary to introduce the building materials with their specific properties; they have been chosen from Revit Materials Browser. These have been edited (Fig. 13) according to our needs, so as to make them as similar as possible, in terms of aesthetics and physical and mechanical characteristics, to the materials of the House of Art.

4.3 Implementation of the texture

For what concerns the building stone, the Jordanian limestone, the limestone present in the Asset Browser of Revit did not respect the aesthetics of the house. For this reason, it was decided to implement the texture by using PBR materials [20], downloadable from online libraries.

PBR - Physically Based Rendering - is a rendering method that leads to higher accuracy of the representation of materials depending on how the light interacts with the surfaces on which is poured in a physically plausible way. For this case, colour, roughness, bump, and ambient occlusion maps were selected (Table 4).

Table 4

| Images contained in the PBR material folder and their characteristics [21]. |
When these maps are uploaded into Revit as the Appearance of the material renamed Jordanian Limestone, it is possible to render the family through a plug-in called Enscape, able to keep design and visualization all in one place, rendering a much more truthful visualization to reality than the realistic visualization of Revit (Fig. 14). From a distance, many details of the limestone can get lost, but looking closer the level of detail is clearly higher, able to guarantee the veracity of the real object.

4.4 Creation of shared parameters

HBIM most powerful feature is the integration of data: creating a parametric 3D model (the BIM families), every object will be linked to a table (the Types Properties table), where its parameters are shown. The main problem with these parameters is that they do not include information like historical documentation, photos, texts, condition details, URLs, despite being largely required in the heritage field.

The solution has been found in the creation of Revit Shared Parameters, which can be used in multiple families or projects and by multiple entities: to do this, Revit creates a .txt file independent of any family file or Revit project, allowing us to access the file from different families or projects (and even different devices). It has been first created the Parameter Group “House of Art” containing all the parameters/information we are interested in showing (Table 4). The parameter group will be loaded among the Family Types and the corresponding description will be added (Fig. 15).

In this way, it is possible to store into one place all the information related to that particular Family and the building to which it belongs. In addition to the simple text parameters, there were introduced URL parameters, capable of storing information such as the Google Maps location of the houses (Fig. 16),
accessible by clicking on the relevant parameter, and image parameters, relating to the position of the element in the architectural plan of the house or its state of conservation.

Once the parametric families have been created, it has been created a web portal where all the families can be uploaded (Fig. 18), to ensure that these objects can be downloaded by every part of the world and by every practitioner operating in the conservation field and used both for buildings in Jordan (specific materials, common material degradations, local construction techniques) and for heritage buildings in general.

5 Online 3d Bim Library

The online BIM library represents the culmination of this project, fulfilling the purpose that has been set at the beginning, which is the divulgation of Jordanian heritage and the promotion of the tourist image of Jordan. This will be the first library of historical elements of the Jordanian built heritage, crucial because it will set a precedent for further documentation and heritage conservation of traditional cities in Jordan, MENA countries and internationally. Once all the families were completed, an online portal was created to upload them, which can be visited from the Herit-IT Jordan project website, thus ensuring that the modelled objects can be downloaded from anywhere and by any professional involved in the conservation of Jordan's heritage.

The platform was created in collaboration with the ICT centre for Cultural Heritage of the University of Salerno[22]; through this platform, the user can register and download the family most suitable for their project, answering only two simple questions that consider the location of the institution or professional that uses the families and the final use of these. He may, if necessary, upload his library of unique families, in such a way as to continue the dissemination of the Jordanian heritage. The families were loaded in .RFA extension (belonging to all Revit loadable families) and can be downloaded in the same extension. For a better compatibility with the software of the other professionals, it was decided to work with the most updated version of the Revit software.

On the platform there will be four types of users:
- The unauthenticated user can browse the BIM library of the models that have been uploaded with public visibility, but he cannot download these elements;

- The registered user can browse the BIM library and download the files attached to it;

- The editor user is a registered user, but he has the ability to upload content on the platform and edit them;

- The administrator user is able to edit any type of content, and manage users. This user is managed by the University of Salerno.

It should also be noted that this methodology allows the work to be conducted entirely remotely, helping to continue heritage conservation even in times of pandemic or in situations that are difficult to access.
The HBIM models generated according to the proposed methodology can, in the future, be used to support heritage conservation interventions, ensuring both an updated record of past interventions and the planning of future interventions.

