

# Implementing BIM on conservation heritage projects: Lessons from renovation case studies

## **Abstract**

### Purpose:

Heritage or Historic BIM, often referred to as HBIM, is becoming an established feature in both research and practice. The advancement of data capture technologies such as laser scanning and improved photogrammetry, along with the continued power of BIM authoring tools has provided the ability to generate more accurate digital representations of heritage buildings which can then be used during renovation and refurbishment projects. Very often these representations of HBIM are developed to support the design process. What appears to be often overlooked is the issue of conservation and how this can be linked to the BIM process to support the conservation management plan for the building once it is given a new lease of life following the refurbishment process.

### Approach:

The paper presents a review of the context of conservation and HBIM then subsequently presents two case studies of how HBIM was applied to high profile renovation and conservation projects in the UK. In presenting the case studies, a range of issues is identified which support findings from the literature noting that HBIM is predominantly a tool for the geometric modelling of historic fabric with less regard for the actual process of renovation and conservation in historic buildings.

### Findings:

Lessons learnt from the case studies and from existing literature are distilled to develop a framework for the implementation of HBIM on heritage renovation projects to support the ongoing conservation of the building as an integral part of a BIM based asset management strategy. Five key areas are identified in the framework including Value, Significance, Recording, Data Management and Asset Management. Building on this framework, a conceptual overlay is proposed to the current Level 2 BIM process to support conservation heritage projects.

### Originality/Value:

This paper addresses the issue of HBIM application to conservation heritage projects. Whilst previous work in the field has identified conservation as a key area, there is very little work focusing on the process of conservation in the HBIM context. This work provides a framework and overlay which could be used by practitioners and researchers to ensure that HBIM is fully exploited and a more standardised method is employed which used on conservation heritage renovation projects.

## **1 Introduction**

Building Information Modelling technologies and processes provide the ability to support the creation of digital datasets of heritage-based buildings. Since the early identification of Historic BIM (HBIM) as a specific paradigm (Murphy et al., 2009) it has seen a significant growth in popularity and application amongst both researchers and practitioners. In the period since this, the range of technology to support more accurate recording of existing buildings has become more readily available and there is more available access to laser scanning and photogrammetry (Dore and Murphy, 2012). This, along with the global increase in knowledge of BIM processes and technology, can be seen as a reason for the substantial increase in HBIM developments.

Much of the work around HBIM has focused on the development of tangible geometric models to accurately record, and model, the geometric properties of the physical built asset. This has given rise to the process now readily identified as Scan-To-BIM which relates to the art of generating a 3D model based on the measured data. Whilst there are some tools now available to support the semi automation of this process (Thomson and Boehm, 2015) these are still limited by a number of factors such as the quality of the initial data collected and the complexity of the architectural asset. Due to this it is often reported that overall process of generating a HBIM can be a costly and time-consuming process Edwards (2017).

In respect to the application of HBIM to the actual heritage management process, Maxwell (2014) suggested that in order for this to be value adding, then all geometric features that were modelled as part of the tangible BIM should include details such as material degradation and intangible aspects such as in-use circumstances. Oreni et al. (2013) note the importance of HBIM in the context of conservation and postulate that in order to support this the BIM should contain information relating to maintenance or restoration activities. In particular this work focuses on preventive conservation interventions and the methods to geometrically model objects and artefacts, but notes the limitations of quality data being assigned to objects in respect to conservation. Acierno et al. (2017) generated an ontology-based framework for the conservation process. Focusing around the investigation side of the conservation process. This work provided a more digital based approach to recording data around conservation, including methods of investigation, responsibility for the data collection and historic developments. As a prototype implementation this database was linked to a BIM database for visualisation through Autodesk Revit software. Whilst it is evident that there has been some work focused on the issue of conservation, it could be seen that often the definition of 'conservation' is not fully defined in respect to HBIM.

With the above in mind, the purpose of this paper is to further elaborate on critical issues when the BIM process and prevailing technologies were used in conservation heritage projects. By initially providing the context of conservation in heritage refurbishment projects, the paper will review the current status of HBIM research in the field with particular reference to studies where the focus has been on the issue of conservation. Subsequently case studies of actual HBIM implementation on building adaption projects undertaken by a UK based architectural practice are presented. Critical issues are discussed which relate to how HBIM can be used to support conservation. This is followed by the identification of a proposed framework for future projects to use HBIM to support conservation plans, both during the design and construction phase and also into the operation phase of the newly renovated building.

## **2 Establishing the context of Conservation**

The historic environment is a shared resource which people value as part of their heritage. "Each generation should therefore shape and sustain the historic environment in ways that allow people to use, enjoy and benefit from it, without compromising the ability of future generations to do the same." (English Heritage, 2008)

Understanding historic buildings is a fundamental part of undertaking any level of maintenance, refurbishments or adaption to an historic buildings or environment. There is no single entity or organisation that regulates or defines the process of building conservation, however there are a number of key legislations and principle documents that seek to define, clarify and guide this process. The Athens Charter of 1964 and the Burra Charter in 1979 (Revised 1981,1988,2013) set out early requirements on the need to understand a buildings significance, with a focus on authenticity and the retention of its cultural significance. The Burra Charter was the first document which set out a logical process of stages and procedures when undertaking works to the historic environment, with a very clear focus on understanding and assessing the significance of a building, defining conservation as "*All the processes of looking after a place so as to retain its cultural significance*" (1.4 Burra Charter, 1979). At the initial time of writing the Burra Charter was considered radical, but is widely acknowledged as influencing the key principles of conservation which we still utilise today, including the implementation of a defined structure and the requirement for a conservation plan.

