Research Article

Development of a Web Application for Historical Building Management through BIM Technology

F. Rodrigues,[1] J. Teixeira,[1] R. Matos,[1] and H. Rodrigues [2]

[1]*RISCO, University of Aveiro, Aveiro, Portugal*
[2]*RISCO, School of Technology and Management, Polytechnic Institute of Leiria, Portugal*

Correspondence should be addressed to H. Rodrigues; hugo.f.rodrigues@ipleiria.pt

Nowadays the built heritage has been recognized as one of the main sectors that can support the economic and sustainable development of countries. In the last years, the built heritage has been subject to several levels of interventions, being now clear its need for a proper maintenance and conservation management. However, in several cases, the maintenance faces lack of building records, which makes the maintenance a harsh, long, and expensive process. Therefore, there is an opportunity and need to apply new technologies, like Building Information Modelling (BIM), as supporting tool to the management of historical heritage. By so, the aim of this work was the development of a management system to be used as a supporting tool to the maintenance and conservation of the existent buildings, in historical context, facilitating to the interested parties the automated and digitized information needed to carry out the most varied tasks, with the particularity to be directly connected to the 3D-BIM model of the building. But in order to test the developed system (its applicability and functionality), it was in an early phase, applied to a pilot project with the significant heritage value. This work follows a development methodology applied to the case study and had different phases: (1) the case study was modelled in Autodesk Revit software, in whose model was inserted all the parametric information and associated metadata; (2) then, a support database of the management system was developed in Microsoft SQL Server, which will support all the information exported from the BIM model; (3) a web application was developed in C# through Visual Studio 2015, which works through and application programming interface (API) allowing the communication between the web application and the BIM model, allowing not only the interaction with the parametric information of this one, but also, a persistent access to a data management system (drawings, inspection reports, specifications, etc.) that has been created. The development of the management system and its application to the case study allows us to show its potential as a tool for the historical heritage management, contributing to its permanent and constantly updated management and cross off the fragmentation and loss of information therefore reducing the consequent investment in data collection.

1. Introduction

During last years, the historical and cultural heritage has been classified as a strategic sector for the development of economic, sustainable, and more cohesive society [1]. Countries have been concerning about the preservation of the historic assets, existing currently a special concern urban centres, which are the main holders of the historic heritage. However, the biggest concern related with refurbishment and maintenance interventions is the lack of data and information about existent buildings. The management and maintenance of buildings is a complex task and an onerous process.

Maintenance theory currently exists but fails when applied in practical application and implementation [2]. Thus, a study of heritage buildings management processes is essential.

Therefore, the main objective of this work is to propose a tool to integrate heritage buildings management within digital technologies, namely, Building Information Modelling (BIM).

The introduction of new digital technologies in the field of heritage is an opportunity to create three-dimensional models as effective communication tools, sharing and visualising interfaces either to physical and structural features, as for its historic inventory [3].

Depending on technology used, it is also possible to obtain other types of information, such as, historical data, conservation state, materials, and constructive techniques used [3]. Thus, it is recognized that BIM is a multidisciplinary technology and it is essential to building lifecycle management, such as, maintenance and development of the growing inventory of heritage [4].

BIM methodology has other applications and can be used as a database, to support project teams and to integrate as-built information in order to plan monitoring and maintenance of buildings during its lifecycle [5]. This information is supported by periodic visual inspections and monitoring equipment that are essential to preserve the historic heritage [3].

In this work, a methodology was developed and to be validated was applied to a case study.

The methodology adopted to be applied to the case study follows the following steps:

(1) Data analysis: architecture and structure projects, historic information throughout documentation analyses, and technical information by tests and visual inspections

(2) The object of study modelling in accordance with the BIM methodology with recourse to Revit Autodesk software

(3) Development of databases for the object of study inventory

(4) Development of a management model in Visual Studio 2015 with recourse to an API developed in C#

(5) Implementation of the management model inside of a web application

(6) Results analysis

Therefore, in the next chapters, some important concepts are approached to understand the methodology applied, and those are presented and validated by applying them to a case study. Finally, the results are analysed.

2. Review

2.1. Heritage Documentation.
Heritage documentation management encourages the use of computerized techniques to preserve the information produced [6]. The quantity of data produced during the working on a site can quickly become huge. The worldwide scientific work on the metadata concept is expanding rapidly. In heritage data recording, forums and institutions appeared, such as The Forum on Information Standards in Heritage (FISH) and the English Heritage Data Standards Units (DSU). This one works for the development of standards for heritage data.

There are also some approaches in web applications for management of cultural heritage, such as a web information system for the management and dissemination of cultural heritage data applied to archaeologist developed by Meyer et al. [6]. A web-based application for interactive users' access and exploration of three-dimensional models providing integrated geometrical and nongeometrical information by an intuitive interface is developed for cultural heritage sites and artefacts by Guarneri et al. [7].

there are some applications of 3D modelling to support cultural heritage management, namely, 3D models that include digital documentation of monuments and sites studied by Styliadis [8]; Pavlidis et al. [9]; Yilmaz et al. [10]; Haggrén et al. [11]; and Grussenmeyer and Jasmine [12].

Bassier et al. [13] compared the complex geometric models, considering the data acquisition, the modelling, and the structural analysis of timber roof structures defined in a Building Information Modelling to a traditional wire-frame model, and showed that the BIM complex models provide a more reliable result in terms of geometry and structural behaviour.

Portier et al. [14] presented a computerized methodology as an assistance tool for archaeological hypotheses. They present a study for storage and consultation of archaeological archives, for the communication functionality, for the exchange of information and creation of a virtual museum for ancient part of historic city. However, the software used was very expensive.

Lopez et al. [15] recognized that the current approaches show that BIM tools and GIS tools supported by auxiliary software are an effective solution for managing and modelling graphical and semantic data, in a semiautomatic way, and this is only possible once the common data structure IFC allows the interoperability of information and communication between the different actors that are involved in architectural heritage rehabilitation, reconstruction, or maintenance processes.

Thus, this paper has some contributions for this area. It aims at presenting a methodology supported by BIM in order to achieve the three-dimensional model, and then through an API, it is possible to connect parametric data between BIM and database (in a bidirectional flow). The 3D model, parametric data, and digitalized information of the project can be depicted and consulted in a web application. Once, in Portugal, there is a delay in the BIM methodology application; the methodology presented in this paper is considered innovative and important to support technicians and heritage managers.

2.2. Building Information Modelling: BIM.
Currently, the use of BIM methodology has been performing a highlight role in the process of architecture, engineering, construction and operation (AECO).

Projects development throughout BIM has become a demand in several countries. Development, study, simulation, and assessment of projects by BIM methodology transformed the current processes of conception, communication and information necessary to do, and delivering a project, in order to posterior construction and management of the building (Lopez, 2016).

Building Information Modelling is an advanced paradigm of collaborative work, based on interactive models applied over information models, regularly updated and synchronized. A set of processes and technologies that

interact between them compose BIM. Thus, this methodology enables to manage the project and its data over its lifecycle [16].

Therefore, this methodology is applicable to historic heritage management, as far as allows registering, studying, modifying, and updating and keeping the object for future generations. In addition, it contains other features, such as three-dimensional visualisation, animations, and automatic production of documents (plans, elevations, sections, construction details, reports, schedules, etc.) [17].

One of the main advantages and applications of BIM methodology is to be able to integrate parametric objects into a 3D model allowing its direct interaction and communication with all the other components, granting a fully parametric model, which precisely permits the functionalities that must be applied and explored in heritage [18].

In order to have a better understanding about BIM, it is necessary to know about its foundations basis which are the modelling oriented by objects and interoperability [19].

Modelling oriented by objects is related to parametric objects (objects such as windows, doors, walls, roofs, and all the elements categorized as part of a project) which are defined as an integrated part of the system, which takes into account the relation and interaction between other objects [17].

Interoperability consists on the ability to communicate between the different systems throughout the different phases of the constructive process, granting an automated modelling and design process to the interested parties without loss of time or information.