6 Final Outputs And Discussion

The present research aims to use an HBIM approach for the conservation of Jordanian architectural heritage, through the generation of a library of architectural parametric elements starting from their survey, accessible by every practitioner operating in the AECO (Architectural, Engineering, Constructions and Operations) sector in Jordan and the rest of the Arabic world. This main platform of the Herit-IT Jordan project (https://herititjordan.com/) and related library (https://hitj.centroictbc.unisa.it/) include a range of digital outcomes for the two pilot heritage buildings of Jordanian House of Art in Amman and Qaqish House in As-Salt, whose potential applications include (see table below):

<table>
<thead>
<tr>
<th>Digital outcomes</th>
<th>Potential applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual tours</td>
<td>Tourist promotion, including e-tourism enabling e-visits during pandemic, real estate promotion. Opportunity to include multiple layers of information, including semantic data and storytelling documenting intangible heritage values.</td>
</tr>
<tr>
<td>Point clouds</td>
<td>Accurate documentation of the state of the building, extremely useful in case of material losses to plan for the intervention of repair.</td>
</tr>
<tr>
<td>H-BIM model of the building</td>
<td>Extraction of 2D architectural drawings, including floorplans, sections, and elevations, usable to support conservation interventions for the specific building and for attracting investors.</td>
</tr>
<tr>
<td>H-BIM families</td>
<td>Systematic gathering of potentially unlimited data, including technical data related to materials, useful both for planning interventions related to the specific building, but also adaptable to similar typologies thanks to the parametric nature of the H-BIM.</td>
</tr>
</tbody>
</table>

The development of the House of Art as a case study through the digitisation of the Jordanian characteristic features demonstrate how the process can be applied to other Jordanian and Arabic buildings, in order to enrich the documentation of traditional heritage for future generations and increase the spread of the promotion and preservation of cultural heritage. Several infographic families generated through this study are not only a 3D reproduction of the real object, but it is able to store information about its essence, capable not only of keeping physical and geometric data of the elements, but also of allowing the analysis of a morphologically complex reality.

Preservation and valorisation of cultural heritage represent a problem that already existed before the Covid-19 pandemic, which has amplified it [23]. There are many challenges that the Jordanian construction sector needs to face regarding the introduction of BIM: they may be identified as the
absence of government incentives, the lack of BIM standards, the lack of BIM awareness and training as its absence in educational institutions curriculum, and low productivity, caused by overtime work and quality specifications [24]. HBIM has the potential to create a classification system for heritage buildings under threat and impact the application of heritage legislation and regulations [23]. The collection, management and storing of data for digital heritage requires an awareness of the issues of time and the power structures that are involved in their collection and upon which they have a profound effect [23]. Finance is a particularly important topic for the adoption of BIM in the Jordanian construction industry. Implementing BIM would increase costs such as the purchase of software, technical support, hardware, training, and services. Importance is also given to the human factor which affects the adoption of BIM in Jordan, such as the shortages of skilled and trained staff, the lack of interest and demand, dependence on unskilled staff in the construction sector, and lack of awareness. Communication represents another latent barrier for the development of BIM in Jordan. This includes weaknesses in communication between project parties, the lack of a legal framework for BIM, the approval system for new projects and traditional work processes [25]. Several surveys and interviews have been conducted during the years, studying the current level of BIM knowledge and experience in Jordan. One of them, conducted by the Al-Ahliyya Amman University between 2016 and 2017, was conducted collecting data among Jordanian architects, engineers, contractors (AEC), and other industry respondents; it shows that only 5% of the AEC companies and organizations are using Autodesk Revit (the most popular BIM software), but without having broad expertise in BIM competences. Furthermore, only big AEC companies deal with BIM on a large scale, whilst small AEC companies do not seem to want to take a step forward into the BIM technology, not being aware of BIM benefits. Another reason behind the little use of BIM in Jordan is the cost of the software, hardware, and training that is necessary to adopt the BIM technology [4].

