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Fixby Hall Case study: Research report

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FIXBY HALL CASE STUDY

SUMMARY RESEARCH REPORT

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F & R Mallinson Ltd.

Acronyms

HGC- Huddersfield Golf Club

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1. EXECUTIVE SUMMARY

This report presents the main findings of Fixby Hall case study which study the potential of using Building Information Management (BIM) as an innovative method to manage historical buildings' life cycle. Fixby Hall was chosen as case study due to its relevance as historical building and its suitability to adopt HBIM for its future interventions.

This case study developed by the PhD candidate Isabel Jordan, (Universitat Politècnica de València, Spain), and supervised by Professor Tzortzopoulos, (University of Huddersfield, UK), is part of the doctoral thesis entitled "Method to manage heritage buildings' interventions using BIM" developed by Isabel Jordan and supervised by Professor Jorge L. García Valldecabres and Professor Eugenio Pellicer Armiñana.

BIM has been used in architecture, construction and sustainability with successful results (Barnes & Davies, 2014). The benefits of applying BIM to historical buildings have been recently studied (Volk et. al, 2014) as Historical Building Information Modeling (HBIM) (Murphy et. al, 2009). Recent research indicates that even though BIM technology is well developed, the processes and the human resources adaptation to HBIM need further study (Mondragon et. al., 2015; Zekabat et.al., 2015; Boeykens et. al., 2012; Brumana et. al, 2014).

The aim of the case study with Fixby Hall is to (1) obtain information about the traditional work processes in the historical buildings in order to improve an initially developed method to manage the historical buildings' life cycle with HBIM (Fig.5); (2) to make the method more user-friendly; and (3) to validate it from its potential user's perspective.

Fixby Hall could benefit of this HBIM Method having a helpful guidance for its future interventions and knowing the possible benefits of applying HBIM to this historical building.

The data collected through the Fixby Hall case study was obtained from different companies and stakeholders involved with the building in the past and/or present. Those are: a Real Estate company, Huddersfield Golf Club (HGC), an architectural studio, an interior design company, a planning consultant company and a local construction company.

The main findings around Fixby Hall are described in part 3, including:

- History summary and Existing use of Fixby Hall
- Existing stakeholders involved in intervention projects at Fixby Hall
- Past refurbishment's approaches at Fixby Hall
- Difficulties identified in previous interventions at Fixby Hall
- Existing building information system at Fixby Hall
- BIM applied to Fixby Hall

The findings show a high level of collaboration between stakeholders, ordered processes and clear structures. The aspects that could be further developed include the lack of HBIM implementation and the lack of a central digital archive system.

The conclusions of the report demonstrate benefits in the possible HBIM application to Fixby Hall and the useful HBIM approaches to this historical building's management.

The main findings around the proposed HBIM Method are also presented in part 3 and include:

- Difficulties for small restoration companies to adapt to the HBIM Method
- UK legislative frame is perceived to slow BIM adoption
- The HBIM Method needs to add the structural study as a complement for the Laser scanner
- The HBIM Method needs to define who documents the model with the construction and maintenance data
- The HBIM Method requires stakeholders with BIM skills
- The HBIM Method needs to define the HBIM model's levels of maturity

The summary of the HBIM Method's findings indicated the necessity to simplify the method, increase its scope to include the whole life-cycle of the buildings and make it more flexible to different project's scales and resources.

2. RESEARCH METHOD

The case study method (Yin, 2009) was used in this research, and the data collection stages are described below (see also Figure 1).

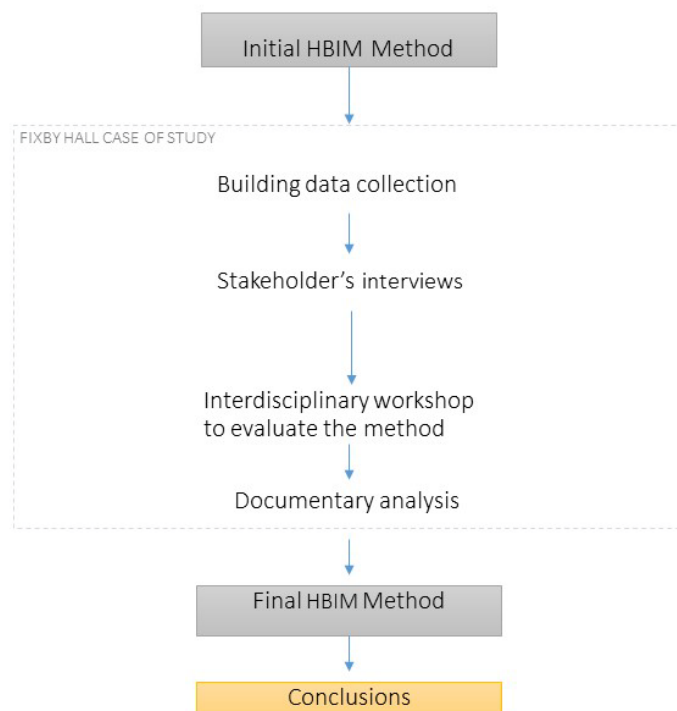


Fig.1. Main activities of the Fixby Hall Case study (2016).

Firstly, data consisting of a general comprehension of the organisation of the building, identification of the involved stakeholders, one site visit, a photographic report and investigation of old architectural designs was collected. This phase also included the identification of relevant historic and architectural documents, personal archives of diverse stakeholders and the study of the 125 anniversary book of HGC (Smith, 2016).

Secondly, seven one hour semi-structured interviews were developed with (a) the property, (b) the HGC President, (c) the HGC secretary, (d) the archivist, (e) the English Heritage Outreach

Manager, (f) the interior architect and (g) the contractor, all involved in previous refurbishment projects in Fixby Hall.

The main questions that were asked follow:

- In case a refurbishment of Fixby Hall was needed, what type of procurement is likely to be adopted?
- In case a refurbishment of Fixby Hall was needed, what would be your involvement?
- Which data would you consider important to include in a BIM model?

The initially proposed method was revised following the analysis of documents and interviews.

In the next stage, the new version of the method was presented for evaluation during an interdisciplinary workshop with the main stakeholders involved in Fixby Hall. The stakeholders evaluated the method stages and activities. This workshop included the director of the Real State Company, the HGC President, the architect, the planning consultant and a BIM consultant.

The last stage of the case study involved the design of the final version of the method, presented later in this report.

3. RESULTS

This section presents the Fixby Hall findings, the HBIM Method findings and the final version of the HBIM Method.

3.1 FIXBY HALL FINDINGS

A set of semi-structured interviews, developed between October and November 2016, was performed with the following stakeholders related with Fixby Hall:

- (A) The property: the Real State Company director, also a chartered surveyor, 26 years of experience.
- (B) HGC President: experienced in banking, hospitality and events management, 8 years of experience.
- (C) HGC secretary: golf club basis management, 28 years of experience.
- (D) Archivist: voluntary position, 12 years of experience as HGC archivist.
- (E) English Heritage Outreach Manager: external consultant for the Real State Company, more than 10 years of experience.
- (F) Interior architect, professional interior designer, more than 5 years of experience.
- (G) Contractor, specialised in plumbing and acclimatization, 15 years of experience.

The interviews had different questions depending on the interviewees' profile. These focused on the processes developed by the stakeholders, relationships with other stakeholders, how information is archived, and the use of new technologies in their work included the following specific questions:

- Would you consider important to have an “as built” BIM model of Fixby Hall for further maintenance control?
- What kind of information do you think would be useful to have on a BIM model of Fixby Hall in order to support its maintenance and refurbishment?
- Would you be interested to contribute personally to the work of the design team through online BIM websites?

The main Fixby Hall historical building findings were:

(A) HISTORY SUMMARY AND EXISTING USE OF FIXBY HALL

Fixby Hall, listed building, grade II, is owned by the Thornhill family since the 13th century when Sir Richard de Thornhill married Matilda of Fixby and it is thought that the Fixby Hall Estate was created (Smith, 2016). The main building is placed in a large Estate with partially wild woodland. The Estate also possesses other relevant buildings as the Orangery or the Stables (Faulhaber, 2010). Since 1808, the building has been occupied by Thornhill family members who have maintained it and done different refurbishments. Among these refurbishments, the building modernisation made in the middle 18th century which transformed it to its present Georgian style (1720-1740) stands out (Smith, 2016). Between 1808 and 1892, Fixby Hall was rented to several tenants like Richard Oaster, labours rights defender. Nowadays, Huddersfield Golf Club is the current tenant, and the letting and

operating is left to the real states company Thornhill Estates Limited, directed by Edmund George William Thornhill, who owns the building.

The building and surrounding area have been rented to Huddersfield Golf Club since 1892. It is being used as a sportive and leisure club, and it has been used recently as an events venue.

In conclusion, this heritage building achieves cultural and constructive qualities to potentially use in HBIM.

(B) EXISTING STAKEHOLDERS INVOLVED IN INTERVENTION PROJECTS AT FIXBY HALL

The responsibility of the historical building conservation, as part of the collective culture, lies not just with the architects and contractors but also the owners, tenants and people involved in the daily life use of the building. The restoration projects usually involve a complex social network and the decision making should be consensual. In previous Fixby Hall’s interventions, different stakeholders have participated collaboratively in the conservation or renovation projects. Figure 2 represents the current map of stakeholders who were involved in Fixby Hall’s management highlighting those related with maintenance and conservation.

STAKEHOLDERS INVOLVED WITH FIXBY HALL’S MANAGEMENT

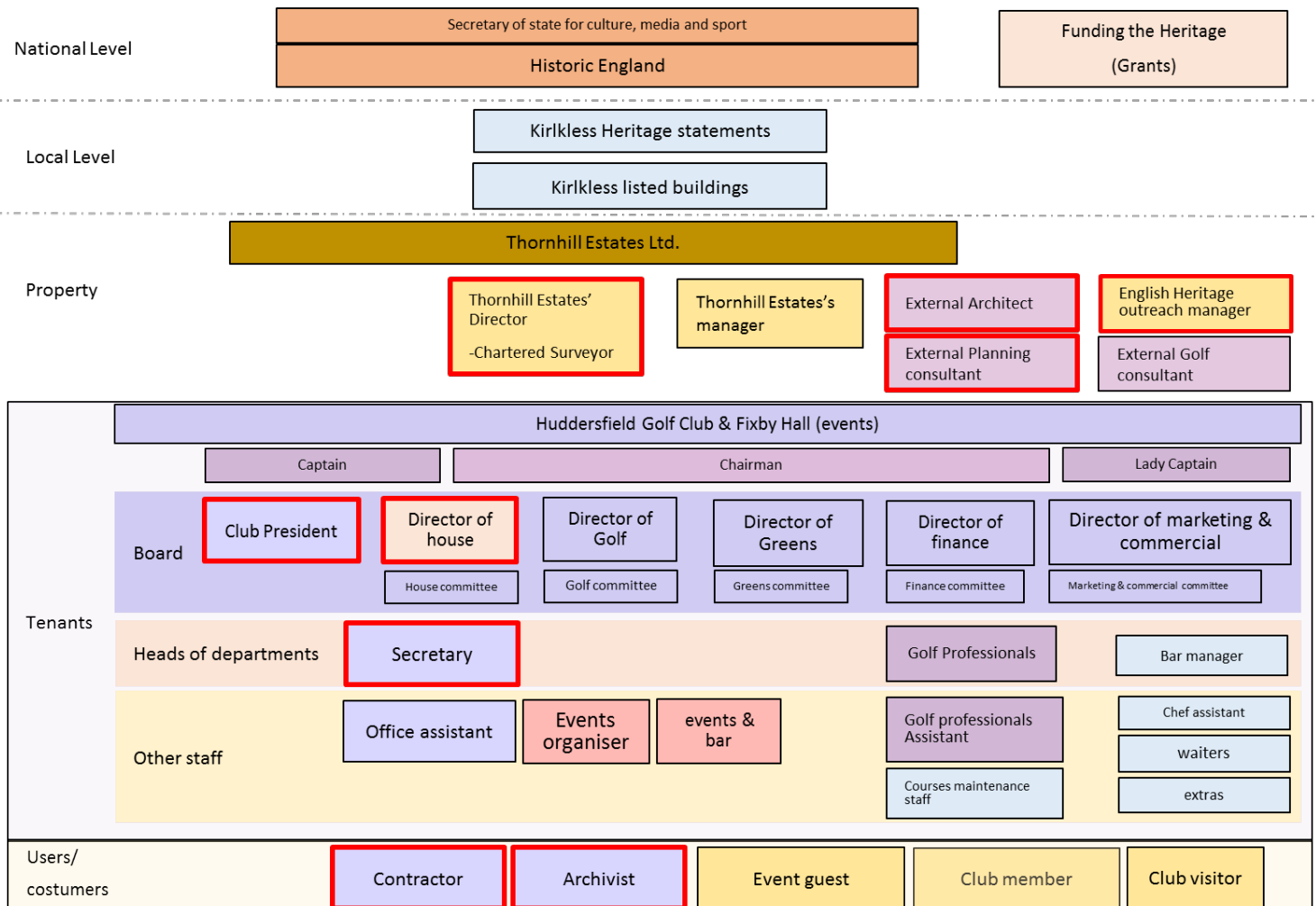


Fig.2. Fixby Hall’s general structure, underlined those whom have implication with the building’s maintenance and with this case study, according to the interviewees (2016).

The **legislative frame** for Fixby Hall’s refurbishments are Historic England at the national level and Kirklees City Planning department and Heritage department at the local level (Faulhaber, 2010).

A Real State Company, **the property**, manages and supervises the use and conservation of Fixby Hall. It owns different properties and the nature of its business is letting and operating owned or leased real estates. The company has a very close monitoring of its properties offering a continuous quality maintenance service (Interview with the property, 2016). The company's director and manager are involved in managing or supervising Fixby Hall's maintenance and conservation. Due to the long-time frame in which Fixby Hall has been rented to HGC, they have a very close relationship.

Sometimes, external consultants collaborate with the Real Estate Company. For instance, a golf consultant has helped in the golf sportive and business approach within Fixby Hall. Also, an English Heritage outreach manager is working on improving social engagement with Fixby Hall (English Heritage outreach manager's interview & Golf consultant's interview, 2016).

HGC, the **tenant** organisation, is led by the Chairman and as a sport club, it has a Golf Captain and a Lady Captain who do not participate in managing refurbishments but in sport issues. The Board, HGC main representative body, is composed by the Club President and the Directors of five departments: House, Golf, Greens, Finance and Commercial & Marketing.

The **House Department** is in charge of the building's maintenance and conservation. It is composed by the Director and its committee, which is formed by five or six members of the club with maintenance knowledge and interest. They manage regular maintenance operations required by an old construction and also major building renovations which are agreed upon with the Board and with the property (interview with HGC President and HGC Secretary, 2016).

HGC secretary, manages the club formalities, communicates issues between different departments and if it is required, she manages any urgent maintenance problems. She also documents the regular and extraordinary HGC meetings, where the Board explains to the golf members not just the normal golf club concerns, but also the maintenance operations and refurbishments. The meetings have been documented since the building was used by HGC. Thus, this records are a large source of information.