Conservation Principles, Policy and Guidance (English Heritage, 2008) is an established document outlining value, sustainability and understanding that is required of the historic environment to maintain and facilitate its long-term future. It is widely used a mechanism and tool to assess and guide modern conservation works, ethics and philosophies. It defines conservation as "*the process of managing change to a significant place in its setting in ways that will best sustain its heritage values, while recognising opportunities to reveal or reinforce those values for present and future generations*" (English Heritage, 2008). There is an acknowledgement that in order to safeguard sustainability of our important heritage assets, a level of change can be considered in order to safeguard the historic environment for future generations. The principles are designed to provide a consistent and clear approach to the process of the assessment of heritage assets and the management and implementation of change to secure their long term future. The document defines the process of assessing the significance of a heritage asset to give a detailed and defined understanding of the place, in order to apply these principles to inform and guide the decision-

making process to fully understand the potential impact of change heritage assets in a transparent manner. Significantly the work delineates a values based approach to assess and define the significance of a heritage assets within the structure of four identified groups:

- Evidential Value: The potential of a place to yield evidence about past human activity
- Historical Value: The ways in which past people, events and aspects of life can be connected through a place to the present; either illustrative or associative
- Aesthetic Value: The ways in which people draw sensory and intellectual stimulation from a place
- Communal Value: The meanings of a place for the people who relate to it, or for whom it figures in their collective experience or memory

These values go beyond physical characteristics, covering a broad range of considerations including; physical remains of past civilizations; associations with the development of cultural heritage; associations with notable families and events; artistic endeavor; expression of innovative technologies and social, commemorative and symbolic meanings. Orbasli (2008) suggested that this values-based approach should be further categorised to explicitly define areas of significance which are less tangible and aren't easily attributed to physical fabric. Very often this less tangible information is documented and presented in a statement of significance. This statement can include a definition of historical evolution and how this relates to the fabric of the asset including such elements as; the use of materials, the significance differing people/communities placed on the environment, local, regional and national significance. Consideration is also given to setting, context, places of similar values and the overall weight and importance of each of the identified values to provide a defined articulation of the detailed significance of a place.

The clear application and definition of significance provides a structured basis to evaluate the impact of any renovation works on the overall significance and heritage values of the building. This allows a transparent framework to establish whether works would be considered acceptable considering other identifiable values, public benefits, or whether wider enhancement or mitigation measured would be required in order to minimise any harm. Under the National Planning Policy Framework (NPPF; Section 16 184-193, 2018) this statement of significance should justify the impact on significance and ensure conservation works in a manner appropriate to its significance. Any negative impact to the heritage asset must be quantified (either as substantial or less than substantial harm) and mitigation measures of enhancements must be presented to offset this in order to protect the heritage asset. This information is presented and embodied in a long term Conservation Plan, establishing the long term future of the building and defining key policies and requirements. This then serves to identify, reinforce and manage its significance and the ongoing evolution of the defined changes in order to demonstrate the protection and retention of its long term sustainability and future.

Wider industry documents including the British Standards (BS7913, 2013) and RICS Practice Standards, Historic Building Conservation, 2009 also highlight the issue of significance. The analysis and creation of a 'statement of significance' and 'conservation management plan' is developed through the collation of a large body of work, documenting information from a wide range of sources; such as surveys, archive records, historic mapping and written records. This is often presented as a written record document and contains a high level of detail, including specifics of value attributes to differing areas of the building. This information is often isolated and maintained as a written record for future reference, however with the advent of HBIM there exists possibilities and benefits to integrate this fundamental information into a accessible and shared digital environment.

Historical building records often includes a large volume of layered information. Often this can be difficult to interpret and understand across multi layered environments, particularly when there is a number of unknown entities resulting from gaps in information leading to difficulty in deciphering the technical aspects of the work involved. Building technology has also changed fundamentally as a process as new innovations have been introduced, and the understanding of a historic building as a breathable, permeable and responsive environment has been impacted by previous interventions. As such there is often a lack of information and some limited understanding of the previous approaches leading to building defects occurring through the incorrect interpretation of details, specifications or a general lack of information. Ensuring knowledge and records are contained in the correct forum and environment has the ability to

contribute to a wider focus and understanding to support a more cohesive, responsive and managed approach to heritage management. Documenting and learning from decisions is an essential part of building conservation to support the regular evaluation and monitoring of the long-term impacts of change (English Heritage, 2008). The simple accessibility of this information and documentation allows the balance of decision making to be related back to the significance and weighting of historical values (RICS, 2009). The potential management of this body of data within one digital environment removes potential disparity in the ability to analyse and interpret information, thus supporting a more logical tangible process to ensure for the long-term future and sustainability of historic buildings. BIM, when viewed as a holistic process that is underpinned by a range of digital technologies can therefore serve as a catalyst to support conservation, provide the method to store layered conservation information and help to record the underlying significance of renovation interventions.

### **3 BIM for Renovation and Heritage**

It is well documented that BIM can yield significant benefits when implemented on construction projects through the utilisation of information rich digital models, however Volk et al. (2014) identified that many existing refurbishment projects are not yet fully utilising the full power available through a BIM methodology. Supporting this viewpoint, Kassem (2014) notes that there is evidence to suggest that the majority of existing buildings are not yet maintained, refurbished or deconstructed using BIM and in more recent work Okakpu et al. (2018) further note this and highlight the more limited amount of research focused on this area in comparison to other BIM areas. There are a range of reasons that could be suggested for this issue, including the complexity of the existing building project, however to help to facilitate the full use of BIM on renovation projects, Carbonari et al (2015) proposed a framework to allow data to be added by the facility managers prior to any redesign taking place to ensure that the final design contains up to date and relevant operational data required for the lifecycle management of the asset. Parisi et al. (2019) note the use of HBIM to develop a digital repository that demonstrates the evolution of a building over time, showing different use classifications.

Ciribini et al. (2015) note that whilst much work has been undertaken on the surveying to BIM aspect of renovation projects, the entire BIM process provides a much broader opportunity to manage refurbishment work. Within this approach, once site works began, phases of the construction process were stored within the BIM and each of these phases also stored digital copies of additional data such as health and safety files. The inclusion of data regarding individual construction objects when 'as built' provided the ability to utilise the work for lifecycle management. This is in line with the UK approach towards BIM Level 2 and the implementation of COBie which provides the opportunity for all operational data to be included within an as built BIM (Jensen, 2015). Considering the wider BIM philosophy, Gökgür (2015) highlighted that 4D simulations were rarely used at the present time on renovation projects, arguably due to more limited use of BIM and 3D geometry on refurbishment projects.