Modelling oriented by objects and an efficient and interoperability flow allows us to take advantage of information to create BIM workflows that are more efficient than the traditional processes based in CAD [19, 20].

Besides this, due to multidisciplinary of the BIM process, to different level complexity of data and to high quantity of tools available to analyse this set of information of each domain, the possibility of information sharing between different software's through Industry Foundation Classes (IFC) format arises. IFC is a format of data archive directed for the object, which allows us to share information between different software. It represents a nonpropriety format being an open source with a common language used for sharing information between models of different developers [21]. It is relevant to highlight that allows integrate XML language enabling the circulation of information. Thus, this is towards other processes than projects.

BIM methodology has specifications, standards, and guidelines established in some countries, which already adopted BIM in their processes [22]. The National Building Information Modelling Standard [23] was developed in the United States of America; the National Common BIM Requirements (COBIM) was developed in Finland; and in the United Kingdom, there is PAS 1192-2: Specification for Information Management using BIM [22]. The requests of BIM implementation allied to current globalisation processes of the construction sector and boost companies to use this methodology in order to increase international competitiveness.

In Portugal, application of BIM is delayed due to several factors, such as lack of need to implement BIM technology; lack of experience in BIM; conventional practice in 2D and 3D; and steep process to acquisition of knowledge in BIM [24]. Besides this, standardisation in Portugal is in the beginning. However, Portuguese Institute of Quality (responsible for the Portuguese standardisation process) is represented in the work group of European Commission for normalisation in order to develop the European BIM standard [25].

In the BIM domain, it is necessary to attribute the definition of strategies and procedures to assets data for the respective model, namely, parameters and information to be attached and integrated in the model. So, when the information and parameters are integrated in the model, this means that there exists an external database associated with BIM model with a bidirectional relation. For example, this database can be Access SQL, Open Database Connectivity (ODBC), or Construction Operations Building Information Exchange (COBie). To be able to manage all the information integrated in the model, it becomes clear the need to ensure the elements classification to all the interested parties, so they are able to work with categorized elements. There are currently several classification systems in place, but the most used are the Uniclass, Master Format, and OmniClass. These classification systems grant every element, building, activity, job, or timeline a code for universal understanding, granting better workflow between different parties.

Besides this, BIM provides ways to manage the building lifecycle through the integration of information in the model. However, the tools to create and manage that same information for existent building projects are being developed in BIM [26].

One of the main concerns of the implementation of the information management based on a BIM model is related to the historical building's records and data, which are almost the times incomplete or obsolete [27]. Thus, the management of historical building was completely ineffective till few years, and it has not been even a reliable methodology to implement it. However, BIM can be applied to heritage since it can digitalize and able to model all the historical and constructive information from the existent buildings. However, there are BIM libraries with objects and families for new construction, and there is a lack of information related to existent and historical buildings. Thus, the need of this development and these difficulties result in the Historical Building Information Modelling (HBIM) to give answer for the complex modelling process of historical buildings' objects.

2.3. HBIM. HBIM is a recognized tool that works like a plug-in for BIM, defined as a system of model of historical structures. These tools work with data obtained from laser scanning and photogrammetry [10, 28–32]. Thus, with these processes, it is possible to speed up the building model and the opportunity of developing object libraries. Besides this, it supports the comprehension of the objects [10]. As recognized by Baik [33], one of the most important parts of HBIM

is transferring the information that is based on the rich data survey into 3D parametric modelling. The model provided by the context to data of different types is no longer the final phase of heterogeneous information synthesis, but it is becoming a working tool that recognizes the construction of geometric and technological manufacturing models as valid support for the monitoring of degradation and of structural behaviour [34].

Figure 1 describes the methodology proposed for HBIM application in historical buildings. This process involves (1) collecting and processing the data from laser scanning/photogrammetry; (2) identification of historical details based on architecture books; (3) construction of historical parametric components/objects; (4) mapping of parametric objects in the project; and (5) production of final projects.

Thus, through HBIM, it is possible to produce automatically complete projects of engineering for building conservation, which includes three-dimensional models, schedules, details, plans, and sections [29].

Besides these features, BIM can add to the project and to the objects other information through shared parameters and project parameters. These parameters are editable, and there are different types since text, numbers, date, dimensions, etc. Therefore, it is possible to complement the project with other data not normalised in the software, turning the application of this tool very significative, being very important the application of these parameters in BIM for historical building [35]. By using these tools, it is possible to combine information that would otherwise be very hard to combine [36].

So, there is an arise of the need to explore the integration of the information from these parameters, in an interactive and intercooperative management model, in order to integrate all the information and data generated by BIM in a management platform. Due to this need, this work aims at the development of a management system to be used as a supporting tool to the maintenance and conservation of the existent heritage buildings. This tool will facilitate the interested parties the automated and digitalized information needed to carry out the most varied tasks, with the particularity to be directly connected with the 3D-BIM model of the building. In order to test the developed system (its applicability and functionality), it was applied to a building with the significant heritage value known as Casa de Santo António located in Ílhavo, Aveiro, in the centre of mainland Portugal. Then, a support database of the management system was developed in Microsoft SQL Server®, which will support all information exported from the BIM model. A web application of heritage building management was also developed through BIM since this methodology is enabled in the domain of data management and data communication. In the BIM project, the main requirements are to ensure the information exchange, and the integrated extraction of documents that when allied to a collaborative methodology of workflow, can increase the integration of every intervenient [37].

In the last year, several research projects in the domain of data collecting and management and HBIM development have been developed or are undergoing in the framework of FP7 and currently progressing EU Horizon 2020 projects, reflecting the high relevance for understanding and support of
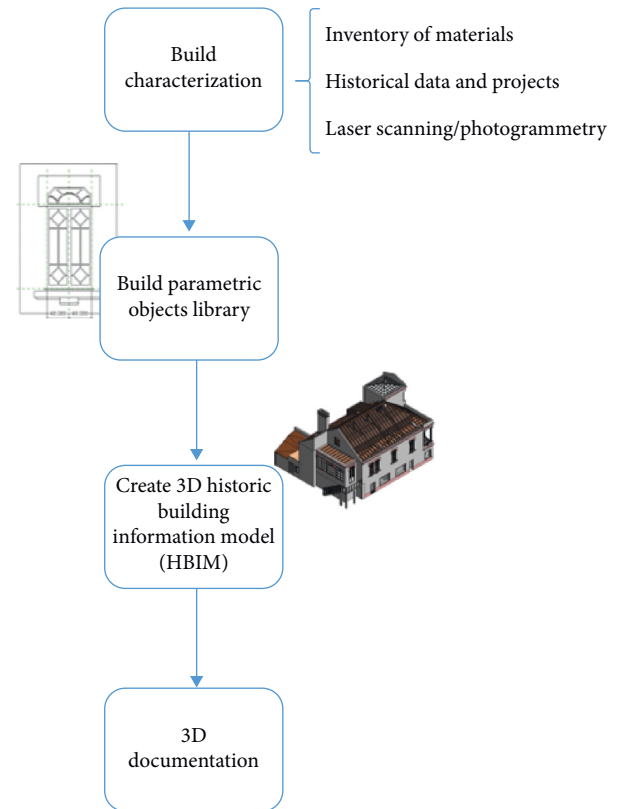

FIGURE 1: Historical building information modelling flowchart.

management of cultural heritage assets. Among the several examples, the INCEPTION project is related to the innovation in 3D modelling of cultural heritage through an inclusive approach for time-dynamic 3D reconstruction of artefacts, built and social environments, and addresses several topics such as the moisture detection in heritage buildings by 3D laser scanning [38], semiautomatic generation of BIM models for cultural heritage [39], and procedures to integrated data capturing requirements for 3D semantic modelling of cultural heritage [40], among others. The HeritageCARE project is part of the Interreg-SUDOE program that aims at the monitoring and preventive conservation of historical and cultural heritage implementing a system for the monitoring and preventive conservation of heritage with historical and cultural values in South-West Europe [41]. BIM4REN is a project devoted to aBIM tools for all the building renovation value chain. The project identified that the innovation in this field can be of major importance to reduce costs, develop smarter solutions, and streamline processes, namely, by the collection of data for the characterization of the existing buildings, management, and consolidation of the data and data driven design for optimal selection.