The **archivist** of the Club studied and summarised this documentation creating the 125 anniversary book. (Smith, 2016). It is a well-made compilation of the History of HGC (i.e. Golf Course, famous visitors, best golfers, and club memorabilia), the Thornhill Family, and illustrious events that happened in Fixby Hall.

A set of flowcharts representing the stakeholders tasks during previous Fixby Hall refurbishments were created. During the interviews, initial and more generic flowcharts were presented to the interviewees to ensure accuracy.

As an example, the property flowchart is presented bellow on figure 3. In the flowchart, the general tasks that the owner develops in his daily work are represented in intense orange. The maintenance and the intervention are the tasks of interest for this study, hence, they are surrounded by a blue dash line and are more detailed.

After the interviews, the flowcharts were updated according to the information provided by the interviewees. The final flowcharts of Fixby Hall stakeholders' tasks related with the building's maintenance and previous refurbishment are presented in annex 1 (Jordán et. al., 2017). As an example, the final flowchart from the owner's point of view is presented in Fig.3.

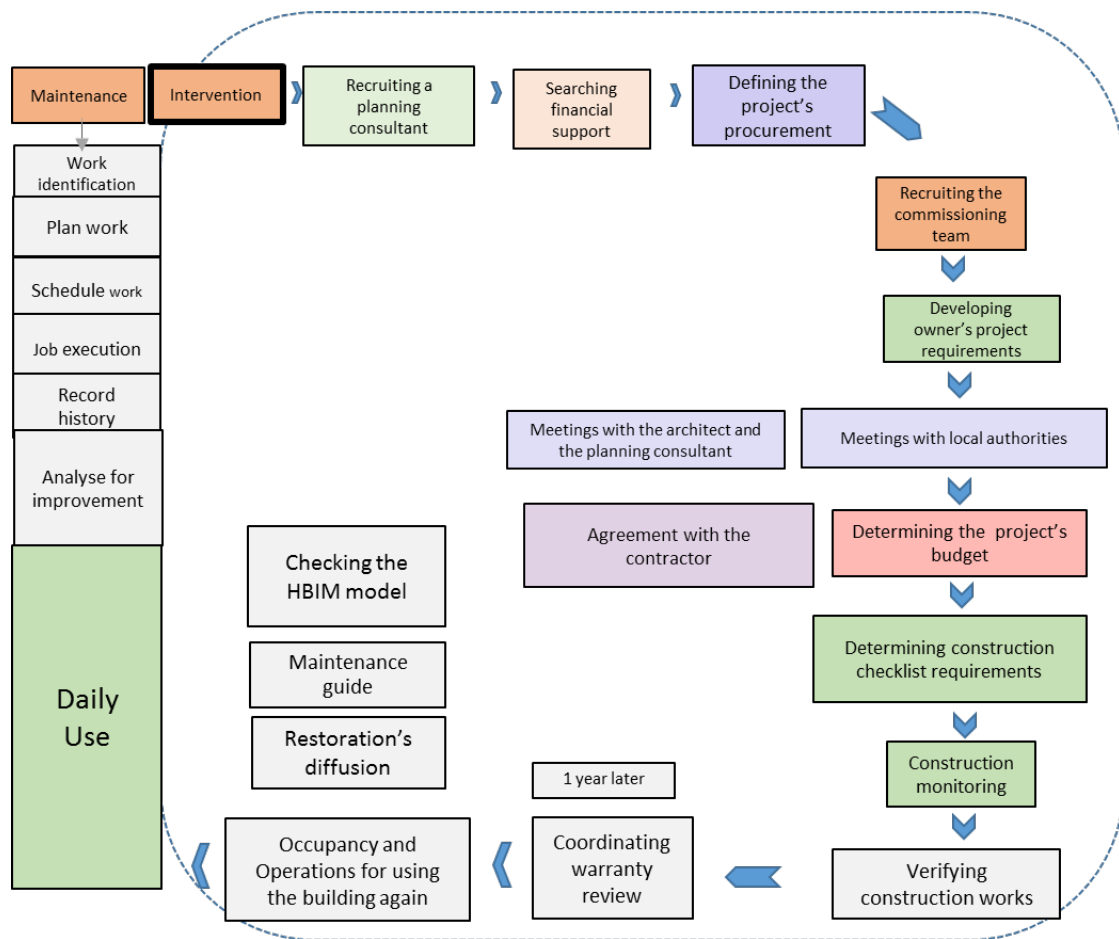


Fig.3. Final flowchart from the owner's point of view presenting the tasks related with the building maintenance and refurbishment. It was developed with the data provided by the owner in the interview (2016).

(C) PAST REFURBISHMENTS APPROACH AT FIXBY HALL

Huddersfield Golf Club is in charge of the building's maintenance and conservation, they have done several repairs and refurbishments, both in the house and in the golf course (HGC President and Secretary).

When a major refurbishment is needed, the Director of House and his counselling committee, after an informal members' consultation and a discussion with the Real Estate Company that owns the building, establish the refurbishment requirements. Following, the Director of House presents the project brief to the Board, and if they give their approval, the project is commissioned to an architect, who usually is also a Club member. The Club members are informed about the refurbishment in a regular club meeting. Once the architect's design is given planning approval, it is sent to three different contractors to generate quotations. Finally, the House committee, together with the Board, decide which contractor is the most appropriate (interviews with HGC President and Secretary).

For minor interventions, which are contemplated in the annual budget of the House Department, the Director of House can directly go ahead with the project without formally addressing it with the Board. The contractor's economical quotation is supervised by the Director of Finances and the refurbishment is informed to the Club members in its regular meeting.

The most relevant recent interventions in Fixby Hall have been: in 2003, consent for internal alterations to form an entrance lobby and a reception office (Kirklees Planning and development

department, 2017); and in 2014, intervention in the locker room and the restroom designed by the interior architect and constructed by F & R Mallinson Ltd (interviews with HGC President, HGC Secretary and contractor). During the construction work of these interventions, the building was not evacuated, so the construction work needed to be coordinated with the regular life at Fixby Hall. This coordination labour was mainly done by the Secretary or her office assistant (interview with HGC Secretary).

These previous interventions in Fixby Hall had been led by the House Department (interview with HGC President). The design and build approach mean that the designers and the contractors are from diverse companies. Concretely, in the locker room refurbishment, all stakeholders involved were members of Fixby Hall: the interior architect, HGC President, is a member of the House committee; the contractor is a club member. Thus, there were frequent coordination meetings in a very familiar environment, which propitiated the successful results of the project (interview with HGC President). The flowchart with the tasks developed by the Fixby Hall stakeholders is presented bellow (Fig.4).

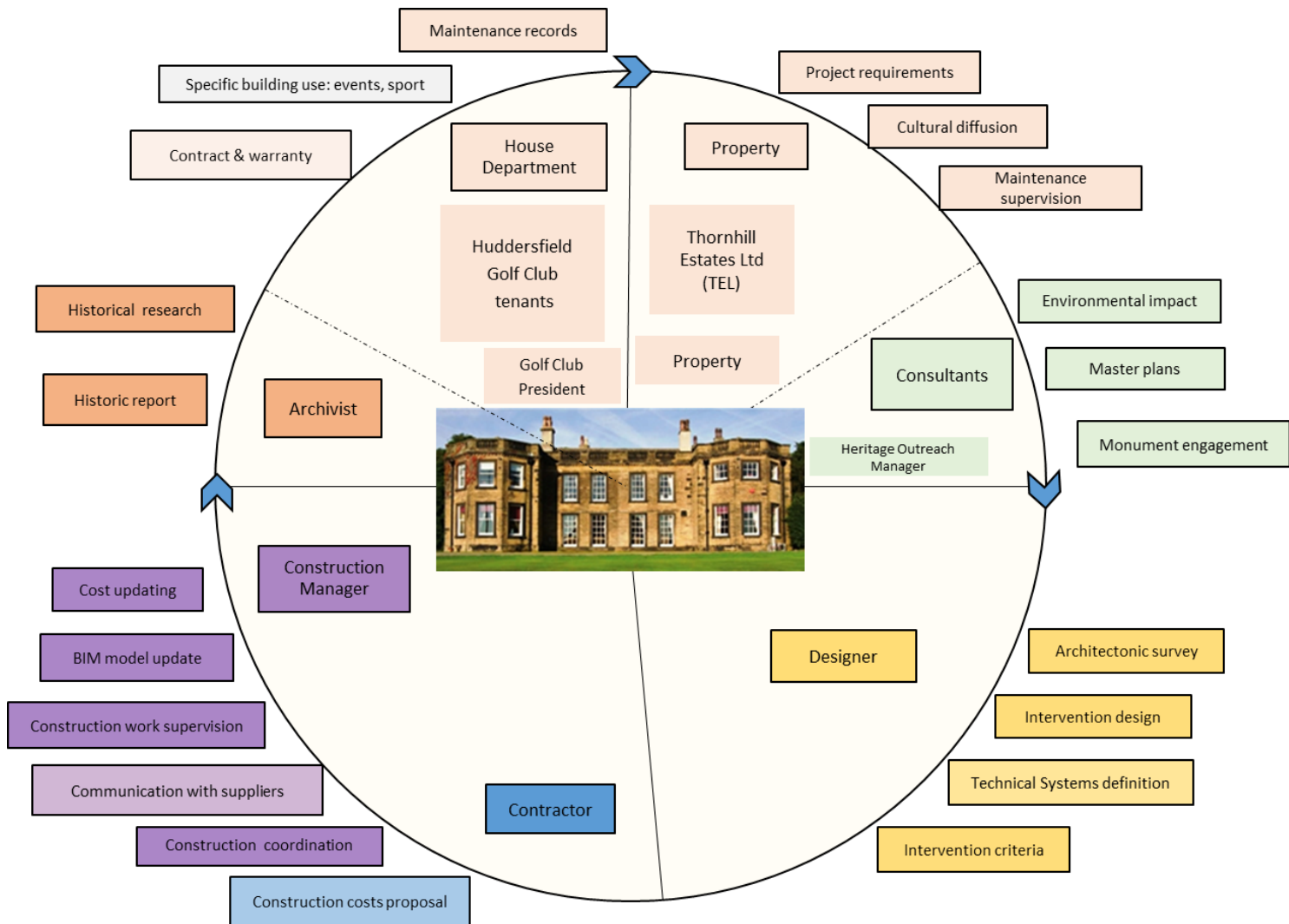


Fig.4. Tasks developed by the Fixby Hall stakeholders.

(D) EXISTING BUILDING INFORMATION SYSTEM AT FIXBY HALL

The information about Fixby Hall's previous interventions and management is separately archived by the different companies involved. Each of the stakeholders archive different types of information in different places as it is described below:

The property, Thornhill Estates Ltd (TEL), has their own digital storage archiving the historical and part of the architectural information of their various properties. This system is thought to modernise into a sophisticated online collaborative database that can archive ordered data of all the buildings that the company owns (interview with the property).

The Golf Club has its own archive with physical folders, which contain the historical records of the Club meetings (interviews with HGC archivist). Recently, the archivist of the Club wrote the book "Huddersfield Golf Club 125 years at Fixby" doing an interesting compilation of the Golf Club paper records. The information of the building management was mainly archived in the Golf Club archive.

F & R Mallinson Ltd, the construction company, works with a digital folder system in which every building they work on is archived, including the e-mailing system and the specific application for managing repairs. They have the technical and constructive data (interview with the contractor).

The architects at Enjoy Design Ltd and the designers involved in the research archived the information digitally and with increasing degrees of online collaboration. They possess the design and technical documentation (interview with the architect).

(E) DIFFICULTIES IDENTIFIED IN PREVIOUS INTERVENTIONS AT FIXBY HALL

Previous interventions in Fixby Hall were very successful in terms of cost and time. There was a high level of collaboration between the different companies' stakeholders, ordered processes and clear department's structure. However, issues that different interviewees pointed out were:

- Lack of preventive maintenance in the building.
- The building information was separately archived by the different stakeholder who participated in the projects.
- High time demanded for the House Director and his committee (interview with HGC President).
- Historic buildings have a series of unknown elements and additional works that may need to be resolved after the contract has commenced, because of the frequent issues founded on site (interview with the contractor).

The diagram below show the tasks that every Fixby Hall's stakeholder develops within a HBIM project.

(F) BIM APPLIED TO FIXBY HALL

There hadn't been a BIM intervention in Fixby Hall due to the last refurbishment being done before this technology was available. However, different stakeholders had declared that the system could be very helpful for future interventions in the building.

The HBIM Method can gather the historical evolution of Fixby Hall facilitating the managing and visualization of future interventions. Fixby Hall has accumulated diverse interventions in its construction items as well as in its surroundings and courses. The application of HBIM could unify and represent the whole constructive-historic evolution in one single file.

A good maintenance plan and service for existing buildings, such as Fixby Hall, is very important for the building users. So, having clear and complete maintenance information in an HBIM model results very useful.

The 'as built' HBIM model would be very useful for contractors, architects and owner because it can control the facility management, explore better sustainability and energy efficient systems, control the degradation of materials and furniture (i.e. cracks, humidity), manage the tenancy occupancy and control the furniture inventory of historic buildings. This aspect could be really useful to manage not just Fixby Hall but also similar buildings. It is recommended to apply HBIM progressively and start using a small building, such as it is the Orangery, as pilot case.

The community engagement with historical buildings such as Fixby Hall is very important in order to raise public awareness about the cultural value of our heritage and the need of heritage resources and education. HBIM models can be used as source of visual information to engage and explain the cultural value of Fixby Hall to the community (interview with the Heritage Outreach Manager).

The HBIM Method should be simple and friendly so all the stakeholders, technical and not technical, can understand and use it (interviews with the property and the contractor). Thus, it is recommended to progressively adapt Fixby Hall to HBIM systems.

The valuable history of Fixby Hall as well as the history of its historic characters could be loaded in a historical online database linked with the HBIM model. The identification of the community with their close culture becomes stronger when having a physical building or a physical 3D virtual building that makes them recreate better the historical facts.

3.2 HBIM METHOD FINDINGS

After carefully studying Fixby Hall, it was considered appropriated to adopt the HBIM Methodology. Different stakeholders related to Fixby Hall were invited to a multidisciplinary workshop in order to contribute with their necessities and requirements within an innovative HBIM Method for managing historic building.

This HBIM Method has been designed taking as reference the Construction Industry Council (CIC) BIM Cyclical Diagram (Construction Industry Council, 2013). Also, different guides provided by recognised Heritage organizations which had studied HBIM such as the International Council on Monuments and Sites (ICOMOS), Historical England, and the Council on Training in Architectural Conservation (COTAC). The Conservation Principles of Historical England had been taken into account as well as the ICOMOS Education and Training Guidelines (Maxwell, 2014).