Murphy et al. (2009) first identified HBIM as a method for modelling historic structures through the use of laser scanning data and BIM authoring tools for the creation of 2D and 3D data. The interest in this field has grown significantly as demonstrated in a wide reaching review study by Lopez et al. (2018) highlighting the significant amount of research published in the field of HBIM since 2009. However, this work does also demonstrate that a significant proportion of the work has been focused on the technical area of digital production of the BIM geometric dataset and developments in the field of laser scanning and scan to BIM generation. Whilst laser scanning has been a key area of research, Apollonio et al. (2017) identify that image based approaches to generating BIM based objects can be undertaken to provide an adequate level of accuracy without the need to undertake expensive laser scans and a protracted manual modelling process. In addition this also this can also support the creation of an extensible library of parametric objects suitable for future HBIM development. In either case, it has been reported that there is still work to be undertaken to ensure that the models developed are reflective of the state of conservation of the physical element (Megahed, 2015) as at the moment they are often developed at a level of graphical detail that does not accurately depict the deformations or erosions of the actual object. This issue of level of detail of the graphical objects contained within a HBIM is also raised by Brumana et al. (2013) as it is stated that the opportunity should exist to modify these as required during the construction process.

Whilst the case of technological developments has been a key area, others working in the field have identified extended uses of BIM as a resource for heritage based data. Fai et al. (2011) and Tommasi,

Achille and Fassi (2016) suggested that a BIM could contain additional data that could be linked to the geometric elements of the BIM, subsequently providing a more robust integrated dataset in order to represent cultural heritage. One issue around this area of linking non geometric data to the elements within the BIM surround how much and what type of information should be include. This is an area identified by Donato et al. (2017) which propose a framework for a HBIM Level of Information to guide the definition of appropriate historical information for linking to the overall BIM. Diara and Rinaudo (2018) discuss the potential of open source tools, including geometric modelling and database systems which could be implemented to support the development of a more comprehensive cultural heritage. This suggests that the use of HBIM can provide significant advantages when moving beyond the realms of geometric modelling alone. By using BIM Server, this work also purports the use of online web based approaches for support HBIM. The use of online based approaches is also discussed by Quattrini et al. (2017) highlighting the benefit of non-proprietary systems to easily access data. However, these approaches also bring about the issue of data security and BIM and this is an additional factor to be considered.

Turning the attention specifically to the conservation element of HBIM, Osello et al. (2017) highlight that HBIM approaches present a clear opportunity to preserve data such as historical events, changes of ownership and transformations in a structured and efficient manner which can support conservation works. Khodeir et al. (2016) discuss the classification of Built Heritage Values, which are categorized into Cultural, Use and Age values. In this study a theoretical framework is subsequently suggested, which presents how HBIM can be implemented to support sustainable conservation with an emphasis on the use of using the developed 3D geometric model at project initiation for optioneering of alternative methods during the design phase. The conservation process is a collaborative effort in any refurbishment project and the use of BIM to support this process is highlighted by Ciribini et al. (2015). The work notes that the ability to store and share data through a BIM workflow is beneficial and the capturing of initial measured information using a laser scanner can support an understanding of the geometric properties of elements within the building. Maiezza (2019) introduces the concept of Level of Reliability (LoR) when HBIM is being implemented. This interesting concept seeks to provide a standardised approach to HBIM, which draws inspiration from the LOD and LOI concepts in more traditional BIM construction processes. A composition of the level of accuracy of the geometric model and the level of quality used to inform the model development, this concept could be further extended to support the development of HBIM for conservation works by identifying the knowledge of the historical developments of the elements of the building. Chow et al. (2019) develop the concept of the Level of Accuracy (LOA) as being a function of the tolerance between the geometric model produced and the original laser scan model. This can then be integrated within the more conventionally accepted level of detail within the BIM environment to provide a further method to classify the HBIM.

Quattrini et al. (2017) did identify a methodology to generate a 3D model with a nominated Level of Graphical Detail which could then link to semantically structured data denoting conservation based information which was then used to generate a more enriched BIM dataset. This approach could be further exploited within HBIM uses on renovation projects to ensure that the BIM serves as a useful tool during conservation renovation projects by providing a dataset that not only looks at the previous historical data but could also be used to provide a record of the work undertaken during the restoration / construction works but also serve as a tool going forward into the asset management cycle of the building.

With respect to harnessing digital heritage data, Fregonese et al., (2015) discuss the development of a web based platform BIM3DGS which presents the ability to link additional data relating to architectural heritage buildings through a linked web interface to an existing 3D BIM dataset. This can then be utilised during heritage based maintenance and updated accordingly to ensure an up to date record is kept of ongoing renovation works which could potentially be aligned to conservation plans. In a similar vein Core and Murphy (2012) discuss integrating BIM and GIS to provide a further level of data analysis for heritage BIM. This approach could serve to bring together further information into the refurbishment process and potentially conservation information. For example, historical planning documents could be bought into the design process to ensure continuation or provide guidelines for any refurbishment taking place in conservation areas. Bringing the power of GIS into the HBIM process opens up a new range of analysis both in the design and construction phases of a renovation project.

An underlying philosophy of conservation of heritage buildings is the process of maintaining and managing the change of the asset that sustains its significance (Heritage England, 2019). This has to act as an underpinning rationale during a heritage-based refurbishment project to ensure that elements of the building are preserved. Digital technologies and specifically Heritage BIM provides the opportunity to record this information to support the entire process including conservation works which are undertaken. Hitherto, it could be argued that much of the work which has been focused on HBIM has predominantly focused on the development of geometric datasets which can then be used to record the geometric properties of artefacts and any subsequent conservation work, whereas little work has specifically been focused on issues surrounding the implementation of BIM processes and technologies to support conservation activities during refurbishment projects. Work that has proposed the use of HBIM has been very much conceptual in nature and thus the following case studies present actual implementations of HBIM on conservation heritage renovation projects.