3. Methodology

3.1. Introduction. According to Baik and Boehm [42], there is a high necessity of the development of an integrate management methodology for historical buildings, in order to grant its preservation and maintenance and allow the decision-makers about which buildings need interventions,

maintenance, and demolition actions. So, the development and integration of the data system within a BIM model and how that same data system can be connected between the BIM Model and the user is presented. Figure 2 depicts the scheme proposed and developed, representing the interconnection between the BIM model, a data system, and a web management platform.

This system is based on an organizational and functional structure, in order to keep sustainability and automation of the historical heritage management. Thus, the system can be divided into two substructures: the core and the user interface.

3.2. Development. The first part core is the system architecture, and inside it, it includes the BIM model, the database system, and the API.

The first step was to develop a full parametric building model in software Revit.

Then, it was studied the Database Link (DBLink) since BIM methodology has the ability to export and import data through the DBLink plug-in. This plug-in was developed by Autodesk, and it aims at exporting and importing data from Revit for an external database, which can be done to Excel, Access, MSSQL, MySQL, Oracle, MongoDB, Redis, or other database management software. The practical application of this plug-in was studied, by connecting the BIM model and the management system. This allowed us to export and import information from one model to another.

The next step was to create a support database to the management system that would serve as a bridge to interconnect the database from the BIM model and the management system. A database is a tool to collect, store, and organize data, like a repository of information related to an issue. Thus, the database management system is software that manages the storage and manipulation and searches the existing information in the database. In this case, the database management system is based on relational characteristics. It was developed using Microsoft SQL Server (MSSQL), and it aims at supporting all the information exported from the BIM model. Thus, the information from the BIM model goes to the database, and it is organized by 3 phases and 5 categories, as it is represented in Figure 3.

It is essential to create credentials to restrain the user access that can be Administrator (access without constraints), Read (access limited only for read material), or ReadWrite (access to read and write but with constraints). Each user has an Id, e-mail/username, and password. Thus, the user can access their list of projects.

Project information includes 5 categories: drawings from Revit or other type of drawings that user wants to add as complement to the project; facility management information and data which allow us to access the external database of BIM model and read or edit the information about any family of objects (edition of data just included in shared parameters); documentation, which allows information storage such as historic contextualization,

intervention information, and photographic collection; reports, which allow the storage of data related to information about the conservation status and include inspection reports, structural analysis, tests and inspection reports, etc.; BIM models that allow us to view any kind of graphic information about any element allowing to update the model when the building is submitted to interventions and/or maintenance actions.

Figure 4 allows a better understanding about the organisation of the management model, where it is possible to see the application of the methodology.

After, a web application (http://www.gestheritage.web.ua.pt) was developed in C# using Visual Studio 2015 software. It works through an Application Programming Interface (API) that allows the communication between the web application and the BIM model, allowing not only the interaction with the parametric information of this one, but also, a persistent access to the data system (drawings, inspection reports, specifications, etc.) previously created. The development of the Web API was done due to the need to facilitate the user to access project information.

Web application was developed, named as "Gestheritage," and was implemented in the hosting service of the University of Aveiro. Finally, the second substructure of the development management system was the user interface, which represents the way that the user interacts with the application. The web application is presented in Figures 5–7.

Thus, the user can communicate with the web application, this one communicates with the API, and the API communicates with the database. The process is represented in Figure 8.

4. Case Study

4.1. Description. The case study is related to a residential house named "Casa de Santo António," located in the centre city of Ílhavo, Aveiro, Portugal. This house is considered one of the most iconic local buildings with great patrimonial value (Figures 8 and 9)

This building was built in 30s of the twentieth century, with the category of residential house. Nowadays, it is the head office of InovaDomus Association. The University of Aveiro and more than 10 companies linked to the construction sector are working in this building, in the scope of the ReabilitaDomus project, since 2012 [43].

This building was classified as a building of excellent architecture, and it is composed by 2 stories and an attic, with a total area of 450 m^2.

The structural materials are composed of masonry, wood, and concrete. Masonry brick composes essentially the structural walls with variable thickness, anchored by continuous foundations of poor concrete and adobe. The ground floor has a regularization screed of 2 cm. The first floor is composed by wooden beams distant of 0.6 m, with a locking system for buckling, constituted by dowel perpendicular to wooden beams. There are some concrete reinforcements (beams and columns) included in the building [43, 44].
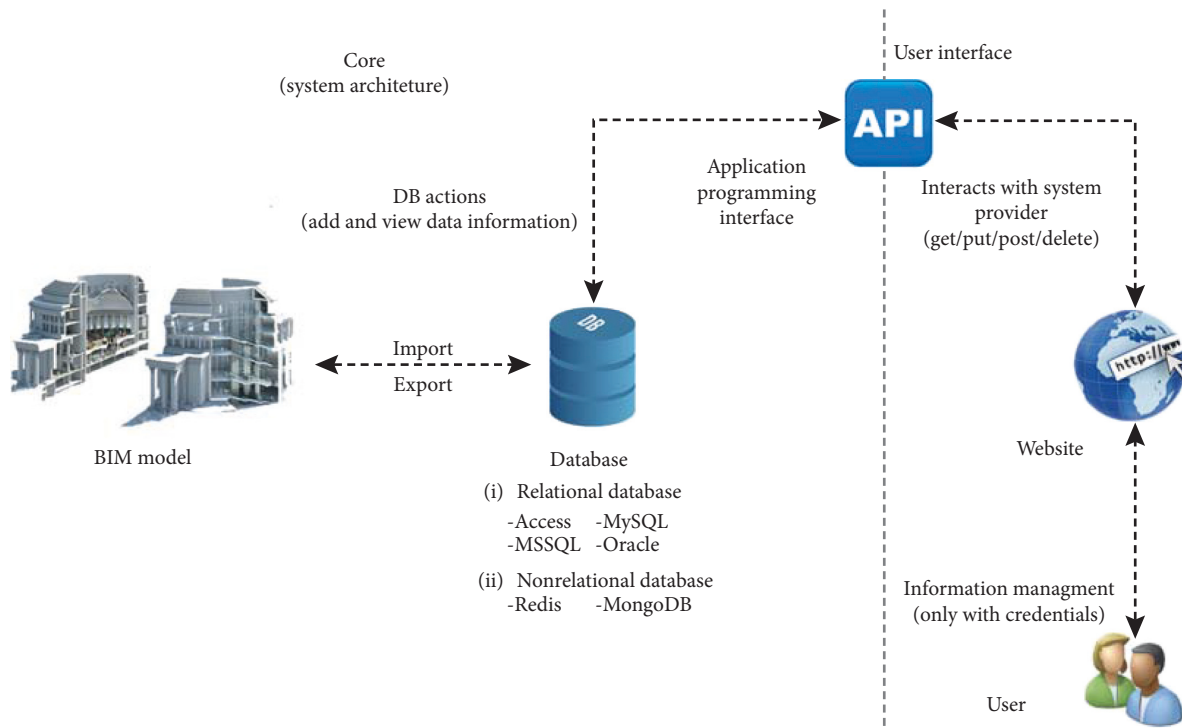
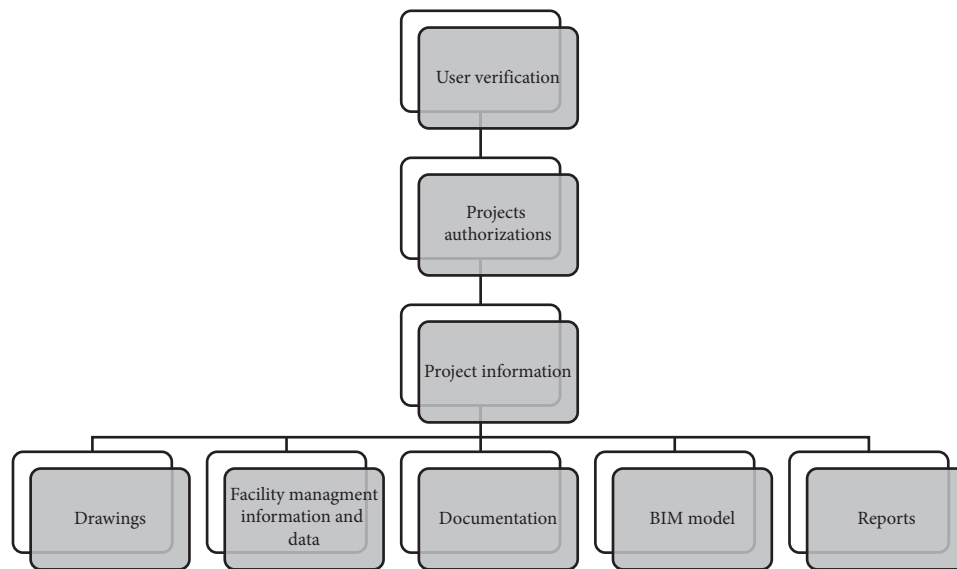FIGURE 2: Scheme of the development of the management of the historical heritage model proposed.