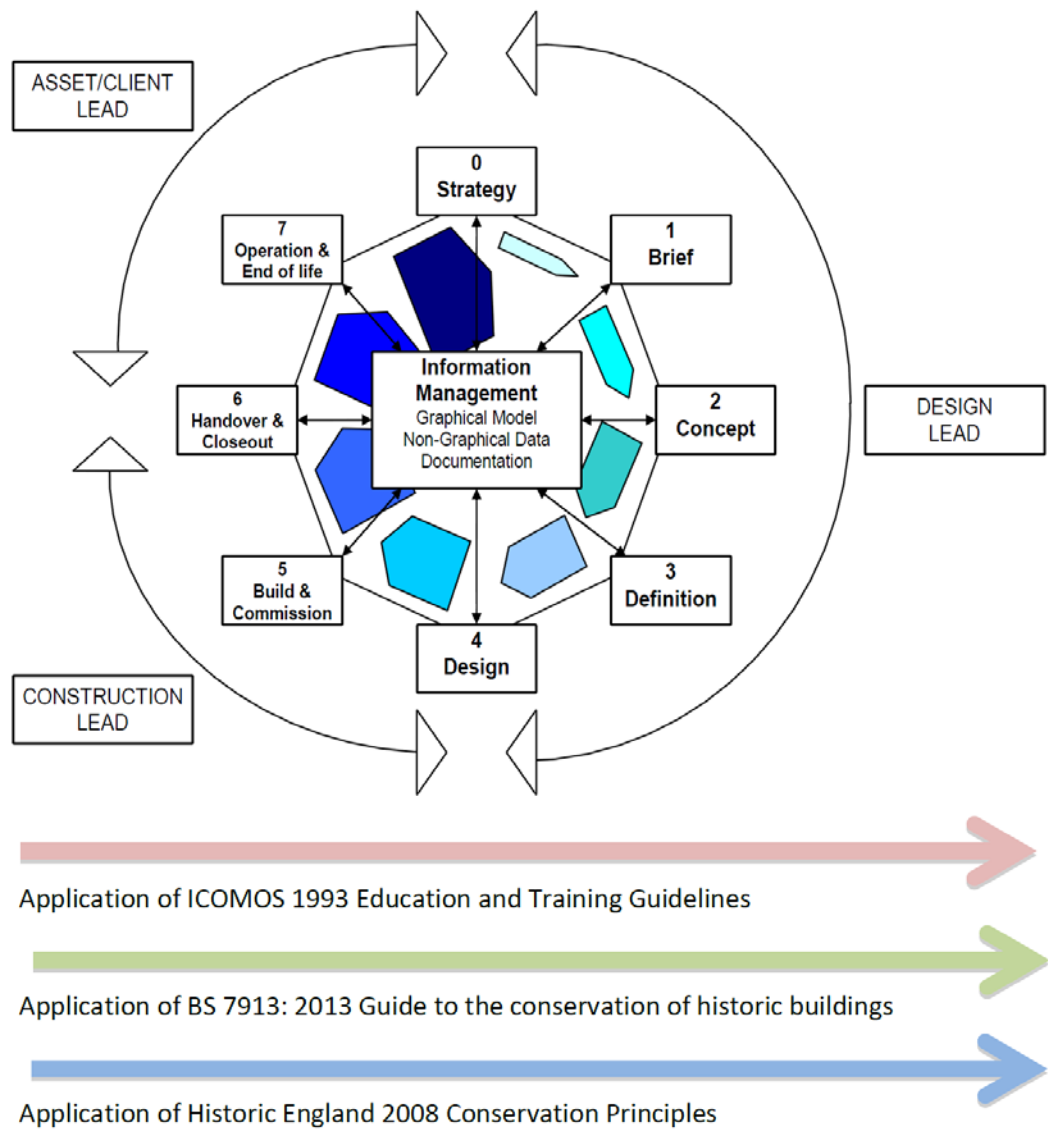


Fig.5. Construction Industry Council (CIC) BIM Cyclical Diagram has been used as reference flowchart to design the HBIM Method.

The workshop was performed with historic architecture stakeholders and BIM stakeholders in order to present and validate the designed HBIM Method in figure 5. The purpose was to discuss the validity and the possible improvements of the designed HBIM Method with potential users.

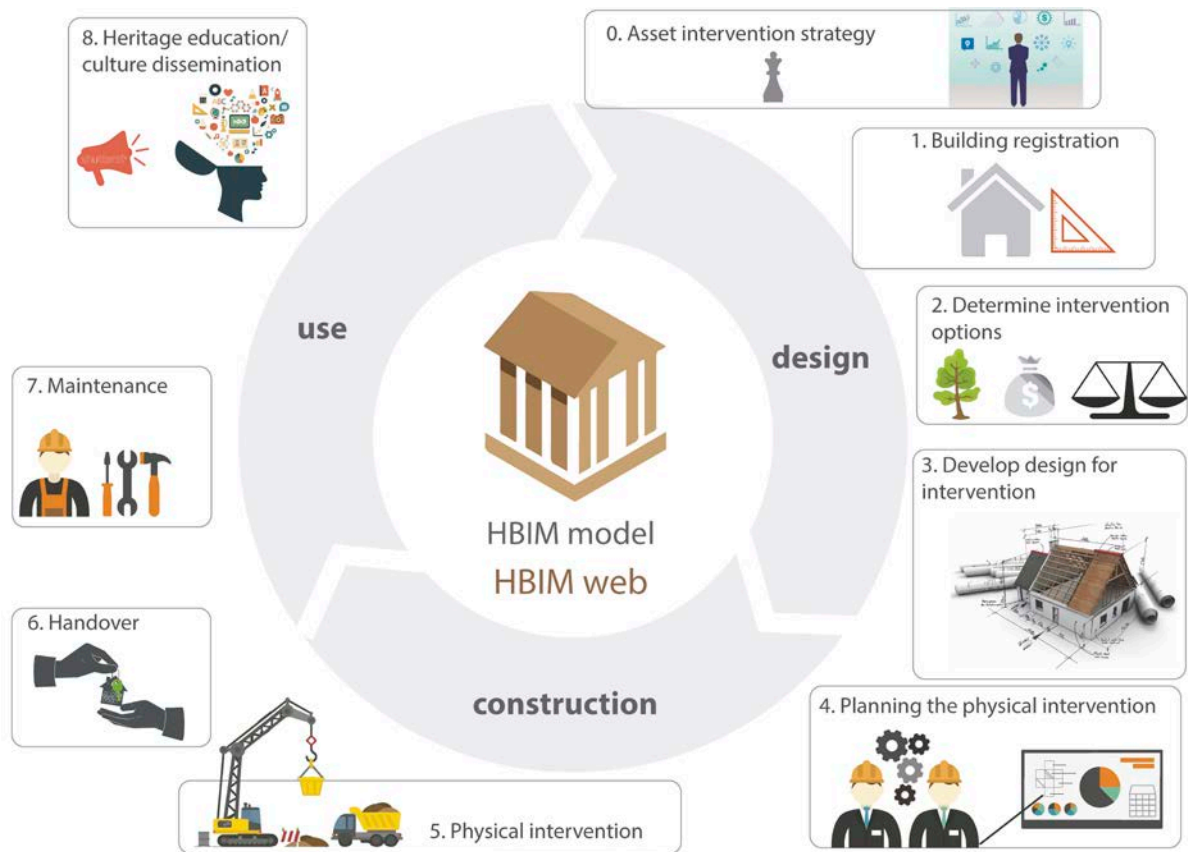


Fig.5 Method. Layer 1. General approach. Presented in the workshop for its validation with potential users.

This one hour and a half workshop was held at Huddersfield University, Queen Street Building, on December 14th, and the participants were:

- (A) Fixby Hall property: the Real State Company director who is also a chartered surveyor, 26 years of experience.
- (B) The architect: who works with BIM and HBIM, has more than 20 years of experience.
- (C) The planning consultant: experienced in heritage buildings, more than 20 years of experience.
- (D) HGC President: experienced in banking, hospitality and events management, 8 years of experience.
- (E) BIM consultant: with knowledge in Lean Construction and in BIM implementation, 4 years of experience.

The workshop started with a short explanation of what the HBIM is. Then, the designed HBIM Method was explained presenting its eight phases. Then, six specific questions were asked, including:

- After seeing the method, are some phases involving the intervention of the historical buildings missing? Are some stakeholders missing?
- Is the model easy to use?
- Who would document the HBIM during construction and maintenance?

The participants were very active creating an interesting debate putting examples of their own experience and discussing possible solutions to achieve potential problems. The main findings about the HBIM Method were:

(A) DIFFICULTIES FOR SMALL RESTORATION COMPANIES TO ADAPT TO THE HBIM METHOD

Even some large construction companies use BIM, but small companies working in historical buildings have generally not enough resources to invest in HBIM. The workshop's participants described that the refurbishments where they have been working were in general not fully performed with HBIM.

Thus, the HBIM Method could not be fully apply in small restoration companies. They will progressively implement the HBIM Method with different levels of maturity, depending on the company resources and clients' needs.

(B) UK LEGISLATIVE FRAME IS PERCEIVED TO SLOW BIM ADOPTION

The participants agree that there are several bodies in the United Kingdom (UK) that need to be consulted since they can object the building intervention: 0) international, 1) national, 2) local, 3) civic societies.

According to the planning consultant's long experience managing tender documentation, these institutions will have a slow BIM adoption because they have neither the human or economic resources to push this process.

UK legislative frame probable slow adoption will condition the HBIM Method complete use.

(C) THE HBIM METHOD NEEDS TO ADD THE STRUCTURAL STUDY AS A COMPLEMENT FOR THE LASER SCANNER

The quality of the BIM model for historical buildings would vary depending on the survey and the starting information. The laser scanner technique saves time when doing the building survey providing a great accuracy on measurements.

During the workshop some participants explained that even the point cloud technology is thought as the best way to document the existing condition of a building; it has limitations as to what is inside the fabrics due to the fact this technology is only able to record the exterior side of the walls.

Consequently, the structural studio to analyse the wall's cohesion and structures' strength is still required and needs to be added to the HBIM Method. The point cloud would just be the framework for a BIM model, on agreeing with the BIM consultant.

(D) THE HBIM METHOD NEEDS TO DEFINE WHO DOCUMENTS THE MODEL WITH THE CONSTRUCTION AND MAINTENANCE DATA

The property representatives argued that they would not have the time or knowledge to update tan hypothetic HBIM model. The technical stakeholders (i.e. architect, BIM consultant) exposed that updating the BIM model with constructive and maintenance information would increase the project's budget since it is an extra service.

The consensus opinion was that the HBIM Method needs to progressively adapt to higher levels of HBIM documentation. Since the contractor or the property may own the model, then a technician from the contractor company would document the model during construction and/or maintenance.

(E) THE HBIM METHOD REQUIRES STAKEHOLDERS WITH BIM SKILLS

Nowadays, just some architects and engineers use BIM, as well as some big construction companies. Consequently, HBIM projects cannot yet achieve a high level of maturity because of the poor BIM knowledge of mainly the non-designers stakeholders, so the productivity is not as high as it could be.

According to the participants, the historical building's stakeholders are: owner, planning consultant, chartered surveyor, historian, archaeologist, monument manager, planning officer prior, architect, engineers, contractor, suppliers, construction manager, construction workers, and restorer. Just some of these stakeholders have BIM knowledge, thus, the HBIM Methods needs to include BIM education for the non-designer stakeholders.

In this line, "HBIM for the property" needs to be as much user-friendly as possible since property agents have no previous technical knowledge.

Thus, an HBIM platform should be added to the HBIM Method. Online BIM platforms, as A360 or BIM Legacy were agreed to be very useful to communicate among different stakeholders during the project because they were thought to be very visual and easy to use.

The construction workers are key stakeholders who should adapt to BIM because they are the last link in the building process. In order to reduce site mistakes, complementary technologies linked to BIM, such as 3D glasses, should be added to the HBIM Method.

(F) THE HBIM METHOD NEEDS TO DEFINE THE HBIM MODEL'S LEVELS OF MATURITY

The participants thought that the level of maturity, how detailed is the modelling and how much information the HBIM model contains, has to be defined in the HBIM Method.

The over working and the duplication of work cause economic loses; consequently, defining tasks in the initial strategy is essential. Thus, different levels of maturity need to be defined depending on the different project purpose and property engagement. A conventional historic building property cannot afford the costs of a maintenance HBIM model. However, in 5 to 10 years' time the levels of maturity of the models would increase.

3.3 FINAL VERSION OF THE HBIM METHOD

All the information collected through the case study participants who were professionals working on Historical buildings and BIM environments was extremely interesting for the development of the HBIM Method's final version. With all the Fixby Hall findings and HBIM Method findings, the final method was designed.

The final version included three layers of development, and each layer has a more detailed approach (figure 5). Layer 1 contains all the phases of the method. It is designed to be clearly understandable by all the stakeholders, technical and non-technical. The structure of the method is circular around a BIM model and a BIM Platform where the stakeholders could have a work space to share data.

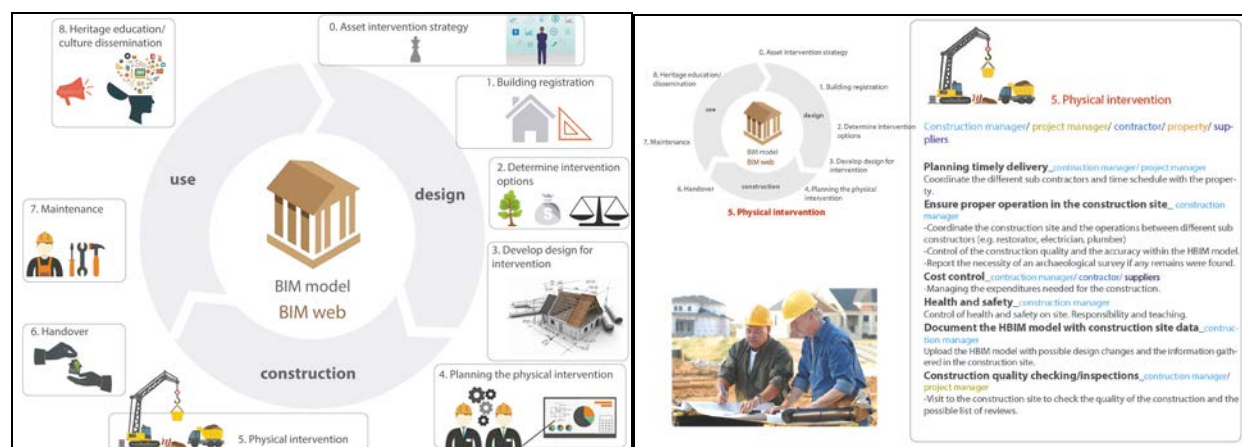


Fig.5 From left to right: the general method or layer 1; and one of the 8 sheets of layer 2 of the method.

Layer 2 consisted of 8 pages with a deeper explanation of each phase. It describes the stakeholders involved in each phase and tasks. It is also designed to be understandable by all the stakeholders, technical and non-technical. Layer 2 is presented in annexe 2 (Jordán et. al., 2017)

Layer 3 will be developed in future research work. It will be a specific explanation of each phase and oriented to the technical team leading each phase. It will be designed for technical stakeholder's use.

PHASES' DESCRIPTION

Phase 0. **Asset intervention strategy** includes the general exploration of the building, the understanding of the client's brief, the definition of the contract, the identification of the significance and value of the building and the historical and archaeological archives records. Also, the valuation of the property, the consultation of the master plan and the definition of the BIM Execution Plan (BEP).

The planning consultant, who manages the tender documentation and the first phases of a project; and the heritage outreach manager, who is in charge of the community engagement and the public awareness about the cultural value of the historical building, should participate in the HBIM system taking as much HBIM data and resources as possible.