#### **4 Case Study 1: Garth House**

##### **Background**

Garth House (Figure 1a) is a Grade II\* listed building (Historic England, 2019) sited within the University of Birmingham. The building was originally built in 1901 for Ralph Heaton of the Birmingham Mint and designed by notable West Midlands architect William Henry Bidlake. Bidlake was a leading figure in the Arts and Crafts movement and noted for his pioneering teaching of architecture at the Birmingham School of Art. He was typically an ecclesiastical architect but undertook a number of private dwellings, which all follow a very formal and geometric layout. Bidlake's work on houses (including Garth House) is recorded in Hermann Muthesius's book *Das englische Haus*, which was to prove influential on the early Modern Movement in Germany (Edgar, 2016). Garth House's significance is embodied in the historical value of its connection to the Heaton family and William Bidlake, while providing an exceptional example of the pleasure grounds, homes and requirements of wealthy local businessmen.

The project focused on significant refurbishment to Garth House as part of a wider development programme for a new hotel and conference centre, of which Garth House became a central focus. From the inception of the project the available documentation on Garth House was limited. Early citations in notable publications provided an outline of the original layout, but no further formal information on how the house developed and evolved over time, or the extent and details of any maintenance works which had been undertaken was available. In addition, the building displayed a number of defects such as structural cracking, water egress, thermal expansion, significant rotting to timber components and areas of mis-matched modern intervention. Initially the focus of the project centred around;

- Understanding the internal evolution of the building and any building works or impacts associated with these to inform understanding and the design process.
- Understanding the presenting defects and identifying the underlying cause to inform potential rectification and treatment options.



Figure 1a: Original design drawings and photographs

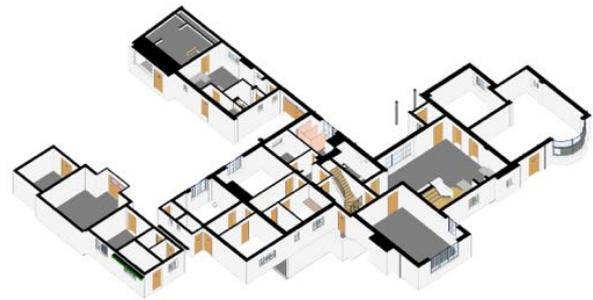


Figure 1b: Existing Revit model based on measured survey



Figure 1c: Scheme drawings with overlaid conservation information



Figure 1d: Demolition and key conservation periods highlighted in 3D BIM environment

Figure 1: Garth House (source: Glancy Nicholls, 2019)

### HBIM Implementation

The BIM requirements on the project sought to align to the UK BIM Level 2 process. Initial discussions with the client highlighted the value of BIM and subsequently requirements for linking asset information into wider computer aided facilities management (CAFM) tool. This would then facilitate both the ongoing management of the building post completion.

The house exhibited a range of complex geometries in the layout, alongside the large volume of modern intervention, and this limited the ability to examine and understand both the long term evolution and contribution of these works to areas of inherent defects. As such, a detailed HBIM was required which exhibited a lower Level of Detail (LOD) (Antonopoulou and Bryan, 2017) and this was then utilized to support phasing within a focused 3D BIM environment to begin to isolate and identify the differing historical layers and areas of the building. Contrary to much of the existing approaches, while this didn't focus in on the more common HBIM techniques of laser scanning, Scan-To-BIM or complex geometric data, the value that this modelling process provided was invaluable. It supported the methodical and analytical review of the building fabric to identify original areas of structure and allowed the focused identification of areas for further investigation in key areas of closed and likely defective works. Being able to segregate and isolate specific areas of the building enhanced the understanding of original proportions, effects of space and light, and aided comprehension of environment.

The development of the model also expanded the design teams understanding and knowledge of the intangible aspects of its significance. This included aspects such as the original home environment, sense of grandeur, room proportions and the appreciation of significant subtle craftsmanship details of the arts and crafts style engrained within the high-quality home of a wealthy businessman. The use of the 3D BIM

environment enabled the design team to physically see, appreciate and evaluate the areas of evolution which were important and which had an intrusive effect on these key qualities that contributed to its overall significance and heritage values (Figure 1b and Figure 1c). This was implemented utilising the use of phasing for key demolition sequences, highlighting the revised proposals against the existing modern layout. The implementation of the phases through isolation of key periods the works were undertaken, when overlaid within the BIM environment allowed the identification of original walls and features that were obscured in the modern context and not easily legible in their layout. This process informed design decisions and allowed the HBIM to be used to apply conservation principles as a mechanism to support the progression of the building conservation project; providing a structured and evidential basis to understand the impact of any works on the overall significance and heritage values. Following the identification of focused investigation works as part of this process, the findings of these works were processed back into the model to clarify the likely wider impact on the wider building fabric and informed the proposals for defect restoration and wider selection of materials and methods.

As specific examples of the benefit of the BIM approach, the developed HBIM environment successfully supported the localised identification of a corroding steel beam through the allocation of modern layers of work under phasing to isolate areas of modifications which were linked into visible areas of structural defects on the external façade, allowing a control and guided opening up process to identify the source of decay. They also facilitated the discovery of an original horse trough sink within the coach house, which had been previously concealed. Through the same method and use of phasing, areas of modern intervention and concealment were easily identified, which were reviewed against the original layout within the central data environment. Additionally, the application and inclusion of visible defects within the central model facilitated the detection of key causes of damp and allowed the careful isolation of timber degradation without substantial opening up and damaging works. By breaking and plotting these elements as modified area components and assets directly into the 3D environment the team was able to visibly see patterns of decay and were able to identify key and localised areas of opening up to identify the defect in a more evidential and applied manner (Figure 1d). Overall this enabled the minimisation of damage to the building fabric as well as increasing overall understanding of the building; a fundamental principle and ethical driver of conservation of the historic environment.

#### Outcomes and Benefits

As noted by SPAB (2013), in order to repair old buildings they must be understood, and developing an understanding its architectural qualities as well as social development aid the understanding of reasons for decay facilitating remediation. The utilisation of HBIM in this instance was implemented to further knowledge, understanding and critical thinking connected to the restoration of the historic environment. However, the delivery of the HBIM information back to the client in the format was still defined by the wider facilities management requirements of the CAFM tool with limited asset information. Key details and specification information was provided in relation to the proposed works, which was extracted using COBIE data sets. In this context the statement of significance and the future conservation management plan were frozen as written record documents unconnected to the HBIM environment. During the project process substantial amounts of time were spent with the client maintenance teams and to further understanding, knowledge and future considerations of the refurbishment heritage asset to ensure future maintenance and ongoing works were undertaken in accordance with the policies and principles established from the works.