FIGURE 3: Organisation chart of the historical heritage management model structure.

The first part of the application of this methodology started with the case study modelling in BIM, through Revit Autodesk being the architecture and structural components of the building modelling.

4.2. Modelling. The characterization of all components included in the building (construction materials, geometry, and structural behaviour) was done. This survey was carried out in situ and throughout documentation analyses, such as reports of structural characterization [44]. Thus, it was possible to do the characterization of the building and develop the BIM model of the building.

4.2.1. Architecture and Structure. Although the building was a particular case with a great architectural detail, it was not possible to model through the point cloud, and by so, the modelling work was highly time-consuming. Adequate objects and families closer to the existent components of the building were developed.
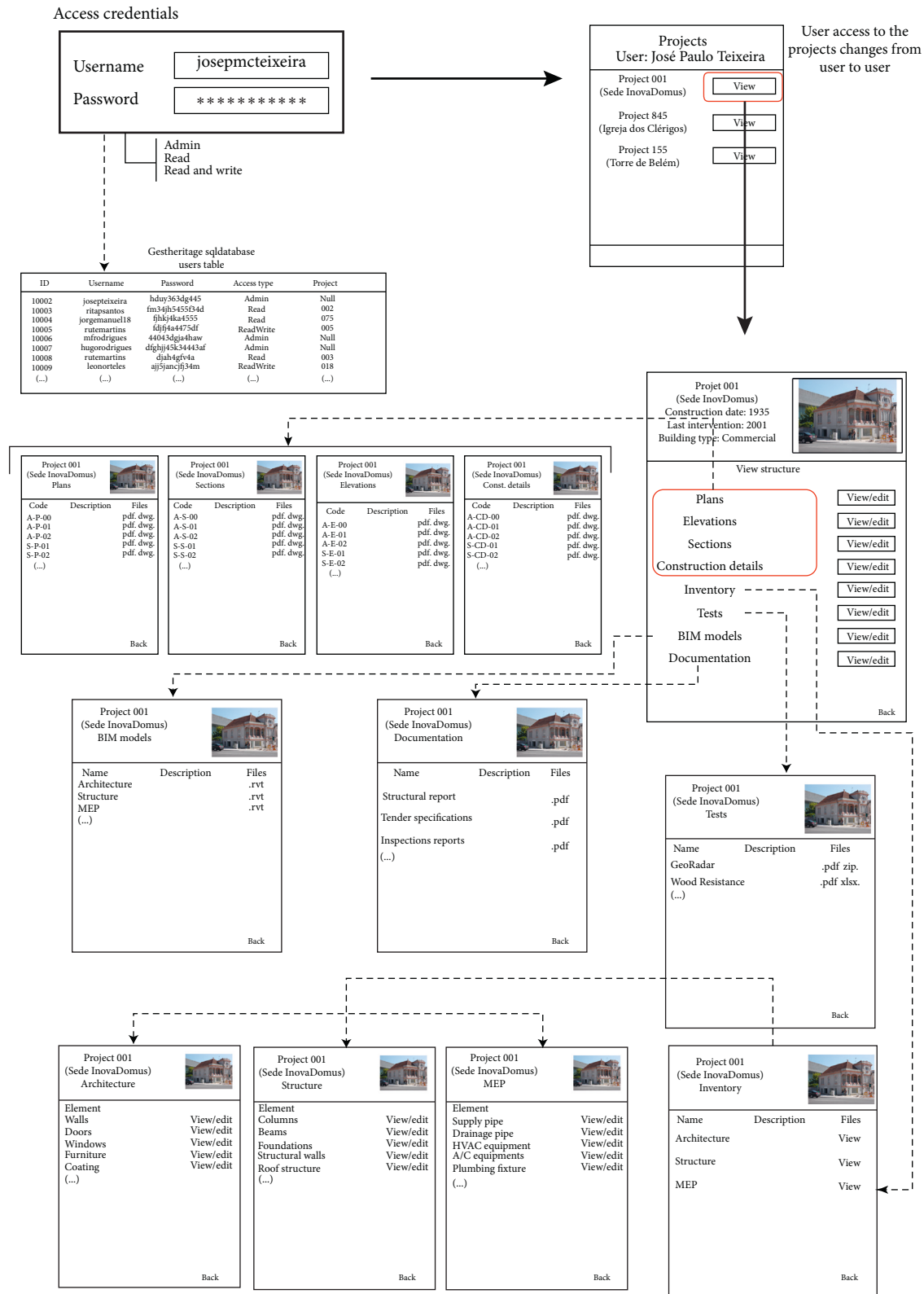
FIGURE 4: Organizational structure of the management model.

In Figure 10, the real building and the BIM model developed and the respective elevations are presented.

In Figures 11 and 12, other views of the building BIM model are represented. InovaDomus provided structural plans, which were used to develop structural components in the BIM model.

This BIM model was used as a plug-in of the Autodesk library—Classification Manager, in order to associate the
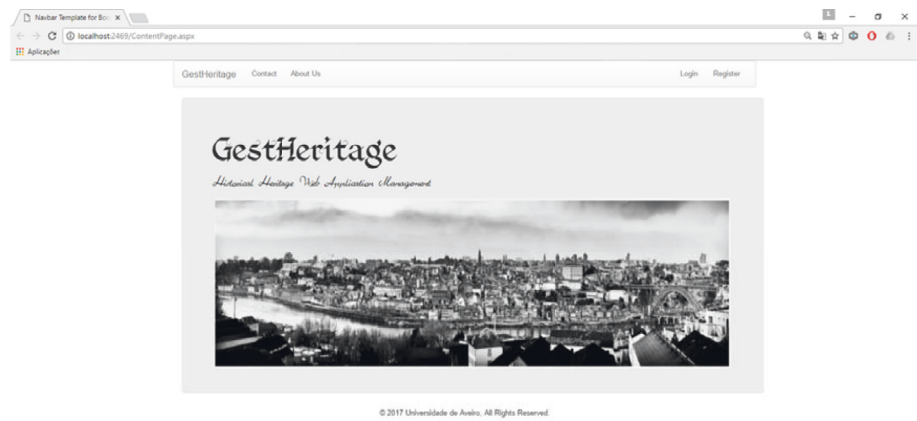
FIGURE 5: GestHeritage index page.
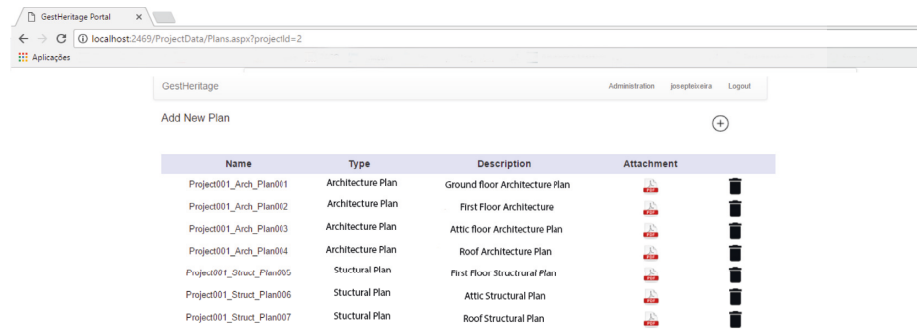
FIGURE 6: GestHeritage Plans page.