The kind of procurement (Integrated project delivery (IPD), classical procurement of design service), the project leadership, the BIM project approach and the property of the HBIM model should be defined in the initial contract.

Phase 1. **Building registration** contains the architectonic 3D modelling of the existing building, the definition of its historic evolution, the modelling of the materials and the degradation pathologies, the M&E modelling, the structure modelling and the HBIM documentation with relevant historic and archaeological data.

The building's registration includes both new and traditional techniques, laser scanning is complemented with the structural studio to analyse the wall's cohesion and structures' strength.

The result of this phase is an HBIM model of the existing situation of the historical building with a high level of development. The previous hypothetic historic-constructive phases have to be done with a lower level of development since usually there is not much information about ancient building's phases.

Phase 2. **Determine intervention options:** describes the definition of the legislative frame, the preliminary cost estimation, the maintenance, environmental, economic studies, the definition of the intervention criteria and the client's requirements.

The scale of the project would determine the procurement and the level of involvement of the stakeholders in the project. The property expresses clearly the aims of the project in this phase.

This phase entails a decision taken that should be agreed on among all the stakeholders. So, a BIM website platform will be the most appropriate system to share the documents generated by the different disciplines. These systems have been studied by different interdisciplinary groups with very good results in improving the productivity (Sackey et. al, 2015).

Phase 3. **Develop design for intervention** includes the assignation of work to different stakeholders, the architectonic and constructive project, the statutory approvals and the structural and M&E project. Architects, construction and structure engineers and planning consultants should lead this phase.

The property is proposed to have a great involvement with the design team as well as the contractor. The HBIM Method proposes that these stakeholders interact with the design team through online BIM platforms that allow the visualization and labelling of the HBIM models as well as commenting them in real time. The tender documentation, usually elaborated by the planning consultant, should be linked to the HBIM Model through the BIM platform.

In this phase, the intervention will be represented in the HBIM model with a new phase. The new phase of the HBIM model should reach a medium level of development.

Phase 4. **Planning the physical intervention**, this addresses the cost estimation and the economical budget and also the construction planning in time synchronising it with the sub-contractors.

This phase is proposed to be leaded by the contractor and supervised by the design team. It is important that the contractor company have technicians with BIM knowledge. The idea is to detail and complete the HBIM model previously created by the design team until it becomes a virtual construction model.

BIM 4D (time) and BIM 5D (costs) should be achieved in this phase adapting to the resources and possibilities of the project (Chaves et. al., 2016). The project's costs calculated by the quantity surveyor should be linked with the HBIM architectonic model.

Phase 5. **Physical intervention** explains the planning timely delivery of the construction works, the operations in the construction site, the cost control during the construction, the health and

safety plan, the HBIM documentation during the building's construction and the construction quality checking.

This phase is leaded by the construction manager. The HBIM model should be updated with all the changes and decisions on the construction site. The result of this phase should be an "as built construction HBIM model" that should contain all the technical and constructive information. The benefits of the visualization of the construction actions have been studied with satisfactory results (Kagioglou & Tzortzopoulos, 2016).

Phase 6. **Handover** addresses the warranty and contract review and the team meeting to learn from decisions and get feedback for further meetings.

The "as built construction" HBIM model is a contract document that should be given in this phase to the property. However, this technical document is not appropriated for managing the building's maintenance or to control space with it because it contains too much constructive and architectonic information.

The "as built management model" should be delivered in this phase. It is a very simple and easy HBIM model with just the required information for a proper building maintenance and, if it is required by contract, the spaces management information. These HBIM models have a non-technical nature since they will be used for non-technical stakeholders.

Phase 7. **Maintenance** phase exposes the schedule of the preventive maintenance, the energy efficiency checking, the environmental policy awareness, the "as built" model to control maintenance and its documentation. The management HBIM models may be updated by a maintenance technician or contractor employee and not by the property or building managers since they have not the knowledge or the facilities information to do it.

Maintenance is the longest phase of the method and it should be carefully planned depending on the building's necessities. The "as built management model" is the document that should unify the data of the different facilities that the building has. BIM 6D, which is energy performance and alternatives consumption studies, is recommended for long term economic improvements.

Ideally, this easy and simple model should be handled by the maintenance manager, but a large number of buildings do not have such a person. Thus, it should be so easy to use that the building manager could be able to update it.

It is also recommended that the construction company, which performed the intervention, should be in charge of the building's maintenance. This matter should be treated in the initial contract.

Phase 8. **Heritage education** is the last phase and it addresses the community engagement, the cultural dissemination and education and the identification of funding bids and government grants.

Heritage buildings could improve the management of their spaces by the use of "as built HBIM models" that could help the quantity of people who is using one space, the degradation state of the building's furniture and objects, and the economic profit in terms of the rent that each historic building provides.

The public governments, institutes and private companies that have a large number of historic buildings could have a data base with all the HBIM models of their property in order to centrally manage them.

The HBIM models are a visual source of data to share with society and engage the general public within the heritage and cultural buildings (Salvador et. al., 2017).

4. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS OF FIXBY HALL CASE STUDY

- Fixby Hall is a well-managed historic building regarding maintenance and refurbishments. However, it has not yet adopted more productive systems such as the BIM.
- The departments and structures of Fixby Hall are well organised and the stakeholders have a good relationship with frequent meetings.
- The building's documentation is spread out between the different stakeholders. There are diverse archives where there are different kinds of documentations related to the building (a.e. HGC archive, Thornhill Estates Ltd.'s computer system, F & R Mallinson Ltd digital archive system).
- The existing drawings of the building (i.e. floor plans, elevations and sections) were generated with traditional architectonic data collection. Even though it is of high quality, nowadays there are better systems which could improve the accuracy of the architectonic survey.

RECOMENDATIONS FOR FIXBY HALL

- It would be very useful to have an "as built" HBIM model for Fixby Hall because it would concentrate all the information related with maintenance, M&E conditions and the building's degradation. Consequently, it would be very easy and fast for the House Department to find specific documentation.
- An architectonic-constructive HBIM model with all the historical phases and changes that the building has had will be very useful for future refurbishments. This 3D HBIM model could also have the historical information of the building linked with the architectonic elements.
- To generate a point cloud with photogrammetric architectonic survey of the building would procure an accurate document to start any kind of BIM model.
- Preventive maintenance in Fixby Hall would be a good practice since it is a considerable large ancient building. Preventive maintenance, with the right BIM documentation, would result in long-term affordable preventive maintenance rather than corrective maintenance, which means to do repairs just when something breaks and in general is more costly.
- It would be beneficial to implement the HBIM Method in the next Fixby Hall's refurbishment to manage the design and construction phases. This HBIM model would be an excellent documentation that could be utilised in further interventions in Fixby Hall as well as in possible interior design projects and furniture re-distributions, enabling 3D simulations.

- In future refurbishments, it would be beneficial to include all stakeholders from the inception of the architectural design.
- The HBIM models are very visual to explain construction actions to a great public. Thus, Department of House could use them to justify any construction action to the club members.
- A unify digital infrastructure is recommended for Fixby Hall in order to order the documentation. It is further explained in Annexe 1.

HBIM METOHD CONCLUSIONS

- The HBIM Method should cover all the life-cycle of the building to achieve successful results. It should not be focused just in the technical point of view but in the social and processual too.
- The processes used traditionally in the refurbishments projects, such as the initial structure survey or the client brief, should be integrated in the HBIM Method.
- Simplicity and clarity are key elements in the success of the HBIM Method. The stakeholders have different backgrounds and limited time to understand the method. Evident and revelling graphics as well as simple vocabulary help the participants to understand the concepts.
- The HBIM Method should be adaptive to the project resources and scale. Factors as the kind of procurement, the project leadership and the property of the HBIM model should be defined to adapt the project degree of HBIM adoption.
- The levels of maturity in the HBIM models should be adapted to the aims, scale and human and economic resources of the historic projects.
- All historic architecture's stakeholders have to be taken into account in the HBIM Method, including the planning consultant, the heritage outreach manager, the quantity surveyor, the property, the building manager, the restorer and the archaeologist.
- BIM education specifically for property and building managers should be provided. The property and building's managers should be active stakeholders, which means that they have to understand methods and models.
- The relationship between HBIM stakeholders will improve when using online BIM workspaces. Tools such as A360 or BIM Legacy will generate the creative conversation that are needed, especially for the first phases of design. HBIM would facilitate for all the consultants to see each other's work; e.g. the legal documents, the technical drawings, the construction reports.

Potential BENEFITS OF HBIM as described in the literature

- With HBIM it is possible to have all the historic-constructive phases of the building in one single 3D model (Brumana & Georgopoulos, 2014)
- All the historic, architectonic, archaeological, legal, environmental, and maintenance data of Fixby Hall can be collected and synchronised as needed (Ariyaci et. al.,2017).

- With HBIM the quality of projects tends to be higher and costs similar to standard projects (Migilinskas, 2013). The standardisation of the constructive 3D elements enables easy sharing of information between all the stakeholders involved in the refurbishments. Once the 3D model is created, it is possible to automatically obtain all the sections, facades and floor plans (Barnes & Daves, 2014).
- The project and construction times are shorter when developing a project with BIM given that stakeholders and consultants can see each other's work as it is developed, enabling them to share data and resources (Volk, 2014).
- HBIM reduces the changes during the construction phase as the virtual construction allows contractors and engineers to foresee any possible mistakes (Lu et. al., 2015).
- HBIM gives clients a clear understanding of the space use through 3D visualisation. This feature will enable clients to better understand the proposed design from its initial stages, and changes can be included before construction starts. Traditionally, there were a lot of processes that the client was unaware of because he/she did not have access to this information and could not easily understand it. However the 3D HBIM models facilitate decision making giving the client an in depth understanding of the project (Zekvart, Moon, Bernold, 2015).
- HBIM can facilitate Fixby Hall's maintenance and use management (Boeykens, Himpe, Martens, 2012).

In conclusion, HBIM will help Fixby Hall to be at the forefront of historic buildings' management by unifying variety of information and enhancing historical values. An HBIM Implementation Plan is the required document to achieve this proposes and continue with this research line.

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FIXBY HALL CASE STUDY

SUMMARY RESEARCH REPORT

UNIVERSITY OF HUDDERSFIELD
UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ANNEX 1

Fixby Hall's flowcharts



GENERAL ORGANISATION

Fixby Hall is an historic building which have had diverse refurbishments. Previous refurbishments in Fixby Hall have adopted the following structure.

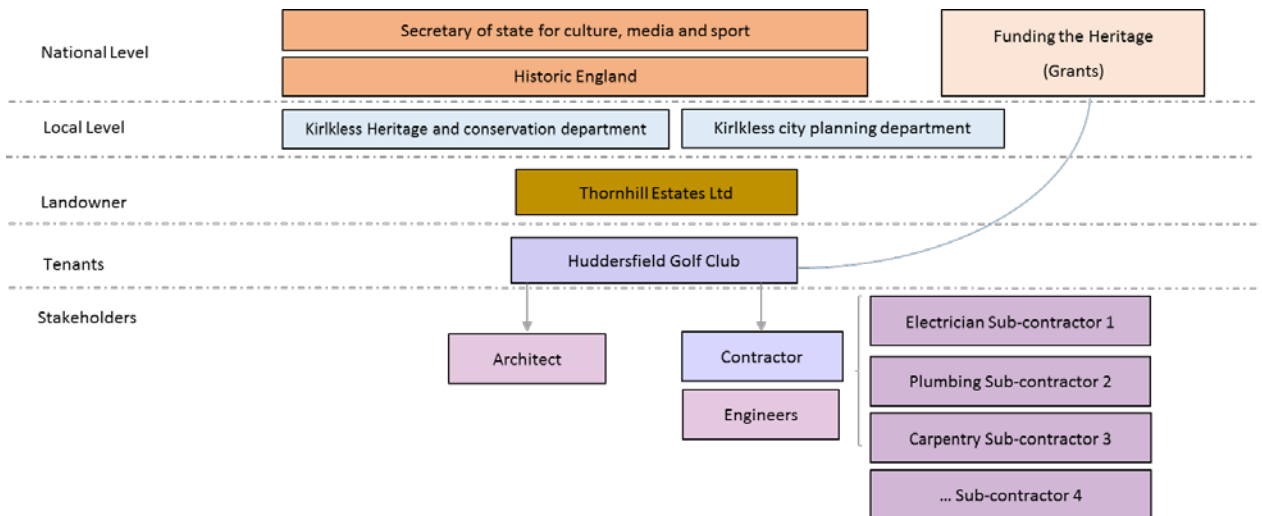


Fig.1. Structure of previous refurbishments in Fixby Hall (2016).

FIXBY HALL'S STAKEHOLDERS

As a result of the interviews, two flowcharts of each interviewee were developed. The first flowchart was created before the interview and it contains the presumable tasks that the interviewee do in his/her job underlining the tasks related with interventions and maintenance. In the interview, the flowchart was showed to the stakeholder and he/she corrected it. Thus, the second flowchart is the corrected flowchart after the interview. Three examples of relevant stakeholders' flowcharts are presented:

OWNER'S TASKS

The following flowchart has in intense orange the principal tasks carried out by a historical building's owner. In the right part of the flowchart, the conservation tasks are detailed and in the left part the tasks related with interventions in the building and maintenance are developed.