The HBIM work undertaken in this project demonstrated the value and allowed significance of specific aspects to be highlighted during the design and construction phase. This facilitated a better working knowledge and understanding of the management and impact of change within the heritage asset. However it was recognised a further level of detail, including maintenance requirements, level and extent of repairs could potentially be applied within components, assets, parameters and markers alongside the phasing within the model to increase understanding and aid future maintenance if utilised as a managed 3D environment. Conservation plans represent a key component in the ongoing management of a heritage asset and are live documents representing planned maintenance, adaptations and repair works during the life of a building. As a central managed BIM model these documents evolve and develop as works are undertaken and requirements change to continually actively conserve and protect the building. The likely ongoing evolution and long-term management of a conservation and maintenance plan as an isolated document can be deemed as a fragmented and disjointed management of information with limited ongoing links to the

developed HBIM. It is acknowledged this could be significantly improved and implemented as an efficient and integrated evolutionary component of the HIBM when linked to the wider available heritage asset database; which had the potential to increase skills, knowledge understanding and support a more informed and appropriate management of change process within the historic environment which is a core suggestion according to English Heritage (2008). The potential for these plans to be integrated into a HBIM model provide the opportunity for these to evolve and develop interactively with model, as well as the maintenance requirements being easily contained and visually available in a more accessible manner than a standard historic written record. The potential impact of this would result in building owners and clients having a greater understanding of maintenance requirements to historic buildings, enabling easier maintenance programming and subsequently a more active rather than reactive approach to conservation management, contributing to a better level of conservation for our national heritage assets.

## **5 Case Study: Municipal Bank**

### **Background**

The Exchange is a project undertaken by the University of Birmingham, UK that incorporates the refurbishment and extension of the Former Municipal Bank - Grade II listed building. The 'Birmingham Municipal Savings Bank' was formerly the Birmingham Corporation Savings Bank, created by a 1916 Act of Parliament to raise money for World War I. Following a further Act in 1919, which allowed the creation of individual branches, the bank needed a headquarters to cope with demand and subsequently constructed a new building on what is now Centenary Square, which opened in 1933. The building was designed by architect Cecil T. Howitt, and formed part of a unexecuted wider masterplan to create a grand formal civic square. However due to the impact of the second world war halting development, only 3 buildings were built; Hall of Memory (Grade I listed), Baskerville House (Grade II listed) and the Municipal Bank. The significance of the Municipal bank is largely manifested in its fabric and materials which represent the sense of grandeur, utilitarianism and standing as part of an expression of the banks significance and its wider role in the ambitious proposals for a grand civic square. The neo classical design over three storeys (Figure 2a) was intended to convey a sense of security and respectability, for a bank of civic stature (Donald Insull Associates, 2018).



Figure 2a: Main entrance to the Bank



Figure 2b: Geometric HBIM model developed using Scan to BIM approach



Figure 2c: Conservation markers implemented within the HBIM

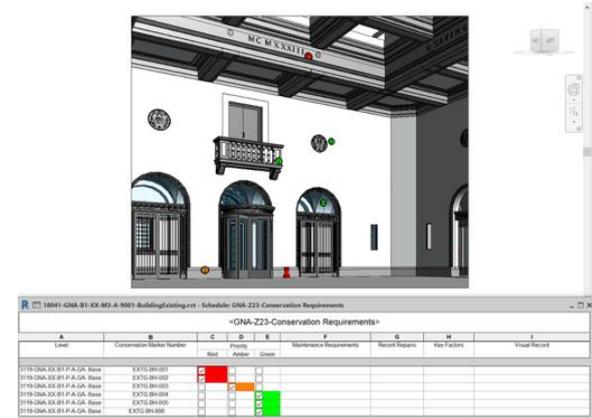


Figure 2d: Maintenance information integrated within the HBIM to support ongoing asset management

Figure 2: Municipal Bank (source: Glancy Nicholls, 2019)

### HBIM Implementation

Based on previous experience of HBIM implementation, the client and design team engaged in this project recognised the potential of HBIM to offer much more a much more comprehensive, fundamental and intuitive 3D environment. A clear defined set of information requirements from the client was underpinned by an understanding of the value proposition that could be gained and this centred around an interactive and focused 3D environment which could be actively updated and managed to provide live facilities management protocols. This was coupled with objectives to more cohesively implement critical information in relation to significance, historical evolution and key conservation information. The project set out with an intent to integrate elements of repair, decay and phasing into the model, to both further understanding and inform key decisions and also to create a greater platform of understanding within the base model for the client. The requirements were outlined to inform the design and construction processes of the implementation of conservation principles and philosophies, providing a mechanism to assess and manage change and the decision making process. In addition this was specified with a vision to establish a more interactive system which could form a self-generating maintenance plan to facilitate planned and considered maintenance thus actively managing and sustaining the historic environment.

A Scan to BIM approach was implemented to record the existing fabric of the building as a baseline and a higher level of detail (Antonopoulou and Bryan, 2017) was used to ensure the geometric modelling of ornate and important details which required restoration within the fabric (Figure 2b). From this baseline model, phasing datasets were utilised to segment and isolate periods of evolution, renewal and removal within the fabric to ensure the historical development of the building was captured and recorded in the HBIM as an evolutionary building record. As noted in the previous case study, the use of this evolutionary information is critical to the decision making process of key conservation philosophies and principles as the extent and type of works continue to be developed and we continue to develop a greater understanding

of the heritage asset through controlled investigation and demolition works. This layering of information and being able to visually track the evolution of the building facilitates key decisions and amendments in the layout. Such an example included the rationalisation of the plans to open up key areas of the Assembly Hall where plasterwork crests were revealed in building works, and the identification of more modern panelling and fixed timber cabinets which were relocated to facilitate the exposure of the plasterwork crests. The phasing allows the visual review and application of significance to be able to ascertain the wider impact of proposed work, allowing a balance and mitigation to be made to establish the most appropriate course of action for that particular heritage asset.