FIGURE 7: Relational scheme between user, web application, API, and SQL database.

FIGURE 8: Current state of the building: left and main facades.

FIGURE 9: Current state of building: main facade.

FIGURE 10: Current Building vs 3D Model: Santo Antonio House and Elevations in *Autodesk Revit.*
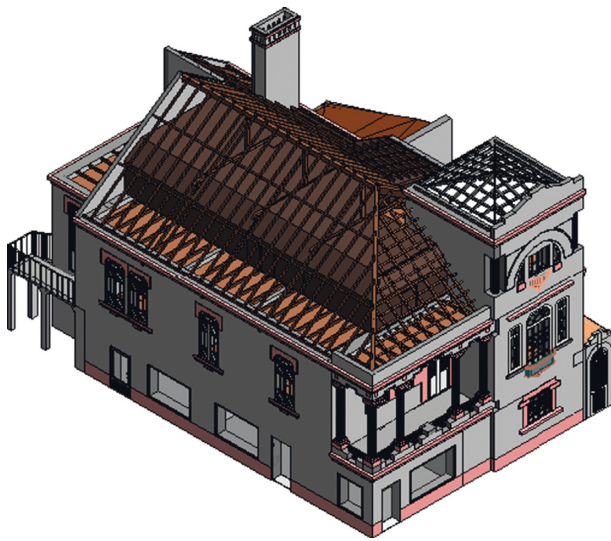
FIGURE 11: 3D view of the BIM model (main and left elevation).

FIGURE 12: 3D view of the BIM model (rear and left elevation).

classification system Uniclass applied to constructive elements, constructive processes, materials, rooms, etc.

4.2.2. Family of Objects. Due to the technical detail and to unique and exclusive objects existence in the building, it was needed to model in place a high number of objects. In Figure 13, it is possible to show the creation of an object (window) in Revit.

It was not only essential to guarantee a precision level similar to reality but also essential to guarantee the family object parametrization, attributing geometric parameters and materials characterization.

4.2.3. Shared Parameters Application. The shared parameters were determined to be applied to add information to the model with information related to maintenance and

conservation actions in heritage (Figure 14). Thus, 2 different parameters were created: general data and maintenance/inspection data.

The general data include the following:

  (i) Facade element: yes/no

 (ii) Facade: text

(iii) Floor level: text

(iv) Room: text

 (v) Span: text

Maintenance/inspection data include the following:

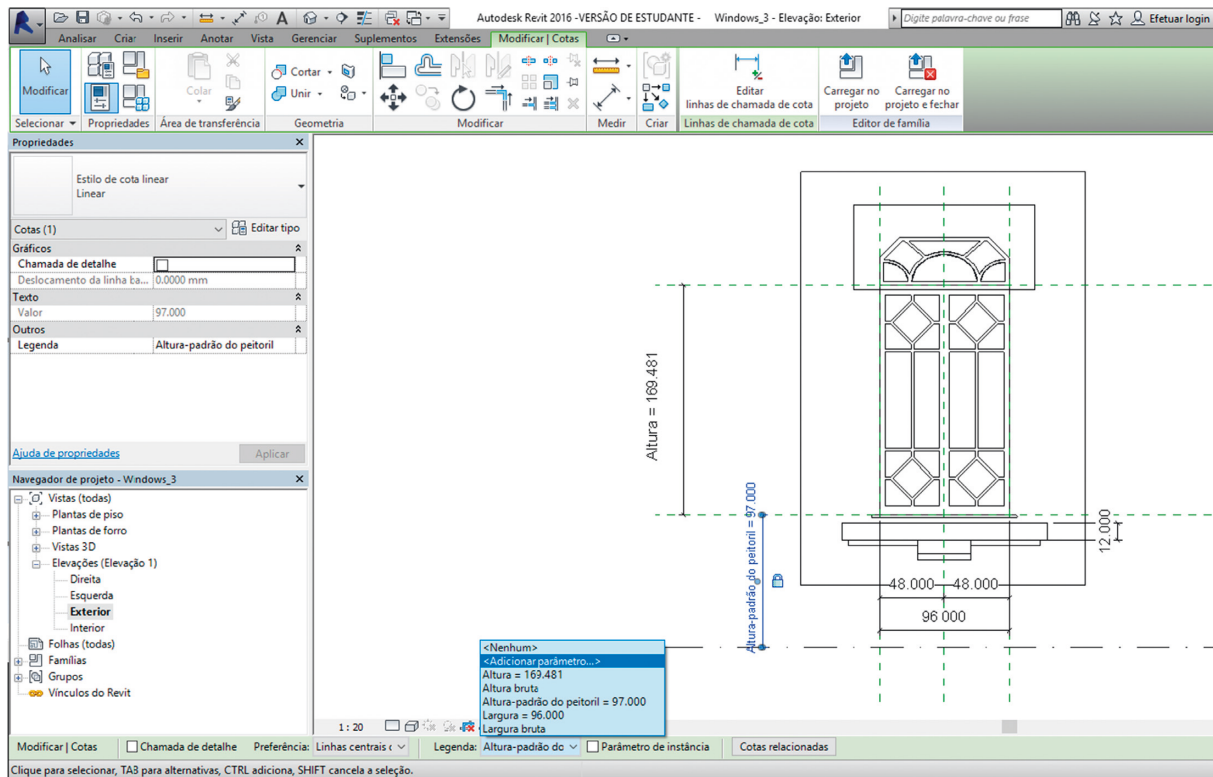 (i) Construction date: integer

 (ii) Date of last intervention: integer

FIGURE 13: Revit interface for creating the window object family.

(iii) Notes: text

(iv) Pathologies report: text

(v) Maintenance cycle: number

(vi) Next inspection/maintenance: integer

These parameters were associated; however, it can be associated other parameters besides those.

After parameters association, the BIM model is ready to export all the information provided in the model to an external database. However, the information to complement the management model should not be provided just from shared parameters.

4.2.4. Drawings Associated with BIM Model. In the development of the management model through BIM application, drawings were developed such as, plans, sections, elevations, and constructive details. This application in the BIM model is an advantage since it allows creating automatic drawings from the model, and it can include annotations, comments, and hatches provided by the designer.

When the model is subjected to changes, the drawings are automatically updated in software. And this is an advantage of the automatic drawings created by the BIM model, which can decrease the inconsistency in the development of drawings.

These drawings perform an important role in the management model since the more the quality and quantity of the drawings developed, the less the difficulty of the project analysis by the user.
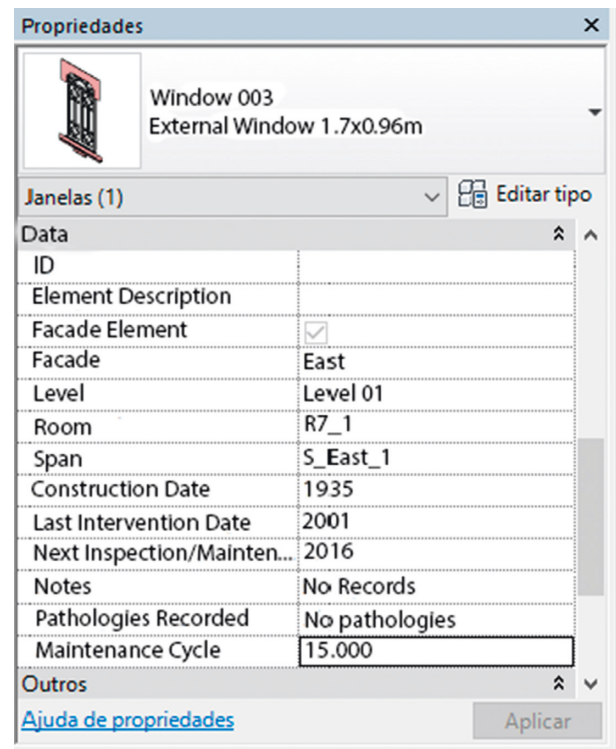

FIGURE 14: Shared parameters association.