HISTORICAL BUILDING MANAGEMENT FLOWCHART (Owner point of view)

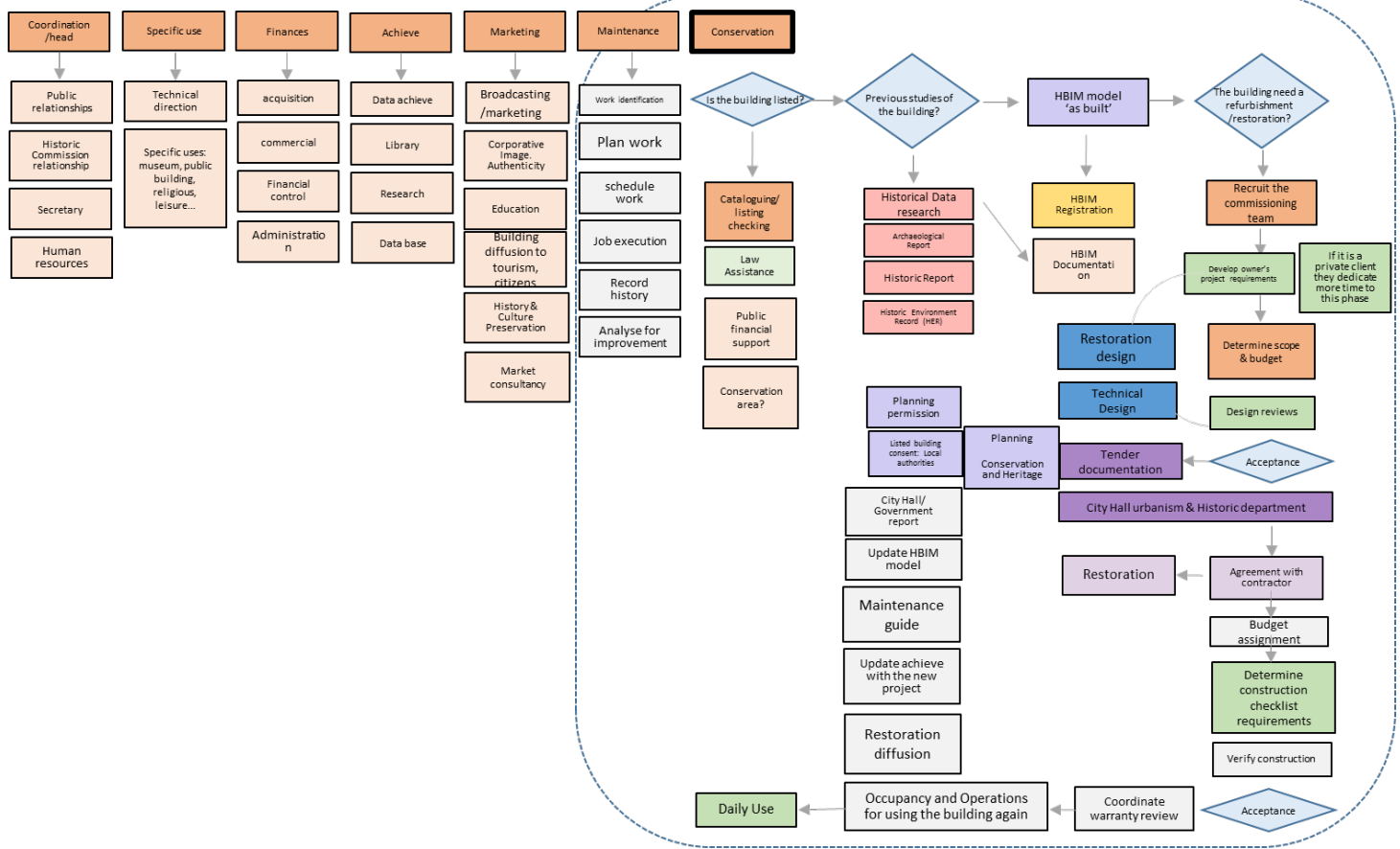


Fig.2. Initial flowchart from the owner’s point of view presenting the tasks related with building maintenance and refurbishment. It was presented in the interview (2016).

The following flowchart was developed after the interview with the property and it contains the tasks of the building’s owners related with the maintenance and intervention phase.

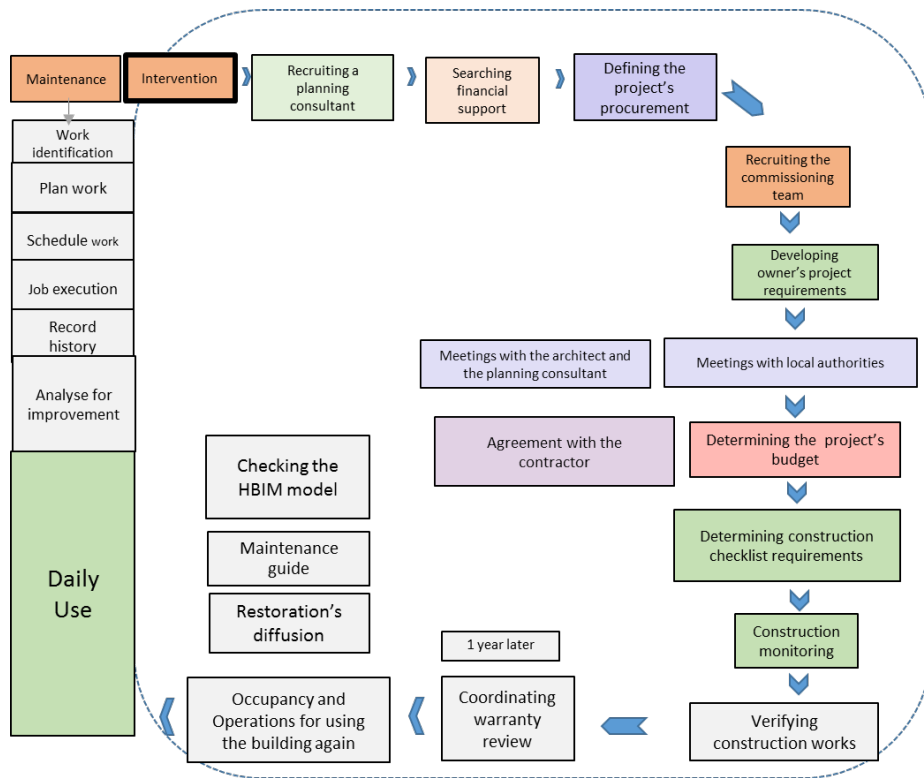


Fig.3. Final flowchart from the owner's point of view presenting the tasks related with building maintenance and refurbishment. It was presented in the interview (2016).

The next flowchart represents the ideal owner's tasks in the design phase of a refurbishment project.

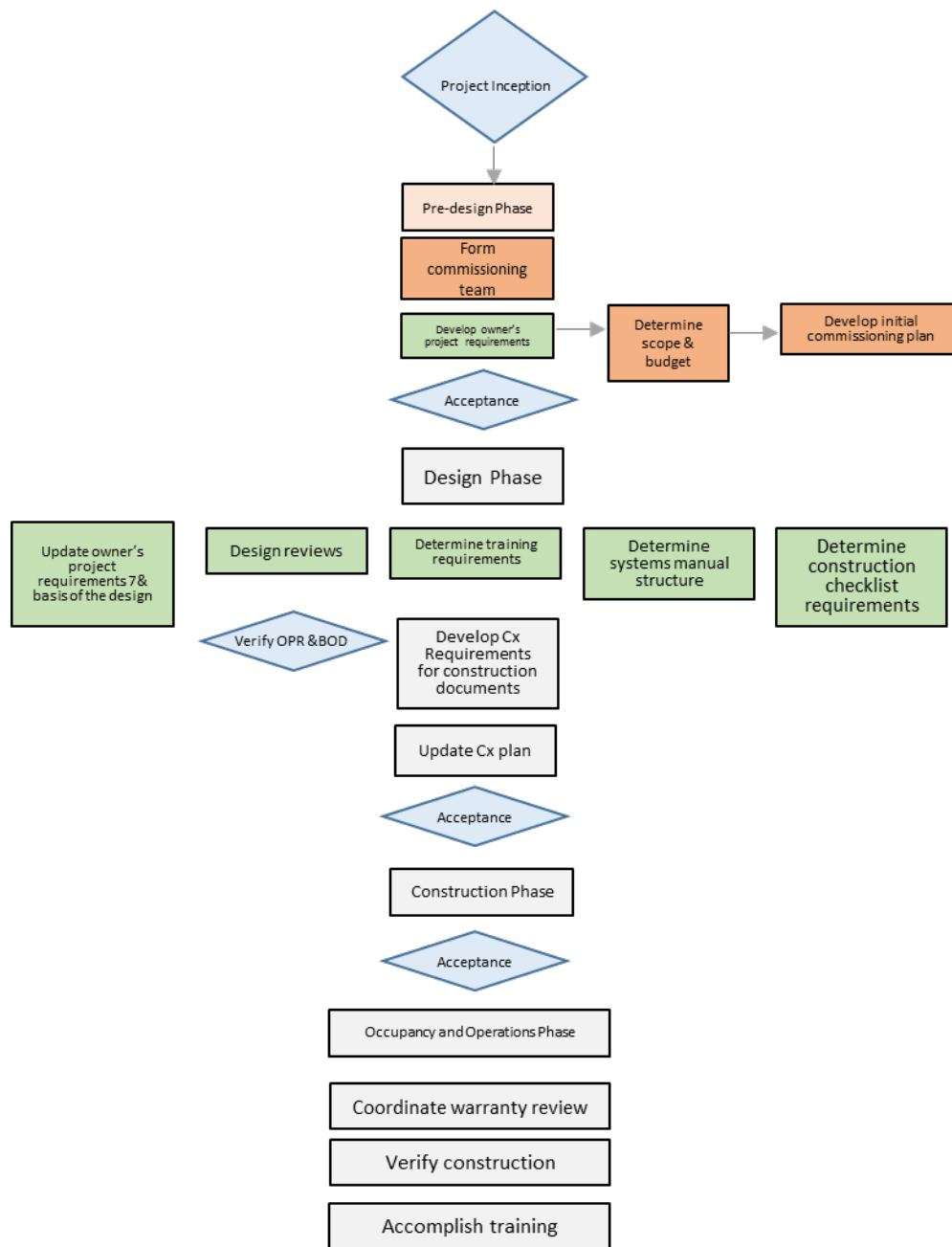


Fig.4. Tasks developed by the owner in the design phase of a project. (2016).

HUDDERSFIELD GOLF CLUB PRESIDENT'S TASKS

The following flowchart has in intense orange the principal tasks carried out by the HGC President. In the right part of the flowchart, the conservation tasks are detailed.

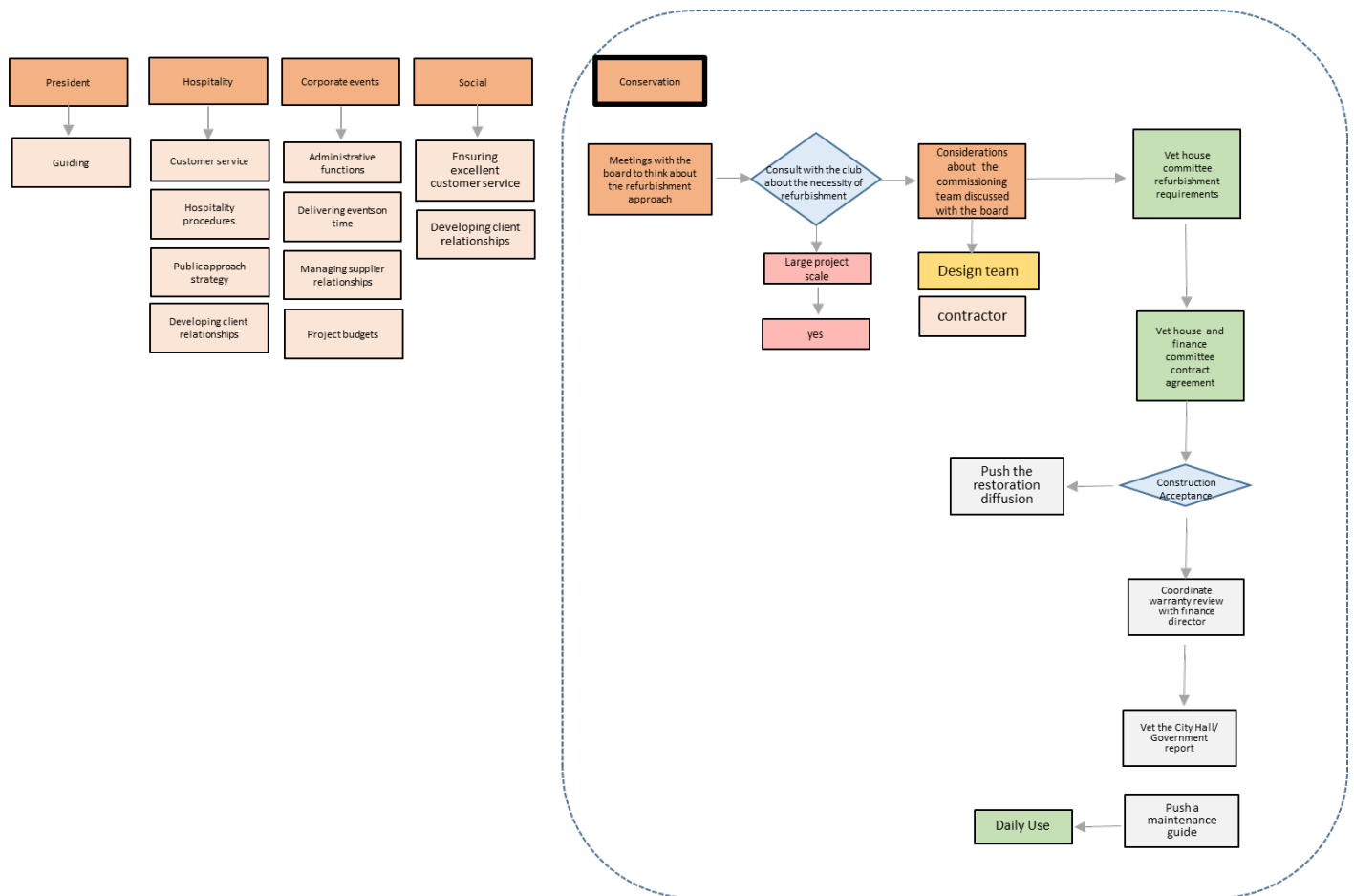


Fig.5. Final flowchart from the HGC President's point of view presenting the tasks related with building maintenance and refurbishment. (2016).

HUDDERSFIELD GOLF CLUB SECRETARY'S TASKS

The following flowchart has in intense orange the principal tasks carried out by the HGC Secretary. In the right part of the flowchart, the tasks related with conservation and maintenance are detailed.

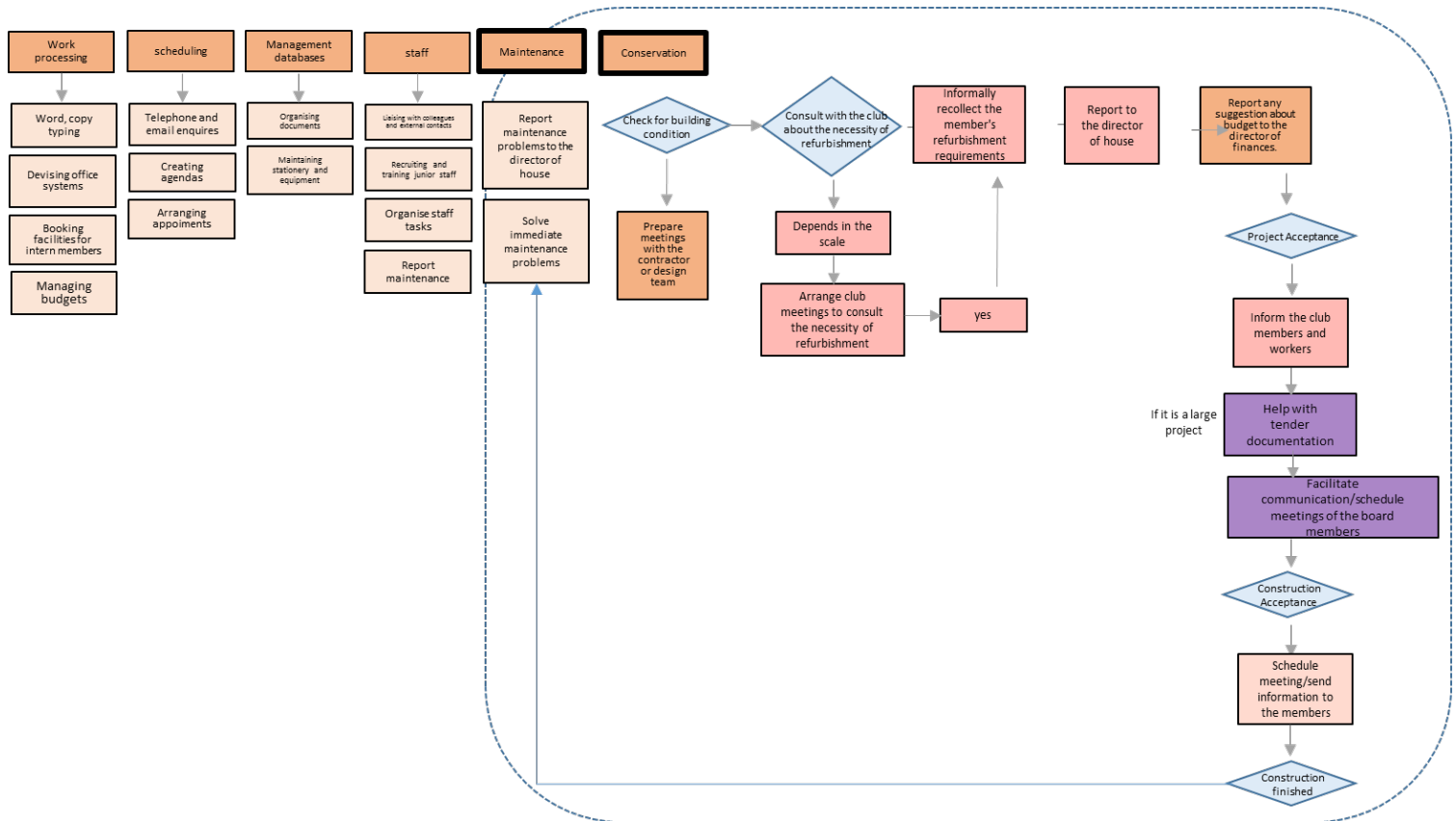


Fig.6. Final flowchart from the HGC Secretary's point of view presenting the tasks related with building maintenance and refurbishment. (2016).