Within the BIM database, the removal of any kind of historic fabric as part of the renovation was recorded highlighting reasons and date of removal. New works within the existing building and renewed fabric were isolated and identified as new construction within the baseline model with a description of the works undertaken, conservation justification and date of undertaking. This displays clear changes within the fabric, providing a clear hierarchy of visible managed interventions for record purposes as well as yielding potential value from early identification of any future defects which may have been influenced or impacted by these changes within a central shared environment. This is partially prevalent in the municipal bank in areas of plasterwork. By recording and displaying these elements in the model, as the building reacclimatises to its new use following the correction of damp and water egress, end users will be able to establish if the residual issues have been corrected in the area of new works, or whether the defect continues to penetrate further within the extents of the existing unmodified fabric. The complex mix of existing plaster types and their breathability provided a difficult scenario to revolve and the recording will continually allow the evaluation of whether the interventions made were successful against the location and process.

The model also provided a sufficient benefit when reviewing stone defects. The surveys undertaken identified a number of substantial structural defects within the Portland Stone ashlar facade, causing large scale fractures, with some visible previous structural stitching repairs. Through the utilisation of a structural 3D model built from the original records, the presence of steel members to the rear of the fractures likely to be contributing to their movement was established. Local opening up revealed localised corrosion of fixing brackets connected to the steelwork, and this contributed to a change in approach to the conservation methodology ensuring rectification of the visual defect and the underlying cause of the decay. Subsequently the team was able to minimise the impact of long term decay and deterioration.

An approach was developed to create an association between issues highlighted in the statement of significance and key areas of the model through the use of a visible heritage marker (Figure 2c). Having these visible elements within the HBIM provides details of the heritage values, level and type of significance and components and materials this affects. Furthermore, this visual and attribute based information application is intended to transpose the key information contained in the statement of significance into the central HBIM environment to enable the easy understanding and importance of the historic environment being maintained, facilitating the management of decisions and change with the appropriate knowledge and information across the wider design team. This will ensure any potential amendments or proposed adaptations to areas of high significance or value will be easily visible and the model can communicate the extent of considerations and review which would be required.

Substantial key components of defined individual significance within the building, such as the safety deposit boxes, ornate timber panelling and coffered ceilings are to receive heightened levels of attribute and asset information to define the extent of repair undertaken as part of the project and potential future maintenance requirements, which will then feed into the live asset management system. This would include specific components in the vault boxes replaced or relocated, such as the locks, vault doors and number plates, which are bespoke and carry substantial maintenance requirements and restrictions to any level of adaptation. The HBIM model elements of the ornate timber panelling contain details of species, construction, patch repairs and finishing waxes including the details of the conservator who undertook them. This ensured any visible defects and maintenance requirements are appropriately considered in the context of the more recent repairs, providing the details of a reputable conservator who has a knowledge of the works. The development of this digital knowledge base will act as an interactive and encompassing historical environment for such critical items that need to be appropriately maintained to sustain their long term future, ensuring the information is always easily available to allow and support appropriate conservation, repair and maintenance.

### Outcomes and Benefits

The continual development and insertion of historic conservation information into the HBIM environment during the design process was a labour intensive exercise, however all members of the team engaged in the project identified significant benefits. The use of a centralised HBIM approach supported a more comprehensive early understanding of the project from key specialists and subcontractors through ease and understanding of complex works within a central environment. This also provided substantial benefit for surveys and replacement of more elaborate and ornate components for engaging and reviewing with conservators. It aided the production of drawn records through the increased level of detail (LOD) of the more significant components, allowing easy transposition of the conservators findings, as well as providing a base template for the replacement and repair of the ornate components from the detail contained within the model. This then supported and informed early trials/reviews and supported the decision-making processes which is fundamental to conservation practices. The early allocation of attributes and asset information in key areas is interactively informing the wider design team on routes and finishes which can't be utilised, with wider information on their conservation importance and material construction. This has significantly progressed and informed the wider coordination of services and structure in the wider HBIM environment in a similar manner to new build BIM. As an example the utilisation of the HBIM allowed the isolation of areas of fragile groin and barrel vaulted ceilings and internal polished limestone cladding which would have been impacted by services. This allowed the identification of an exclusion zone around these significant areas, defining more low impact routes in lesser significant and more common fabric in other parts of the building. Early localised opening up based on this strategy verified voids and proposed routes, which minimised the impact on the listed building, and to date are both coordinated and verified against the existing visible historic fabric. The initial findings of this process are implying a high level of 3D coordination and clash detection can be utilised to minimise the impact of intervention from building services and structure on the historic fabric, reinforcing the important conservation philosophy of minimal intervention.

The visibility of the asset information and heritage markers within this environment provides substantial benefit of key information and considerations which could affect the significance, which can often be lost or misinterpreted on a project of this size or scale with large volumes of information and records which are disparate from the model. Fundamentally it functions as a measure of justification and impact which is always present within the model, linked back to the heritage values and significance that define the importance of the building, and ensures these values are imbued into all crucial thinking and decisions of the design process and long term future of the building.

This project is ongoing and development work is focused on the enhancement of the HBIM to include a series of maintenance markers which link into a wider self-generating conservation maintenance plan. The potential of using a 3D environment to identify future interventions whilst also recent conservation history was discussed by Walsh and Bernardello (2018). In the case of the Municipal Bank HBIM, this will be operated on a traffic light system linked into urgency of works, extent of works and periods of undertaking for planned and continued maintenance and repair of the building (Figure 2d). The potential for a live self-automating conservation maintenance which can be managed in a 3D environment offers fantastic potential to support and advance the ongoing maintenance to this historic building in an informed, planned and appropriate manner, while forming a continuous ongoing record of extent of building works for many years to come. Each marker linked into an element or component will be set based on a defined time period of which the work should be undertaken, rising to red for urgent works. Once undertake this marker will be reverted to green until the next defined maintenance requirements are scheduled. This will be linked into a generating form/spreadsheet detailing the type, specification, extent and key items for the works which can be isolated to see the full extent of required and planned maintenance for a set period (Figure 2d). The development of this digital based BIM approach to conservation management will facilitate much more cohesive and appropriate project maintenance planning and will subsequently visually bring attention to areas of works which haven't been undertaken and the likely impact, ensuring the client is continually aware of the building requirements. Often once a project is complete, the conservation management and maintenance plan isn't always followed through and adhered to. By creating a more interactive basis which can be easily managed, it presents to opportunity for a greater level of engagement and understanding to ensure repairs are undertaken, promoting active rather than reactive conservation management.