4.3. Database. After the development of the BIM model, the exportation of parametric information to an external database is the next step.

The support database (GestHeritage) included in the management model was developed for supporting all the databases exported from BIM projects. For each project, GestHeritage will be associated with the, respectively, external database of the project.

Thus, information from database to the database management system Microsoft SQL Server with name "Project001_CasadeSanto António" was exported as shown in Figures 15 and 16.

This process was done through the plug-in DBLink that is able to extract all the parametric information of the constructive elements from Revit. This plug-in exports the linked tables, allowing the organisation of information in an interlinked and structured way, easier to the user. The exportation of the information from the BIM model to the external database is a high potential application; however, it is necessary the implementation of a management model to organize and catalogue all the information from the database in order to support the user during the maintenance and conservation actions in historical heritage.

4.4. API Connection.
Since the management system is already developed, it is possible to start with the association of the projects with the system. Thus, the association of this case study model with the API developed through Visual Studio 2015 was done.

4.4.1. Elements Drivers.
Taking into account that API works based on CRUD drivers, each element has its own driver providing specified information type and how it should be organized in the project database.

For example, for walls, the information that should be presented in inventory for the user and how it was organized is

   (i) Object ID ⟶ *[dbo].[Walls]* ⟶ "ID";

   (ii) Object Name ⟶ *[dbo].[WallType]* ⟶ "Name";

   (iii) Length ⟶ *[dbo].[Walls]* ⟶ "Length";

   (iv) Thickness ⟶ *[dbo].[WallType]* ⟶ "Thickness";

   (v) Height ⟶ *[dbo].[Walls]* ⟶ "DisconnectedHigh";

   (vi) Materials ⟶ *[dbo].[MaterialQuantities]* ⟶ "Material Id" ⟶ *[dbo].[Materials]* ⟶ "Name";

   (vii) Structural use ⟶ *[dbo].[WallUsageEnums]* ⟶ "Name";

   (viii) Object in facade ⟶ *[dbo].[Walls]* ⟶ "Element_in_Facade";

   (ix) Facade ⟶ *[dbo].[Walls]* ⟶ "Facade";

   (x) Floor ⟶ *[dbo].[Walls]* ⟶ "Floor";

   (xi) Room ⟶ *[dbo].[Walls]* ⟶ "Compartment";

   (xii) Span ⟶ *[dbo].[Walls]* ⟶ "Span";

   (xiii) Construction date ⟶ *[dbo].[Walls]* ⟶ "Construction date";

   (xiv) Date of the last intervention ⟶ *[dbo].[Walls]* ⟶ "Date of the last intervention";
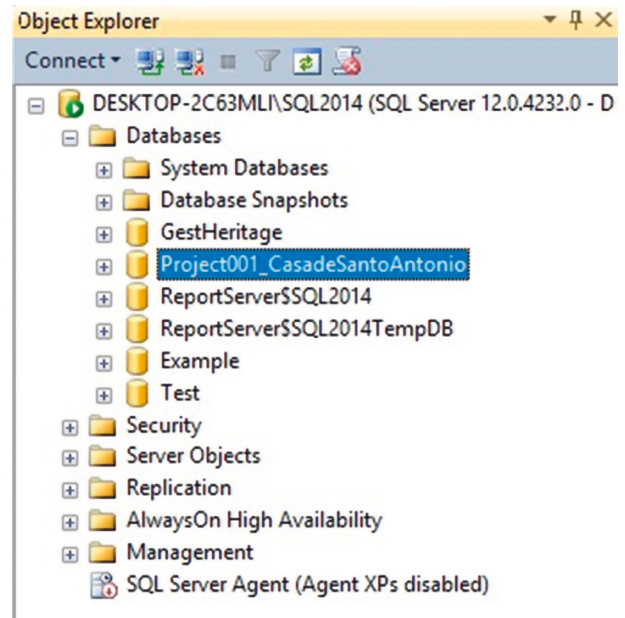

FIGURE 15: Microsoft SQL Server databases.

   (xv) Observations ⟶ *[dbo].[Walls]* ⟶ "Observations";

   (xvi) Recorded pathologies ⟶ *[dbo].[Walls]* ⟶ "Recorded pathologies";

   (xvii) Maintenance cycle ⟶ *[dbo].[Walls]* ⟶ "Maintenance cycle";

   (xviii) Next inspection/Maintenance ⟶ *[dbo].[Walls]* ⟶ "Next inspection/Maintenance".

Through these parameters, it was possible to develop the drivers. However, it is highlighted that these parameters can easily be modified according the user needs.

4.4.2. Provision of Databases.
Before the application of the case study in web application, it was needed to feed the support database (GestHeritage) with all adequate information and data for management. This information includes drawings developed by the BIM model and all complement information to categories of the management model (reports, BIM model). Figure 17 shows an example of association of drawings with the project of the case study.

4.4.3. Application Web Involvement.
The database in the application web turns possible the visualisation and edition of the information from the BIM model by the user. The information must be structured, organized, and concise in order to provide the adequate accessibility for user.

With the association of the database of the project with the management model developed, the implementation of dynamic tables developed was possible, when it connects the application web with drivers, for every driver involved in this case study.
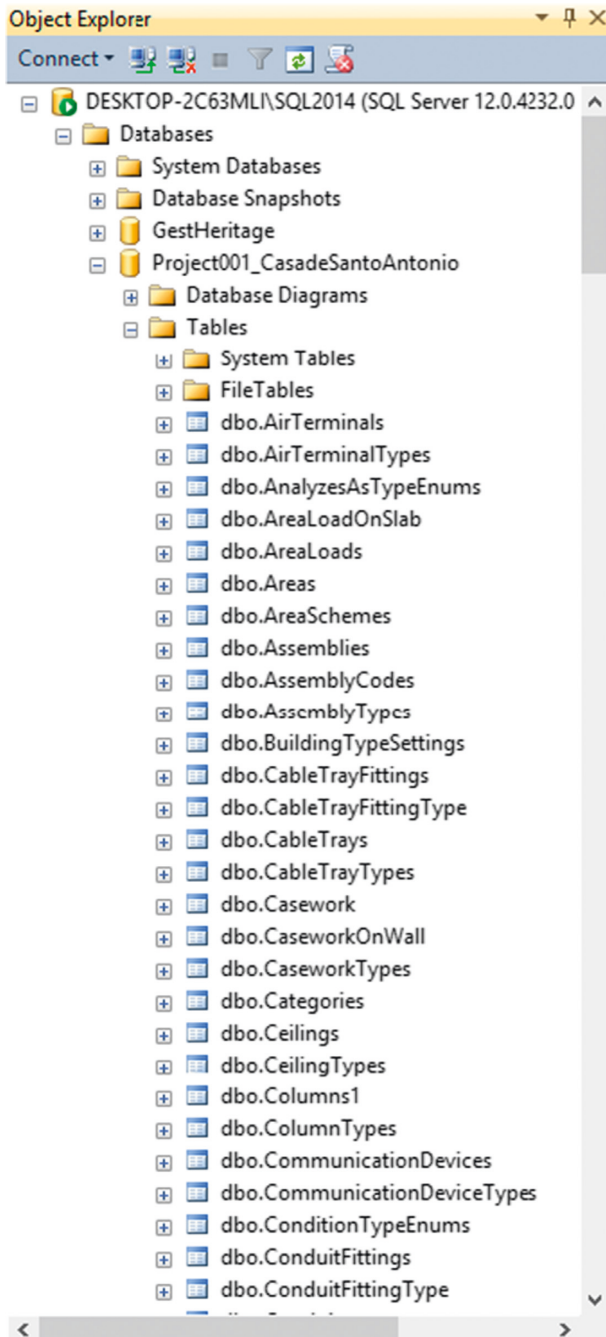
FIGURE 16: Tables generated by DBLink from the case study.

Thus, it is possible to not only see just the information included in exported database from the BIM model but also edit this information directly from the database and consequently from the BIM model. However, this information editing is just possible by accredited users (Admin or ReadWrite).