DIGITAL HBIM INFRASTRUCTURE

In the case Fixby Hall would like to adopt HBIM the digital infrastructure required is exposed in the following flowchart. The flowchart specify the system needed in each of the building's life cycle phases.

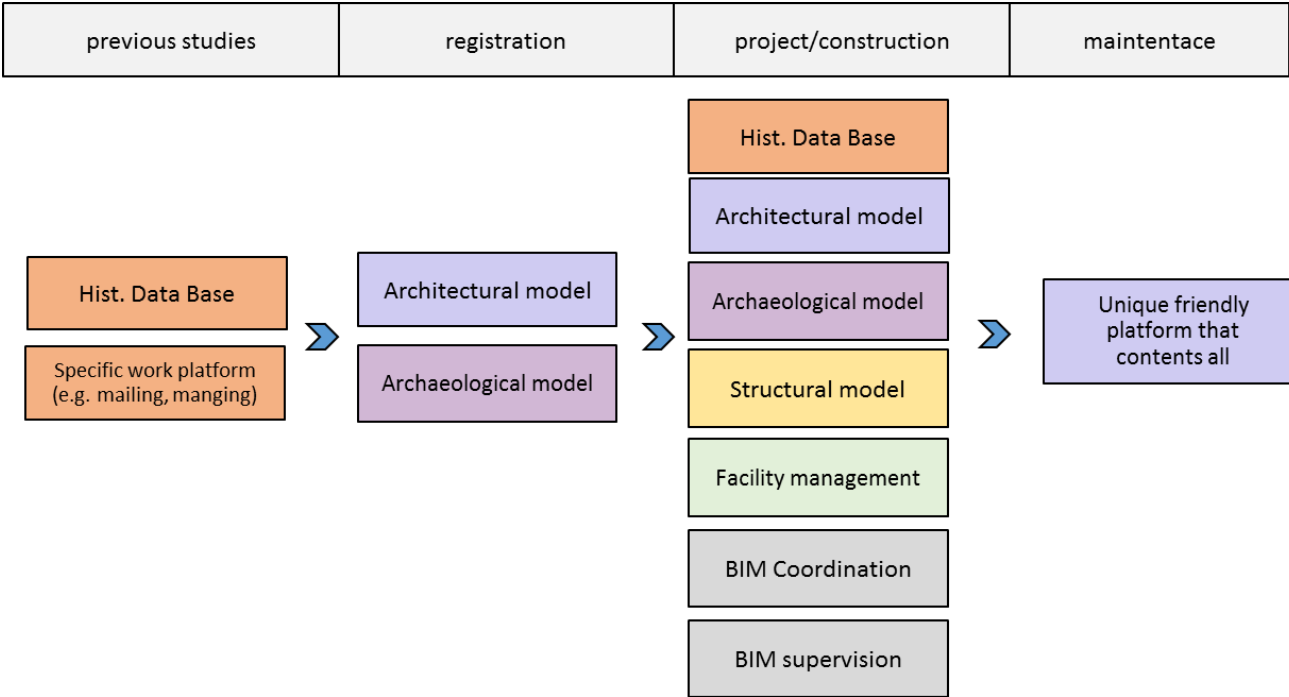


Fig.7. Digital infrastructure needed to apply HBIM to Fixby Hall (2016).

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ANNEX 2

HBIM method flowcharts



The HBIM Method has a graphic nature and it has been created as an evolution of flowcharts which summarised different documents relevant to HBIM or Heritage Conservation.

The 'Council on Training in Architectural Conservation' COTAC, has been one of the main sources of information. This organization has showed interest in HBIM and had published two reports, one in 2014 and another in 2016 related with HBIM.

The following flowcharts summarised the Heritage Integrating Digital Technologies in support of Historic Building Information Modelling, 2014 COTAC report.

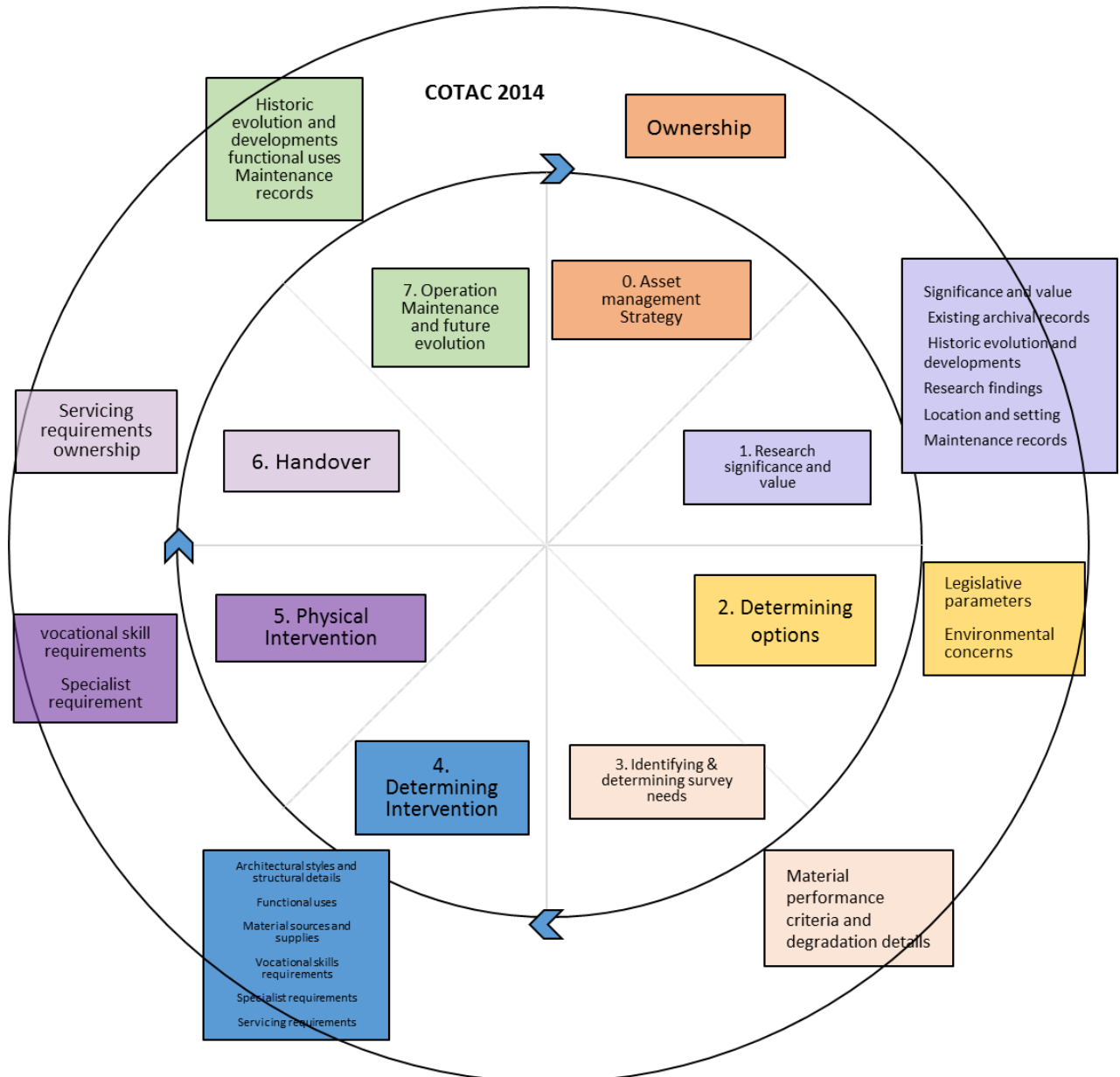


Fig.1. Summary of the Heritage Integrating Digital Technologies in support of Historic Building Information Modelling, 2014 COTAC report (2016).

The main ideas of the ICOMOS Guidelines on Education and Training in the Conservation of Monuments, Ensembles and Sites (1993), had been added to the designed HBIM Method.

Also, Historical England has published a series of intervention criteria which had been also incorporated to this HBIM system.

The flowchart below shows a fusion of both documents represented in one single picture.

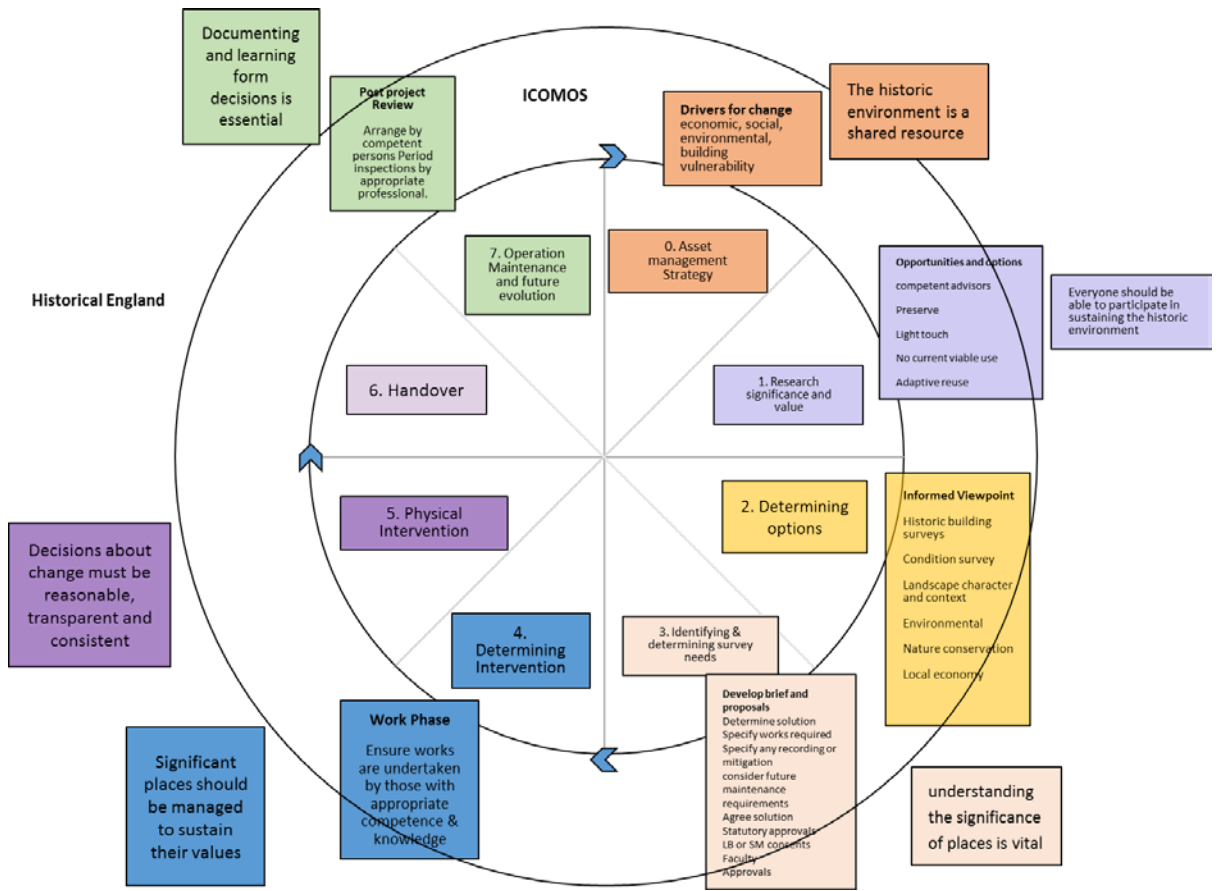


Fig.2. Summary of the ICOMOS guide and the Historical England conservation principles (2016).

The colours of the HBIM method follows the phases in the life cycle of a building. The phases and tasks were completed adding concepts related with cases studies of the scientific literature.

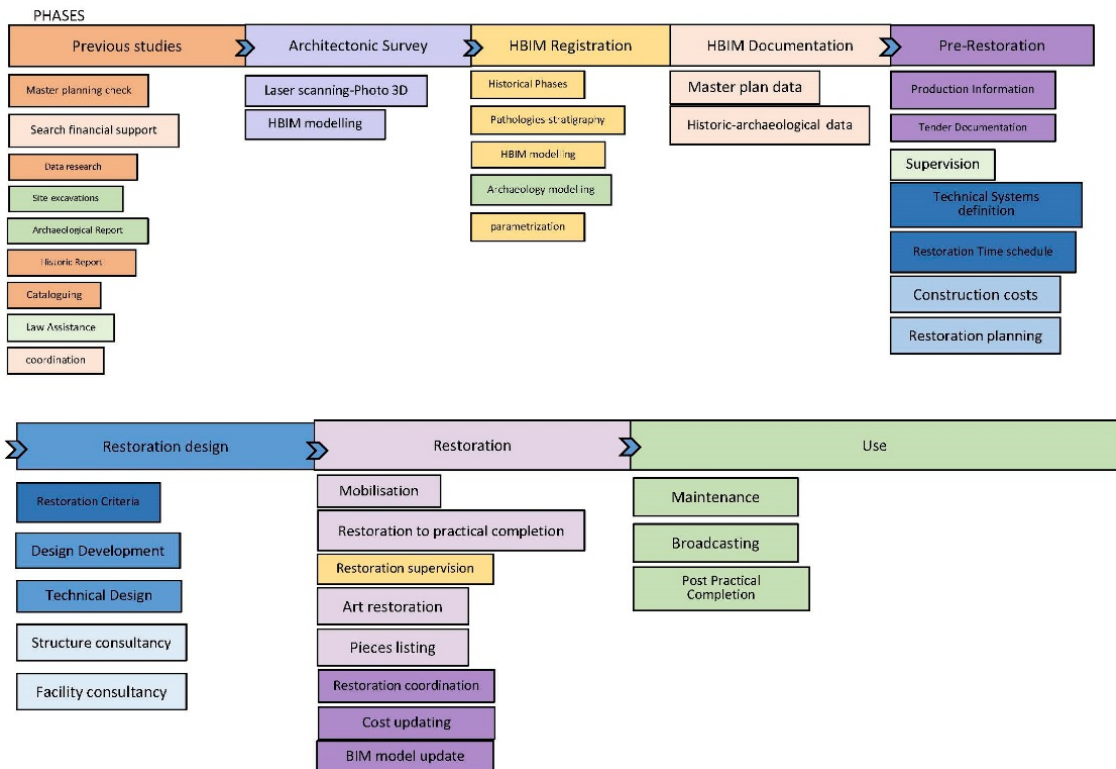


Fig.3. Phases of an HBIM project (2016).