## 6 Discussion

Based on the foregoing discussion of conservation principles, previous and emerging research in the field of HBIM and the industry focused case studies presented, it is clear that the issue of conservation management is still an area in need of future direction. Building on some of the key issues identified above five critical elements are proposed in the development of a framework to support the implementation of HBIM for conservation heritage projects (Figure 3). Noting that much of the work thus far with respect to HBIM has been focused on the recording of artefact data as it exists in the in-situ state prior to an renovation or adaption work being undertaken or conceptual with respect to conservation. Further a significant body of work in this field, including guidelines by national bodies has focused heavily on the capture and modelling of buildings and individual components with less regard to the issues surrounding conservation work.

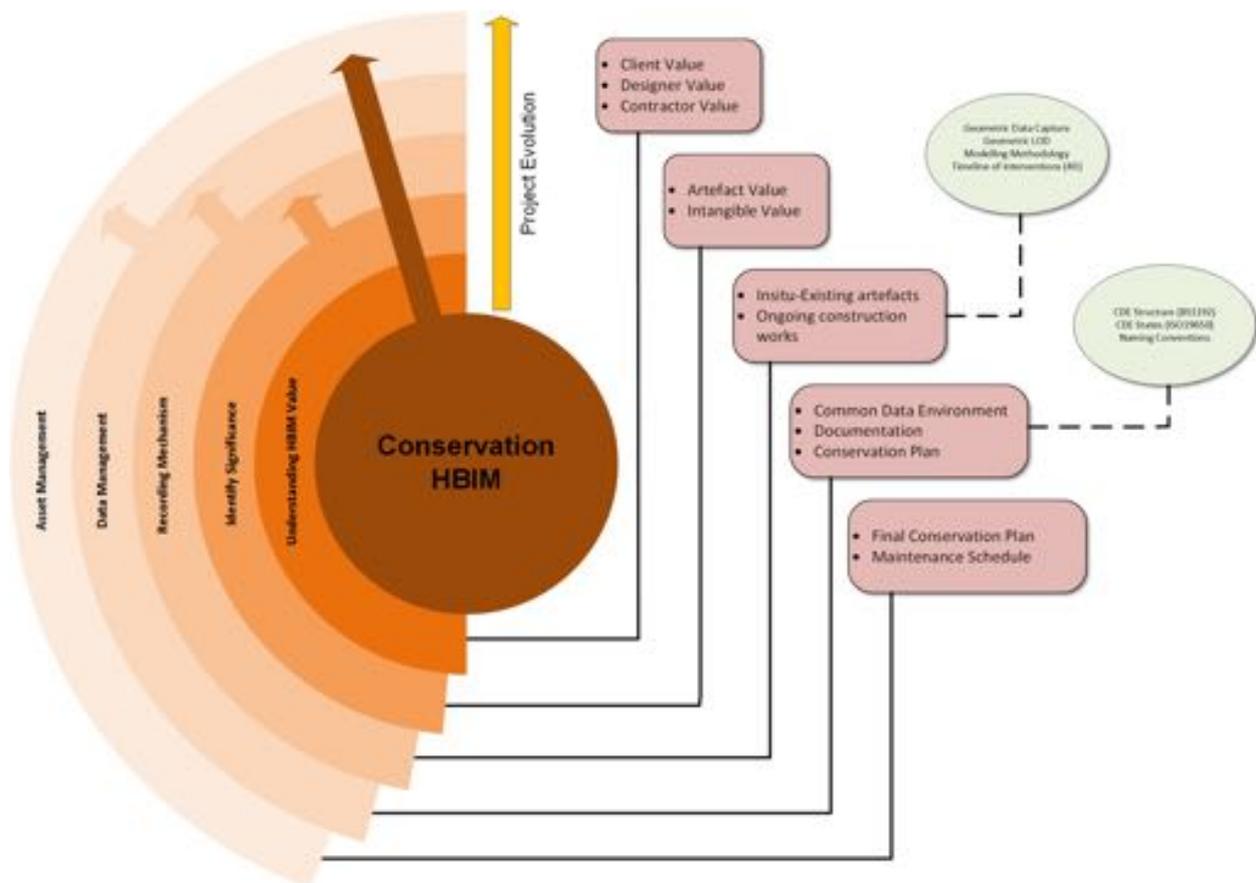


Figure 3: Framework for HBIM on conservation heritage projects

### Understanding HBIM Value

Prior to HBIM being deployed on a conservation heritage construction project, it is vital that the value of HBIM is identified. In particular the value should be articulated for the design and construction team and also the client. Value of implementing HBIM in conservation renovation projects lies in the ability to better coordinate data and subsequently design and construction work, however this may mean the upfront cost is increased. This should be balanced with the ability of implementing a BIM based approach to de-risk elements of the project.

### Identifying Significance

In the context of conservation, significance is a critical factor, and this is identified by salient bodies in the field. The focus of significance could be at a number of levels of granularity when looking at the building/project being undertaken. The entire building could be of value, specific zones or parts of the building could be deemed as having significant value or individual artefacts within the building. In order to support the development of the HBIM, this would need to be identified and documented. Furthermore,

whilst this may deal with the geometric and physical properties of the element(s) in question, there is also a need to identify the non-tangible value of any of the above.

#### Recording Mechanisms

Building on the identification of significance, the elements identified then need to be recorded as part of the conservation plan - both in the pre-construction state as a historic record, and during the construction works to identify the changes made during the process. At the present time, HBIM work is predominantly focused on the pre-construction state of the recording and documenting the elements which are deemed to have value. With respect to conservation heritage projects, it is also proposed that both geometric and non-tangible data is continually recorded and logged during the construction phase. Furthermore the recording should also be used to maintain a log of ongoing work, methods employed during construction and conservation knowledge to ensure that this is maintained in a digital repository to ensure the future sustainability of the building.