The result is based on a dynamic table with the requisition system (Get) and transmission (Put) of the database and contains the advantage of deliver for user, just the essential information of the element, as the example in Figure 18.

With the application of the management model of this case study, it was possible to verify and validate the usefulness of the heritage management system. It is also verified that there exist an easy access of the user to the information of the BIM model and also a complement system of management of information elements (drawings, documents, and reports) in the digital format. Thus, it is possible to guarantee a reliable library of information and with easy access to user, decreasing the information loss and its outdating.

5. Conclusions

This work demonstrates the necessity of development and implementation of a strategy of intervention which contributes to the preservation and maintenance of heritage, through the application of a management system able to answer this need in a reliable process.

The practical application of the management system can revolutionize the way the management and maintenance of historical heritage is seen. It is allowed not only to reorganize and structure all Portuguese historical heritages but also to manage them, assuring its constant and updated maintenance, avoiding its degradation.

The success of the implementation of this management system proves its ability to adequate the management for any kind of historical building to digital format. This ability guarantees a decrease of the information lost and improves the access by the users to this information.

BIM shows that is a methodology able to meet the user's needs in an every-day more challenging society.

In practice, BIM is still less explored in the implementation of management systems with success. This process opens an opportunity to this model in the scope of the maintenance, conservation, and refurbishment for heritage and for all existent buildings.

Besides this, it is possible to have a three-dimensional parametric and detailed model of the building, providing the decision-making more reliable and quicker.

The connection of the BIM model and database is done through DBLink included in Revit Autodesk and performs an important role in the developed management model. However, the functionality of the plug-in demands an extraperformance approach since it should predict the exportation not only of the parametric data, but also of drawings associated with the project, which it cannot do. The disability to update automatically and the changes between databases and BIM model are other disadvantages of the DBLink. DBLink should have the ability to update automatically, instead of the manual command inventory user.

The practical application of this management model achieves the expectations designed for this work since it was possible to update the way how the management of heritage was done for a management system which follows a concept of new information technologies. Thus, it is possible to guarantee a reliable update of the data and information reached by the user.
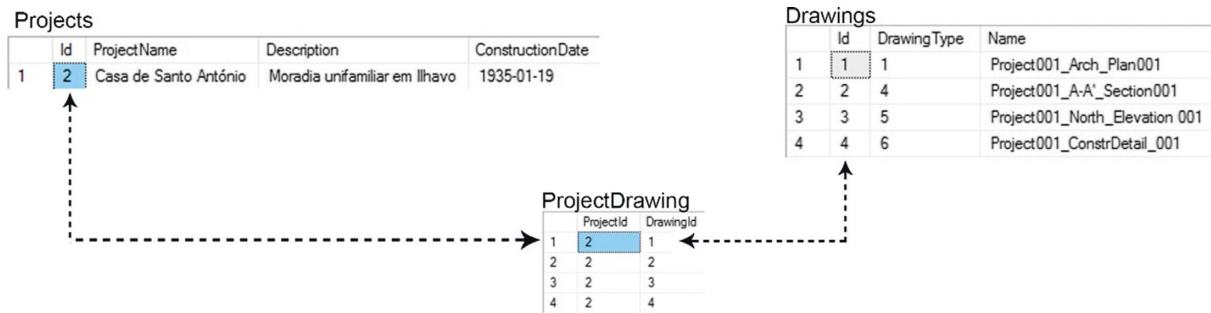
FIGURE 17: Association of the case study project with the respective drawings.

FIGURE 18: Dynamic table of the element walls of the case study in the web application.

Although this work was developed and applied to the management of heritage, it is essential to highlight the practical application of this model to existent buildings, namely, without any historical value but with conservation or refurbishment justified in medium/long term.

So, the model developed and proposed can help management entities, such as general direction of historical heritage, to have a resource to maintenance and conservation of heritage, allowing its management and maintenance through a digital platform.

The practical usefulness of this management model will enhance the use of all existent resources in the heritage.

The information will be stored in the digital format in a management platform able to manage all the information related with projects, assuring the interoperability between system and user.

Besides this, these models are a solution to the existent gaps and incoherence in the drawings through BIM methodology. Therefore, there is a decrease of the incoherence in the draw parts, allowing us to have and manage contextualized and consistent drawings.

The documentation and reports are also included in the model, so it is possible to inform the user about conditions, documents details, and historical framework of the project supporting the user to know about the evolutive situation of the project.

Finally, this management system highlights the management of the elements of the project, improving a management of detail and parametric maintenance in project inventory.

This inventory includes all constituent elements, allowing not only a general maintenance of the project, but also a partial maintenance of the elements, rooms, facades, for a reliable and focus maintenance management.

It is possible to conclude that the application of the model was a success and all the objectives proposed were completed. The work presented and the work analysed in the literature review show that HBIM applications are often

needed to jointly perform different kinds of analysis and to properly connect the related environments and formats; thus, it is clear why there is a need to focus the development of HBIM applications with a heterogeneous multi-models' interoperability with a standardised approach.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] J. P. Bernardes, L. F. Oliveira, R. Moreira, and T. Valente, "Património Cultural Edificado : reflexões em torno da gestão do Património Classificado," *Lusophone Journal of Cultural Studies*, vol. 2, pp. 34–52, 2014.

[2] A. Forster and B. Kayan, "Maintenance for historic buildings: a current perspective," *Journal of Quality in Maintenance Engineering*, vol. 27, no. 3, pp. 210–229, 2009.

[3] E. Dezen-Kempter, "Digital Dialogues : integration of documentary data in model based information systems for the conservation," in *Proceedings of the XVII Conference of the Iberoamerican Society of Digital Graphics-SIGraDi: Knowledge-Based Design*, vol. 1, pp. 293–296, 2014.

[4] S. Fai, K. Graham, T. Duckworth, N. Wood, and R. Attar, *Building Information Modelling and Heritage Documentation Carleton Immersive Media Studio*, Azrieli School Of Architecture And Urbanism, Ottawa, Canada, 2011.

[5] A. Akanmu, O. Olatunji, P. E. D. Love, D. Nguyen, and J. Matthews, "Auto-generated site layout: an integrated approach to real-time sensing of temporary facilities in infrastructure projects," *Structure and Infrastructure Engineering*, vol. 12, no. 10, pp. 1243–1255, 2015.

[6] É. Meyer, P. Grussenmeyer, J.-P. Perrin, A. Durand, and P. Drap, "A web information system for the management and the dissemination of Cultural Heritage data," *Journal of Cultural Heritage*, vol. 8, no. 4, pp. 396–411, 2007.

[7] A. Guarnieri, F. Pirotti, and A. Vettore, "Cultural heritage interactive 3D models on the web: an approach using open source and free software," *Journal of Cultural Heritage*, vol. 11, no. 3, pp. 350–353, 2010.

[8] A. D. Styliadis, "Digital documentation of historical buildings with 3-d modeling functionality," *Automation in Construction*, vol. 16, no. 4, pp. 498–510, 2007.

[9] G. Pavlidis, A. Koutsoudis, F. Arnaoutoglou, V. Tsioukas, and C. Chamzas, "Methods for 3D digitization of cultural heritage," *Journal of Cultural Heritage*, vol. 8, no. 1, pp. 93–98, 2007.

[10] H. M. Yilmaz, M. Yakar, S. A. Gulec, and O. N. Dulgerler, "Importance of digital close-range photogrammetry in documentation of cultural heritage," *Journal of Cultural Heritage*, vol. 8, no. 4, pp. 428–433, 2007.

[11] H. Haggrén, K. Koistinen, H. Junnilainen, and A. Erving, *Photogrammetric Documentation and Modeling of na Archaelogical Site: The Finnish Jabal Project*, The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Mestre-Venice, Italy, 2005.

[12] P. Grussenmeyer and J. Yasmine, "The restoration of beaufort castle (South-Lebanon). A 3D restitution according to historical documentation," in *Proceedings of CIPA XIXth International Symposium of New Perspectives to Save Cultural Heritage*, Antalya, Turkey, September 2003.