The digital infrastructure needed was also represented in flowcharts.

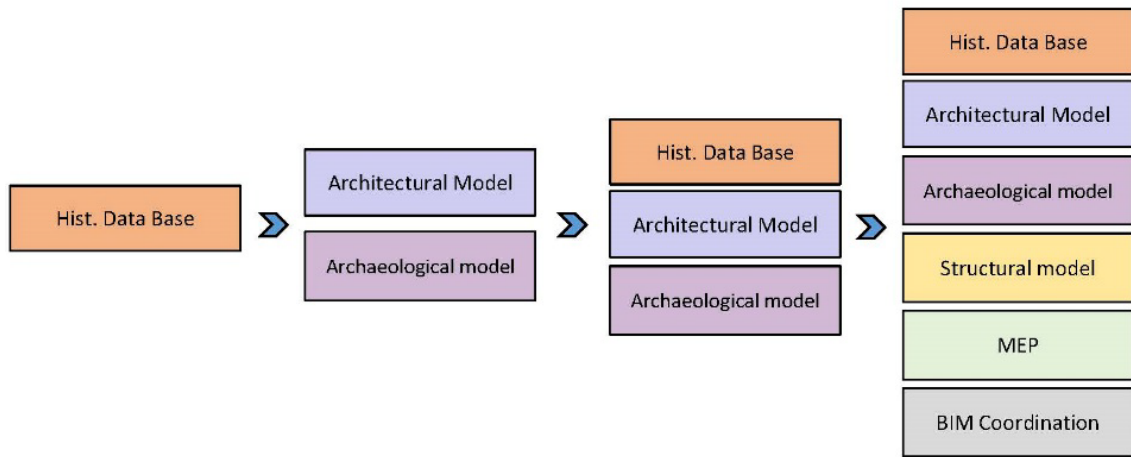


Fig.4. Digital infrastructure required in an HBIM project (2016).

The compilation of all phases and documents generated a very complex flowchart.

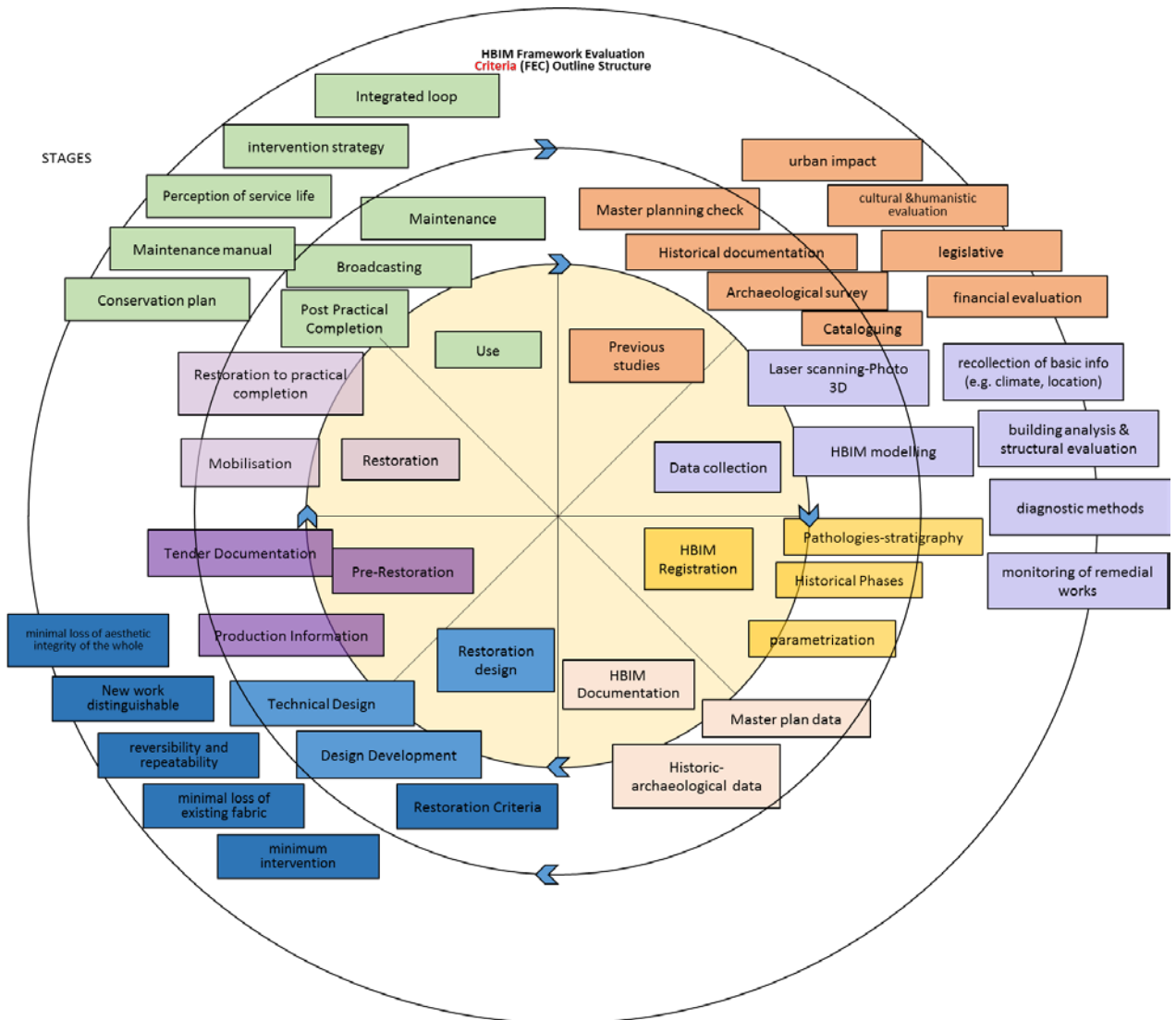


Fig.5. Tasks by project's phases in an HBIM project (2016).

The method was getting more and more complex, so a simplification was needed in order to make it understandable for non-technical stakeholders.

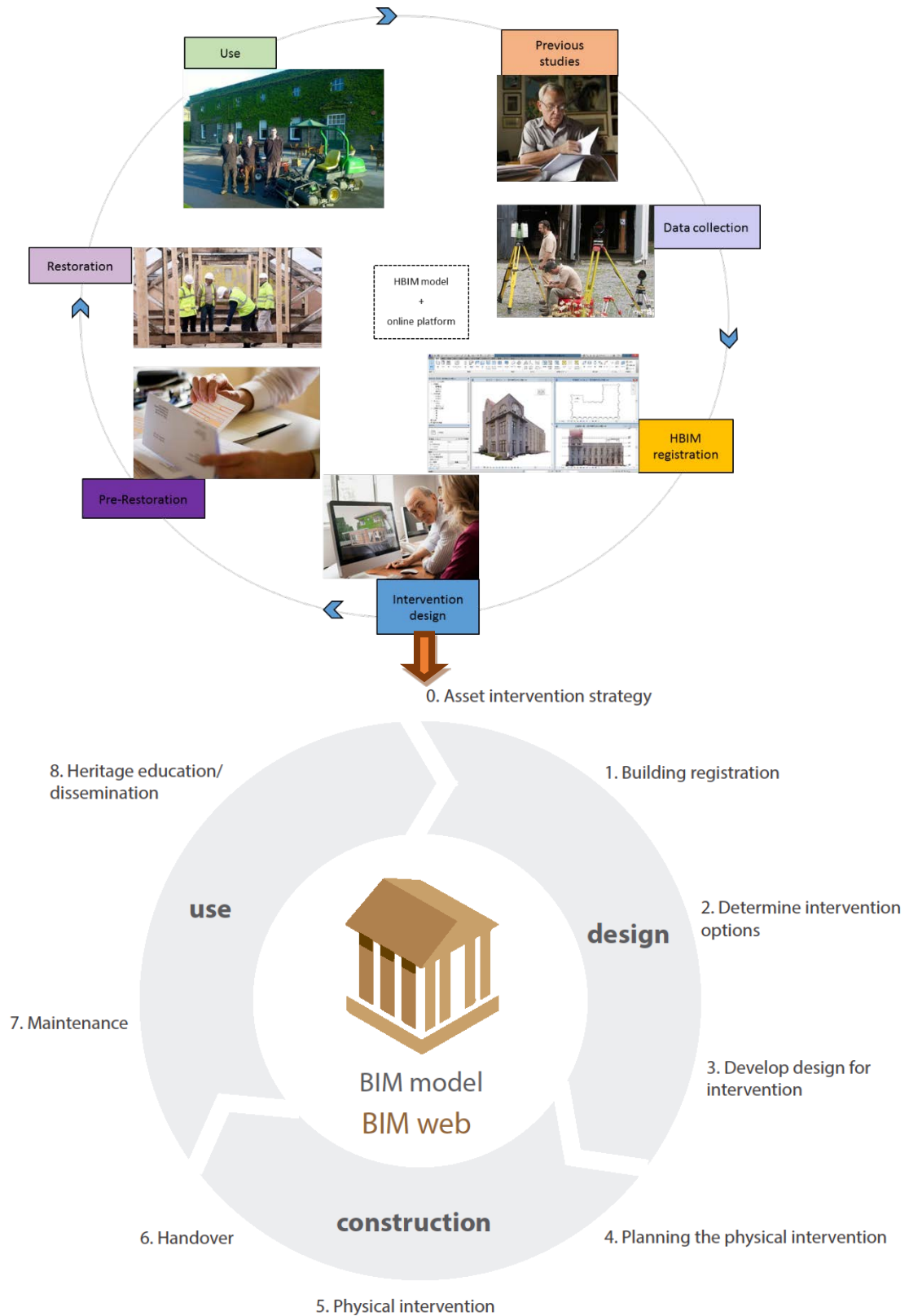


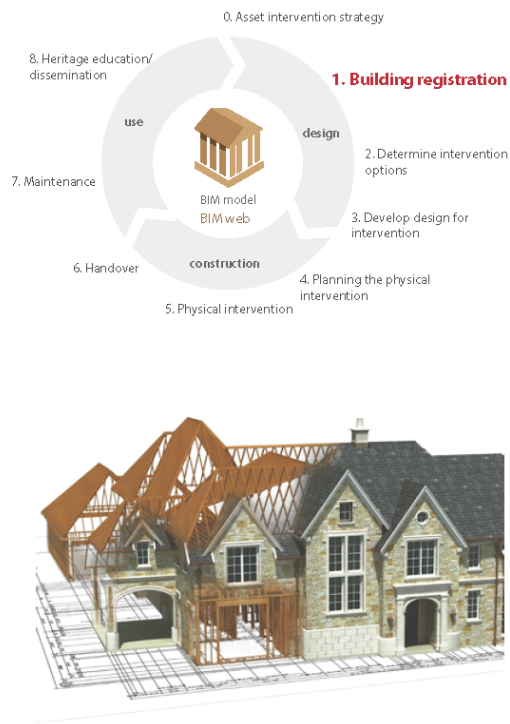
Fig.6. Simplification of the HBIM Method (2016).

LAYER 2 OF THE HBIM Method

The following flowcharts represent a detailed sheet of the HBIM phases. In each sheet the involved stakeholders are named, and then the tasks needed to the right HBIM application are exposed.



Fig.7. HBIM Method layer 2. Phase 0 Asset intervention strategy. The graphic design is an original composition which uses logotypes of www.freepic.com.



1. Building registration

Architect/ project manager/ archivist/ chartered surveyor/monument manager/archaeologist

Historic evolution definition_project manager/ archivist

-Define which historical phases need to be represented in the 3D model.

HBIM building survey. Architecture modelling_architect/ project manager/archaeologist

0. Architectonic laser scanner survey. Some alternatives are photogrammetry or traditional survey.

1. 3D modelling of the surroundings (generic) and the existing phase of the building (great detail).

2. Model the archaeological remains in a linked archaeological 3D model.

3. 3D HBIM modelling of the previous historic-constructive phases of the building.

4. Generate the BIM families by standardizing the constructive elements that are repetitive in these types of buildings.

Modelling the material records_architect/ chartered surveyor

-Analyse the building's material and document the HBIM model with the material details of the different parts of the building.

Modelling the Degradation/condition details_architect/ chartered surveyor

-Analyse the buildings condition and report the degradation problems. Document the HBIM model after.

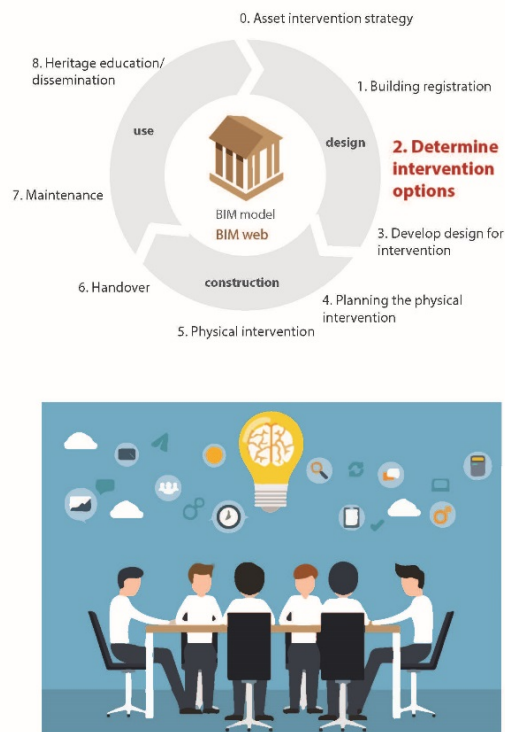
M&E modelling and structure modelling_architect/engineer

These 3D models of existing facilities and existing structure may be linked with the architectonic model.

HBIM documentation_planning consultant/chartered surveyor/archivist/ project manager

-Link the models to relevant information such as historic, archaeological, maintenance records archived by the property and any information related with the condition of the structure and the condition of the facilities.

Fig.8. HBIM Method layer 2. Phase 1 Building registration. The graphic design is an original composition which uses drawings of HZR Homes.



2. Determine intervention options

Project manager/ property/chartered surveyor/planning consultant/Architect/ contractor

Legislative parameters_planning consultant

-Know the legislative frame in order to plan a suitable intervention in four levels: international, national, regional and local.

-These will require consultations with the City Hall planning and heritage departments.