As a result, the digitisation of cultural heritage gives the means to be able to link society and architecture digitally: this approach allows the realisation of the asset even at a distance, through the creation of virtual tours to make the spaces accessible for everyone, especially the non-technical sector. These alternative ways to visit these assets should not be considered as an alternative way to experience the site, but only as a promotional tool useful to widen the way to access cultural heritage, mostly in times of impossibility, such as during the pandemic. Jordanian government should, then, encourage BIM implementation in the construction projects at least on public works, offering incentives for BIM-based projects that can guarantee a positive outcome. Local standards for the BIM industry should also be set by the government, from a management point of view. This platform was created to that has the potential to become a single point of entry for all the digital data concerning heritage and to enable a unique knowledge sharing instruments to Jordanian planners, restorers, conservationists, citizens, and developers. In fact, in the Herit-IT Jordan project, these parametric 3D models will come with a table containing their parameters and characteristics creating a library of specific smart objects accessible to all users [26]. By creating a library of 3D parametric models of elements typical of the traditional Jordanian architecture with BIM methodology, Jordan can acquire attractiveness on the part of tourists and art lovers, starting a chain reaction to get even more digital documentation and heritage conservation of the most historic cities in Jordan and, in general, in the Arabic world.
Future uses and perspectives to expand this work to have the possibility to cover other buildings in Jordan, to create a complete documentation system, leading to a different level of knowledge of the architectural object, its story and its characteristics, and this will only be possible through an accurate digital survey and digital model. Careful attention should be given to surveying and reproducing in modelling software the historic heritage, because of its unique characteristics, materials, and construction techniques which make it non-reproducible. In the future, the BIM models can also be used for the management of the plans of heritage cities, boosting the tourist attractiveness of Jordanian cities, and helping in decision-making for conservation interventions. It would also be possible to keep an updated record of the maintenance logs, enhancing the facility management of the building and plan intervention in the short, medium, and long term through a PPM (Planned Preventative Maintenance). The application of this management model could revolutionize the way the management and maintenance of historical heritage are seen, not only allowing reorganisation and structure of the entire Jordanian historical heritage, but also ensuring constant and up-to-date maintenance, thereby preventing its degradation. Also, the ability to rely on a detailed parametric model allows any type of analysis without implying constant inspections of the element, providing a rapid and effective decision-making process. Moreover, the system could be linked with fire systems and security systems to protect these buildings.

7 Conclusion

It can be stated that there is a wide area between Jordan and the Levant that contains an abundance of rich heritage buildings and historic sites. However, considering the current unstable situation in the Levant caused by the war in Syria, Iraq, Iran and other war conflicts, nowadays the influx of refugees is prominent, and they are taking possession of the heritage buildings as living spaces, which clearly generates architectural changes. If the local government continues to ignore this problem, Jordan's heritage could be subject to demolition and/or alteration by these users (refugees). For this reason, it will be essential that research groups raise awareness of local needs and document historical and architectural heritage by sensitising and training the local community in the use of digital technologies.

In conclusion the library of BIM objects can be managed by those representing the entire construction industry and anyone who may be interested in the conservation of Jordan's heritage, because each object will carry important information for the correct conservation of that element. In the case of the Herit-IT Jordan project, the principal stakeholders for the pilot case are represented by The Greater Amman Municipality, Jordan Tourism Board, The Jordan Museum and another stakeholder as designers, companies, professional organisations, and universities with the ambition to extend this “network” in all the country not only regarding the tangible heritage, but also raising awareness among all people.

Declarations

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Competing interests**

The authors declare that they have no competing interests

**Funding**

This work was supported by the Royal Academy of Engineering and Industrial Research Development Fund with the Industry Academia Partnership Programme - 18/19 (project: IT and Conservation of traditional architecture and heritage, IAPP18-19\244).

**List of abbreviations: Not applicable**

**Authors' contributions**

Conceptualization, C.T and R.A.; methodology, C.T, R.A, C.M.; contextualization, A.M, C.U, K.B; resources, R.A, C.T; 3D BIM Objects development, E.P. and V.C; writing— original draft preparation, E.P, V.C, writing—review and editing, C.M, V.C, E.P.

**Acknowledgements**

The authors thank our funding bodies and all the stakeholders and experts who generously offered their time and expertise to support the data collection, including industrial partners including but not exhaustive of the Jordan Tourism Board, Greater Amman Municipality, As-Salt Municipality.

**References**


25. A. Alshdiefat, “Developing an Assessment Model for the Adoption of Building Information Modelling to Reduce the Cost of Change Orders in the Jordanian Construction Industry,” The University of Salford, Salford, 2017.


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