[13] M. Bassier, G. Hadjidemetriou, M. Vergauwen, N. Van Roy, and E. Verstrynge, "Implementation of scan-to-BIM and FEM for the documentation and analysis of heritage timber roof structures," in *Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection. EuroMed 2016. Lecture Notes in Computer Science*, M. Ioannides, Ed., Springer, Cham, Switzerland, 2016.

[14] S. Portier, J. Maltret, and J. Zoller, "Computer graphics: asssistance for archaelogical hypotheses," *Automation in Construction*, vol. 9, no. 1, pp. 117–128, 2000.

[15] F. López, P. Lerones, J. Llamas, J. Gómez-García-Bermejo, and E. Zalama, "A review of heritage building information modeling (H-BIM)," *Multimodal Technologies and Interaction*, vol. 2, no. 2, p. 21, 2018.

[16] D. Pasini, V. Caffi, B. Daniotti, S. Lupica Spagnolo, and A. Pavan, "The INNOVance BIM library approach," *Innovative Infrastructure Solutions*, vol. 2, no. 1, p. 15, 2017.

[17] M. Tolentino and B. Feitosa, *A Utilização de Tecnologias Digitais Na Documentação do Patrimônio Arquitetônico*, 2014.

[18] A. Costin, A. Adibfar, H. Hu, and S. S. Chen, "Building Information Modeling (BIM) for transportation infrastructure – literature review, applications, challenges, and recommendations," *Automation in Construction*, vol. 94, pp. 257–281, 2018.

[19] J. D. R. T. Soares, *A Metodologia BIM-FM aplicada a um caso prático*, 2013.

[20] K. M. Kensek, "BIM: "I" is for interoperability. BIM is more, chapter 3: data exchange and interoperability," in *Technical Design Series: Building Information Modeling*, pp. 83–89, Routledge, Abingdon, UK, 2016.

[21] C. A. Jacoski, *A Utilização de Arquivos IFC Para a Integração de Dados Junto à Indústria da Construção*, 2002.

[22] F. Pinho, *Norma BIM Portuguesa*, Tese de Mestrado em Engenharia Civil, Faculdade de Ciências e Tecnologia, Univeridade de Coimbra, Coimbra, Portugal, 2015.

[23] V. Bazjanac, *Impact of the U.S. National Building Information Model Standard (NBIMS) on Building Energy Performance Simulation*, pp. 1377–1382, Lawrence Berkeley National Laboratory, Berkeley, CA, USA, 2007, http://escholarship.org/uc/item/3v95d7xp.pdf%5Cnhttp://escholarship.org/uc/item/3v95d7xp.

[24] M. J. F. Silva, F. Salvado, P. Couto, and Á. V. e. Azevedo, "Roadmap proposal for implementing building information modelling (BIM) in Portugal," *Open Journal of Civil Engineering*, vol. 6, no. 6, pp. 475–481, 2016.

[25] A. A. Costa, *O paradigma BIM e a Normalização Como fator de competitividade*, Instituto Português da Qualidade (IPQ), Caparica, Portugal, 2014, http://www1.ipq.pt/PT/Site/Destaques/Historico/Paradigma-BIM-e-a-normalizacao-como-fator-de-competitividade.aspx.

[26] F. Re Cecconi, S. Maltese, and M. C. Dejaco, "Leveraging BIM for digital built environment asset management," *Innovative Infrastructure Solutions*, vol. 2, no. 1, p. 14, 2017.

[27] R. Volk, J. Stengel, and F. Schultmann, "Building Information Modeling (BIM) for existing buildings - literature review and future needs," *Automation in Construction*, vol. 38, pp. 109–127, 2013.

[28] C. Dore and M. Murphy, "Integration of Historic Building Information Modeling (HBIM) and 3D GIS for recording and managing cultural heritage sites," in *Proceedings of the 2012 18th International Conference on Virtual Systems and Multimedia, VSMM 2012: Virtual Systems in the Information Society*, pp. 369–376, Milan, Italy, September 2012.

[29] M. Murphy, E. McGovern, and S. Pavia, "Historic building information modelling (HBIM)," *Structural Survey*, vol. 27, no. 4, pp. 311–327, 2009.

[30] L. M. Khodeir, D. Aly, and S. Tarek, "Integrating HBIM (heritage building information modeling) tools in the application of sustainable retrofitting of heritage buildings in Egypt," *Procedia Environmental Sciences*, vol. 34, pp. 258–270, 2016.

[31] G. Saygi and F. Remondino, "Management of architectural heritage information in BIM and GIS: state-of-the-art and future perspectives," *International Journal of Heritage in the Digital Era*, vol. 2, no. 4, pp. 695–713, 2013.

[32] M. Murphy, E. McGovern, and S. Pavia, "Historic building information modelling-adding intelligence to laser and image based surveys," in *Proceedings of 38th ISPRS-International Archives*, pp. 2–4, Trento, Italy, March 2011, http://adsabs.harvard.edu/abs/2011ISPAr3816W...1M.

[33] A. Baik, "From point cloud to jeddah heritage BIM nasif historical house - case study," *Digital Applications in Archaeology and Cultural Heritage*, vol. 4, pp. 1–18, 2017.

[34] D. Oreni, R. Brumana, and B. Cuca, "Towards a methodology for 3d content models: the reconstruction of ancient vaults for maintenance and structural behaviour in the logic of bim management," in *Proceedings of 2012 18th International Conference on Virtual Systems and Multimedia*, pp. 475–482, Milan, Italy, 2012.

[35] S. Logothetis and E. Stylianidis, "BIM Open Source Software (OSS) for the documentation of cultural heritage," *Virtual Archaeology Review*, vol. 7, no. 15, pp. 28–35, 2016.

[36] P. Pauwels, R. Bod, D. Di Mascio, and R. De Meyer, "Integrating building information modelling and semantic web technologies for the management of built heritage information," in *2013 Digital Heritage International Congress (DigitalHeritage)*, pp. 481–488, IEEE, Marseille, France, 2013.

[37] B. Caires and I. C. BIMMS, "Data Management & Comunication. BIM is More," *Chapter 05: Application, Subchapter 5.3, BIM Project Implementation Lessons Learned*, pp. 90-91, 2016.

[38] P. M. Lerones, D. O. Vžlez, F. G. Rojo, J. G. Garcia-Bermejo, and E. Z. Casanova, "Moisture detection in heritage buildings by 3D laser scanning," in *Studies in Conservation*, Maney Publishing, Leeds, UK, 2016.

[39] F. J. López, P. Martin Lerones, J. Llamas, J. Gómez-García-Bermejo, and E. Zalama, "Semi-automatic generation of BIM models for cultural heritage," *International Journal of Heritage Architecture: Studies, Repairs and Maintence*, vol. 2, no. 2, 2017.

[40] F. Maietti, R. Di Giulio, E. Piaia, M. Medici, F. Ferrari, and B. Turilazzi, "Integrated data capturing requirements for 3D semantic modelling of cultural heritage: the inception protocol," *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. 42, pp. 251–257, 2018.

[41] L. F. Ramos, M. G. Masciotta, M. J. Morais et al., "HeritageCARE:preventive conservation of built cultural heritage in the South-West Europe, book: innovative built heritage models," K. van Balen and A. Vandesande, Eds., CRC Press, Boca Raton, FL, USA, 2018.

[42] A. Baik and J. Boehm, "Building information modelling for historical building Historic Jeddah - Saudi Arabia," in *Proceedings of 2015 Digital Heritage International Congress, Digital Heritage*, pp. 125–128, Granada, Spain, 2016.

[43] R. Gamelas, "Caracterização e monitorização para reabilitação da sede da InovaDomus," M.S thesis. Universidade de Aveiro, Aveiro, Portugal, 2013, https://ria.ua.pt/handle/10773/12903.

[44] InovaDomus, *Relatório de Caracterização Estrutural da Sede da InovaDomus*, 2016.

[45] A. Styliadis, *Digital documentation of monuments and sites with 3D geometry and qualitative information*, PhD Thesis, Faculty of Rural and Surveying Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece, 1997.