#### Data Management

An underlying philosophy of BIM is the ability to store digital data in a central repository for the project. The structure of a CDE is established using prevailing standards such as BS1192 or ISO19650, however these do not currently specify approaches for the storage and structure of conservation-based information. It is therefore proposed that a structure is developed as future work to create a formalized approach for storing conservation heritage data as an integral part of the CDE.

#### Asset Management

The ultimate goal of implementing a HBIM approach to conservation heritage projects is the ability to maintain an ongoing digital log which can be subsequently used for asset management during the lifecycle of the building. Currently the digital data stored in the BIM/CDE contains operational information which can support management of maintainable assets. In order to support the ongoing asset management the conservation HBIM will contain a wider range of information, such as those discussed above detailing construction methods and the date of heritage interventions. At the present time COBie is highlighted as the standard for documenting and sharing asset data for the operational phase of a building, however there is potential to further expand and exploit this for sharing of conservation data and linking to the conservation plan which could include a planned maintenance schedule.

Building on the above and the framework for implementing HBIM on conservation heritage projects, the proposed augmentation to the BIM Level 2 process as detailed in PAS1192-2 is proposed (Figure 4). Whilst it is noted some of these elements may be subject to amendments with the development of ISO1950, the prevailing process could be simply adapted. The proposal detailed is view as additional considerations which need to be taken when dealing with conservation projects and should align with the existing processes and documents currently used.

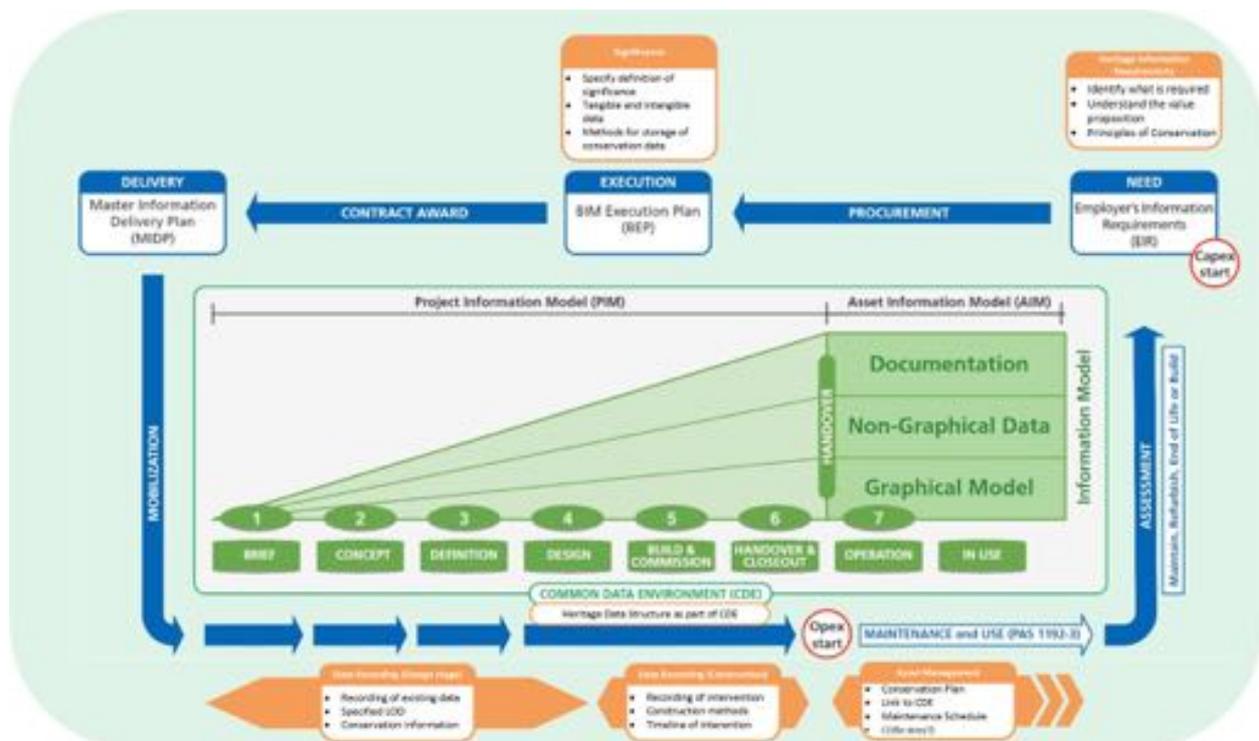


Figure 4: Conceptual implementation of framework in PAS1192:2 BIM process (Source: Adapted from BSI, 2013)

## 7 Conclusion

The issue of conservation when dealing with the renovation of heritage buildings is critical to preserve and sustain historic information for future generations. Heritage BIM has demonstrated the ability to capture and record information related to heritage buildings and the use of advanced measurement techniques such as laser scanning and photogrammetry have underpinned a rapid rise in the use of HBIM. However, much of the work in this field has focused on the use of BIM tools to generate highly accurate graphical geometric representations of buildings. Often these are used to support the design process, however to fully exploit the digital approach BIM should contain information relating to maintenance or restoration activities from initial design, through construction to handover and operation. Using a pathology based approach this can be implemented in the pre-design phase to understand the history of the building and subsequently what is to be conserved and further to document work as the project progresses to detail the type, date and range of intervention. Based on literature and case studies, this paper has demonstrated that BIM also has a substantial role to play in the recording of conservation information including significance and value of both the entire building and individual artefacts. Often this may require investment and so, at the start of a project, the client must understand the value of implementing HBIM in this context and the potential benefit this can have for the ongoing asset management process. Not least it can link to the conservation plan for the building and support the client in managing planned maintenance. The framework provided could be used as a guidance for clients, architects and contractors when undertaking renovation or adaption of existing heritage buildings as an approach ensuring sustainable conservation of the building. Future developments of the case studies presented could seek to include the ability to make the HBIM database available online through a web-based platform. This would provide a more readily available approach to the asset management teams and allow a range of conservation data to be synchronously updated within the model during site works. Whilst this holds a number of benefits in respect of accessibility, the issue of data security also becomes a critical factor. This is particularly true of data which is sensitive to aspects such as building accessibility.

## 8 Acknowledgements

The authors would like to thank Glancy Nicholls Architects and the University of Birmingham for allowing the inclusion of the case study projects and access to the information.

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