Preliminary cost estimation/ budget definition_contractor/ project management/ property

Definition of the project budget

Consider future maintenance_project manager/ architect/ planning consultant

-Study the intervention strategy taking into account the maintenance and sustainability of the building.

Environmental impact_project manager/ planning consultant

-Research about the environmental impact of the future intervention. -Study the integration of the intervention in the existing landscape.

Economic impact_chartered surveyor/ project manager

-The use given to the building needs to be economically sustainable to secure appropriate building's maintenance and conservation.

Intervention criteria_architect/ project manager/ property

-Establish the intervention criteria after studying the different conservation, restoration and rehabilitation criteria according to the international and national principles and laws (e.g. ICOMOS, Historic England).

Define procurement_project manager/ property

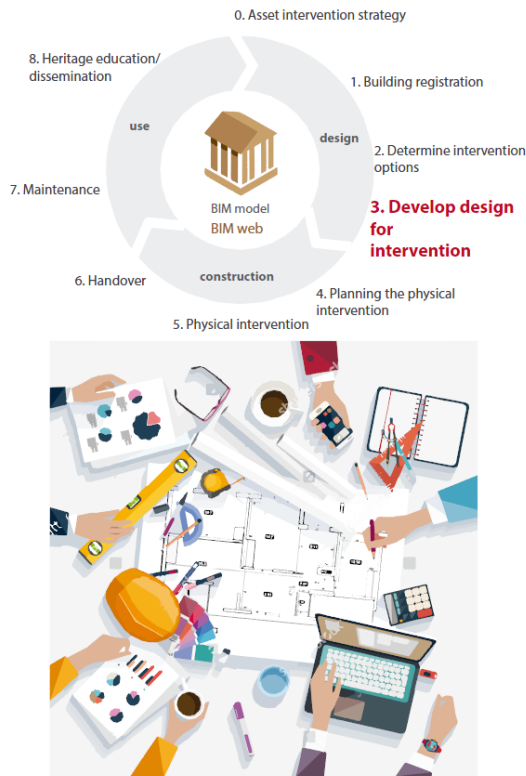
Ideally this would be an Integrated project delivery.

Definiton of the pre-contractual BEP.

Client requirement management_project manager/ property

Review the initial client requirements and adapt them to the possible intervention options.

Fig.9. HBIM Method layer 2. Phase 2. Determine intervention options. The graphic design is an original composition which uses logotypes of www.freepic.com.



3. Develop design for intervention

Project manager/ architect/planning consultant/monument manager/ engineers/ construction manager/ suppliers

Specify required works *project manager*
 -Define and assign work to the different stakeholders depending on the project needs. Review the BEP and generate the post-contract BEP if required.

Architectonical solution *architect*
 0. Conceptual design of the building's intervention represented in BIM masses and design options.
 1. Detailed design of the intervention represented in a new phase of the HBIM model.

Statutory approvals/tender documentation *planning consultant/ project manager/ monument manager*
 -Prepare the tender documentation for the City Hall departments in order to get the construction licences.

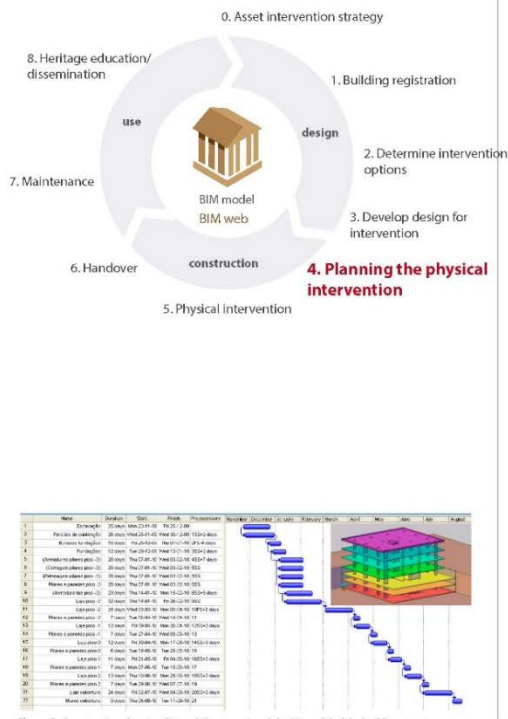
Constructive solution *architect/ suppliers/ construction manager*
 -Detailed solution after consulting with the contractor, construction manager and the suppliers. The goal is to achieve a consensus on the design since the early design. This will be done through BIM platforms.

Technical details *architect/ project manager/ engineer*
 -Asset the best technical solution in the right degree of detail.
 -Analyse and evaluate the environmental impact of the designed scenarios.

Structural intervention design *engineer*
 This would be done with the BIM4ES (BIM for existing structures model). Also, the new structures required for the intervention would be calculated.

M&E intervention design *engineer*
 This would be done with the Facility management BIM model.
 Analyse and evaluate the environmental impact of the designed scenarios.

Fig.10. HBIM Method layer 2. Phase 3. Develop design for intervention. The graphic design is an original composition which uses logotypes of stock vector website.



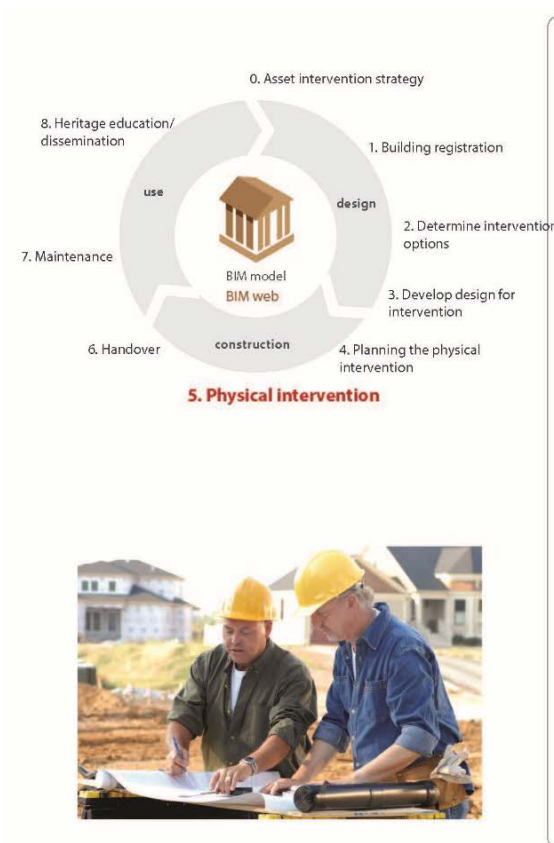
4. Planning the physical intervention

Construction manager/ project manager/ contractor/ architect/property/ suppliers

Cost estimation *contractor/ project manager*
 -Obtain the dimensions from the HBIM model in order to produce an accurate economic quotation. The materials and qualities defined in the HBIM model will be listed to help the accurate quotation.
 -Produce the cost estimation for the building's intervention looking at the economical budget and time that this would take.

Construction planning *construction manager/ project manager*
 -Plan the construction phases and plan the coordination between the different sub-contractors.
 -This planning will be synchronized with the HBIM model.

Fig.11. HBIM Method layer 2. Phase 4. Planning the physical intervention. The graphic design is an original composition which uses logotypes of www.freepic.com.



5. Physical intervention

Construction manager/ project manager/ contractor/ property/ suppliers

Planning timely delivery_ construction manager/ project manager
 Coordinate the different sub contractors and time schedule with the property.

Ensure proper operation in the construction site_ construction manager
 -Coordinate the construction site and the operations between different sub constructors (e.g. restorator, electrician, plumber)
 -Control of the construction quality and the accuracy within the HBIM model.
 -Report the necessity of an archaeological survey if any remains were found.

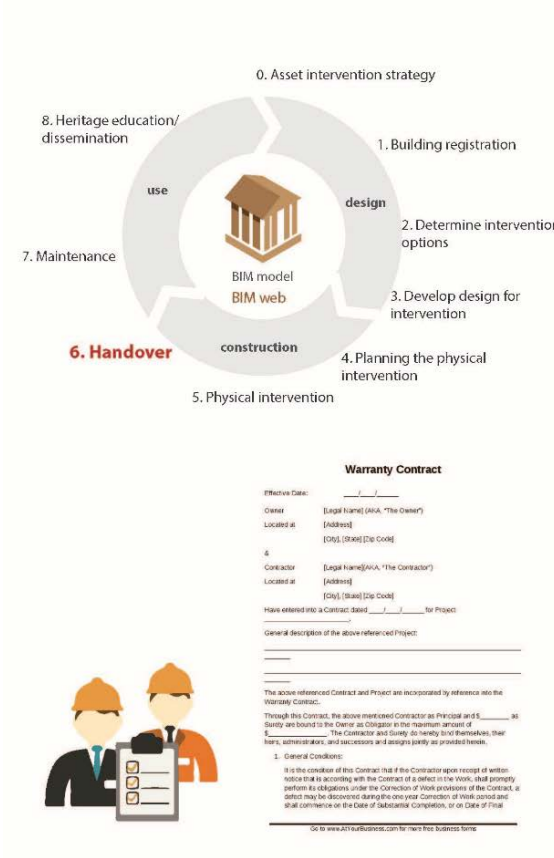
Cost control_ construction manager/ contractor/ suppliers
 -Managing the expenditures needed for the construction.

Health and safety_ construction manager
 Control of health and safety on site. Responsibility and teaching.

Document the HBIM model with construction site data_ construction manager
 Upload the HBIM model with possible design changes and the information gathered in the construction site.

Construction quality checking/inspections_ construction manager/ project manager
 -Visit to the construction site to check the quality of the construction and the possible list of reviews.

Fig.12. HBIM Method layer 2. Phase 5. Physical intervention. The graphic design is an original composition which uses logotypes of stock vector website.



6. Handover

Construction manager/ project manager/ contractor/ property

Warranty and contract review_ contractor/ property/ project manager
 -Meeting between the owner and the contractor to close down the contract and to define the warranty policy.

Learning from decisions: Feedback_ construction manager/ project manager/ contractor/ property
 -Analyse the problems and the gains of the project from the different sides and try to establish the causes and the possible solutions for future projects.
 Document it in the HBIM model.

Warranty Contract

Effective Date: _____

Owner [Legal Name] (AKA, "The Owner")
 Located at [Address]
 [City], [State] [Zip Code]

&
 Contractor [Legal Name] (AKA, "The Contractor")
 Located at [Address]
 [City], [State] [Zip Code]

Have entered into a Contract dated _____ for Project _____

General description of the above referenced Project:

The above referenced Contract and Project are incorporated by reference into the Warranty Contract.

Through this Contract, the above mentioned Contractor as Principal and as _____ All Sundry are bound to the Owner as Obligor in the maximum amount of \$ _____ The Contractor and Sundry do hereby bind themselves, their heirs, administrators, and successors and assigns jointly as provided herein.

1. General Conditions:
 It is the condition of this Contract that if the Contractor upon receipt of written notice that is according with the Contract of a defect in the Work, shall promptly perform its obligations under the Contract of Work provisions of the Contract, a defect may be discovered during the one year Correction of Work period and shall commence on the Date of Substantial Completion, or on Date of Final _____

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Fig.13. HBIM Method layer 2. Phase 6. Handover. The graphic design is an original composition which uses logotypes of stock vector website.

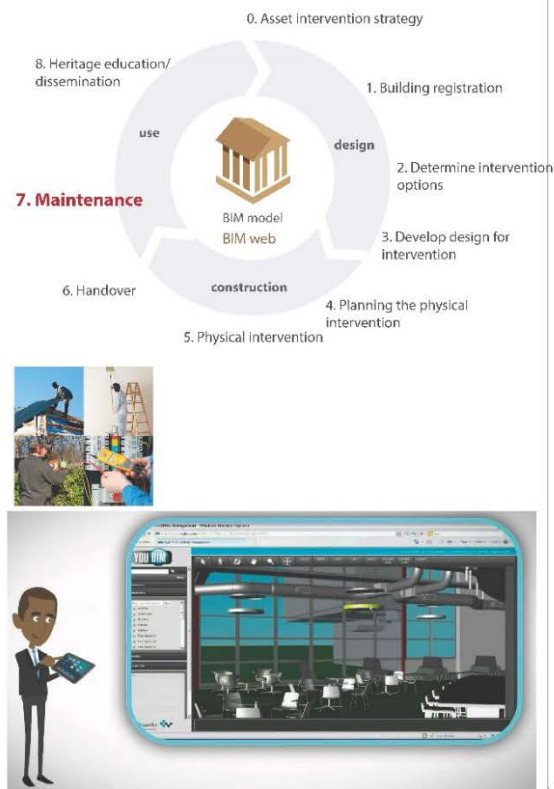


Fig.14. HBIM Method layer 2. Phase 7. Maintenance. The graphic design is an original composition which uses logotypes of stock vector website.



7. Maintenance

Property/ monument manager/ contractor/ project manager

Preventive maintenance_ monument manager/ contractor

Schedule a preventive maintenance plan for checking the building condition, plumbing, electricity, monitoring and telecommunications.

Energy efficiency checks_ contractor/ property

Check the building's energy consumption and fix the inefficient systems.

Environmental policy_ monument manager/ project manager?

Be aware of the last environmental regulations and the government initiatives and try to apply these.

'As built' model_ construction manager/ project manager

-In case the property requires and M&E model, generate a HBIM model version specifically design for this aim with the concrete information. Aspects of quality to check in this model:

Details of any changes made. Up to date the construction model.

Any additional testing and commissioning information.

Operational and maintenance information.

Health and safety information.

Actual performance information such as metered utilities information

HBIM continuous documentation_ monument manager / project manager?

The BIM models should be updated with the maintenance operations that take place in the building.

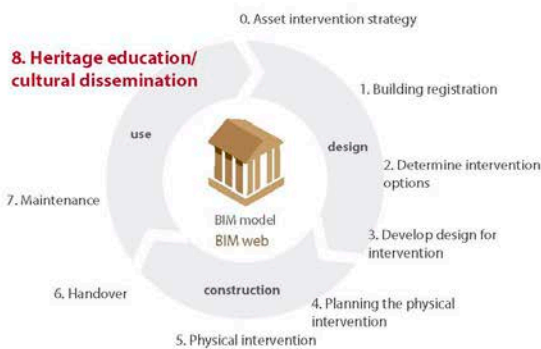


Fig.15. HBIM Method layer 2. Phase 8. Heritage education/cultural dissemination. The graphic design is an original composition which uses logotypes of stock vector website.



8. Heritage education/ cultural dissemination

Property/ monument manager

Community engagement_ monument manager/ property

Heritage outreach, engaging new audiences with the historic environment. Market consultancy about what the people want from the historical buildings in order to warranty the appropriate use for the building.

Cultural dissemination_ monument manager

Cultural dissemination, heritage interpretation, public visits, and tourism.

Define the best strategy to get the general public to engage with the historical buildings (e.g. see the museums, become members).

Heritage education_ monument manager

-Develop awareness campaigns about the respect and importance of cultural heritage.

-Involve educational communities (e.g.university, schools, high-schools)with historical buildings preservation.

Identification of funding bids, government grants_ monument manager/ property

It is important to be aware of the government initiatives and building conservation grants.

