Understanding the complexities of managing historic buildings through heritage BIM: a case study of Durham Cathedral

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Abstract

The adoption of Building Information Modelling (BIM) in the management of built heritage is an exciting prospect, but one that presents some unknowns and complexities additional to those of modern buildings. If challenges can be identified and overcome, the adoption of Historic Building Information Modelling (HBIM), could offer a number of advantages, including: more efficient and effective archiving, monitoring, inspection and surveying of sites; better evaluation of conditions and historical development; and more informed procurement, estimating and scheduling of interventions, particularly those that are outsourced. HBIM offers a new approach of visualising and managing historic building and estates by offering efficiency and effectiveness in the conservation, long-term management and presentation of historic built assets. The key factors are (1) the 'parametric' and 'intelligent' potential of BIM; (2) the capacity of BIM to embed non-geometric information (specifications, material properties, reports, etc. along with unique theoretical and heritage information associated with heritage buildings); and (3) the accessibility and flexibility to access and utilise the data, both graphical and non-graphical. However, despite this potential, and growth in interest, there has, to date, been little research into what Maxwell's (2014) COTAC BIM4Conservation report highlights as 'a specific HBIM approach that is coherent and relevant, whilst also taking fully into account the wide diversity of issues that affect the heritage'. It is from this challenge, that the research discussed in this paper aims to contribute. Using Durham Cathedral as a case study, this paper presents an overview of BIM-based workflow processes and technologies applied to improve the way this UNESCO world heritage site is managed. The paper sets out the challenges and complexities in managing the estate and provides an insight into the approach taken to capture and visualise a HBIM solution that provides functionalities that improves efficiencies compared with traditional pre-BIM workflows. In doing so, the research provides an underpinning narrative for understanding the potential advantages, disadvantages, challenges and drivers of HBIM adoption for facilities management across the heritage sector. The paper draws conclusions and areas of future research that identify the need for a stronger understanding of the culture within heritage building for managing historic assets, and identification of Heritage Information Requirements (HIR) and the unique theoretical and heritage information associated with heritage buildings, in order to deliver a coherent and relevant HBIM approach.

Keywords: HBIM, BIM, Facilities Management, Historic England, Durham Cathedral

1. Introduction

Heritage buildings are unique in their characteristics and are more than just physical entities. They hold universal value to all humanity and have a legacy for generations to come. They promise to have forms, assets and systems that have been crafted and installed over centuries of modifications, repairs and developments. As a result, heritage buildings can offer complexities both in their form and the information they retain. How to record, organize and manage these complexities is a constant struggle for the parties that manage heritage buildings. However, tools, processes and approaches promoted by Building Information Modelling (BIM) could potentially provide a solution (Maxwell, 2014). The last decade has seen an increasing use of BIM within the Architectural, Engineering and Construction (AEC) industry. Primarily focused on the design and construction processes for new builds, the co-ordination, centralizing and visualization of information has also been applied to facility management processes to existing and heritage buildings. It is within this context, the use of BIM as a solution for managing heritage buildings where this paper is focused. The adoption of BIM in the management of built heritage is an exciting prospect, but one that presents some unknowns and complexities additional to those of a traditional or modern building. However, despite this potential, and growth in interest, there has, to date, been little research into what the Maxwell's (2014) COTAC BIM4Conservation report highlights as 'a specific HBIM approach that is coherent and relevant, whilst also taking fully into account the wide diversity of issues that affect the heritage'. It is from this challenge, that the research discussed in this paper aims to contribute. Using Durham Cathedral as a case study, this paper presents an overview of BIM-based workflow processes and technologies applied to improve the way this UNESCO world heritage site is managed. The paper sets out the challenges and complexities in managing the estate, and provides an insight into the development of a HBIM solution that provides functionalities that improves efficiencies compared with traditional pre-BIM workflows.

2. BIM and managing heritage buildings

BIM, as a term, can refer to both a model (i.e. a geometrical representation of an asset or a project with information attached) or the process of "creating and managing information on a construction project across the project lifecycle" (NBS, 2017a). It is the former application that is of interest in the current context and its potential within the context of historic buildings. The use of BIM on existing buildings within this context, is focused on creating an information rich 'intelligent' model to support the operation phase of building. This version of a BIM is referred to in BSI (2014) PAS 1192-3 document as an Asset information Model (AIM), a "single source of validated and approved information that relates to a built asset and is used during the operational phase of a building" (NBS, 2017b). The information comes in the form of both geometric and non-geometric data (parameters, reports, documents, etc.), with the geometrical data acting as a visual portal for the attached non-geometric data.

Within the context of Facilities Management (FM), a structured AIM can offer advantages over traditional approaches including: more efficient and effective archiving, monitoring, inspection and surveying of sites; better evaluation of conditions and historical development; and more informed procurement, estimating and scheduling of interventions, particularly those that are outsourced. Within the current culture of heritage building, information (2D plans, elevations and drawings, photographs, reports, operation and maintenance manuals, etc.) can be fragmented and not consistent. This can lead to inefficacies in how the data is used, and in the resulting outcome. The operational phase requires comprehensive set of well-structured information regarding the building asset (Nical & Wodyński, 2016). The adoption of an AIM allows for a central source of operation data to be created and structured, acting as a visual and accessible digital record for a project and its assets. Non-graphical information held within an AIM for modern buildings would typically relate to the operational information of an asset and may include the: manufacture; material; cost and performance rating, it's geometrical parameters, ID and location, related optional and maintenance manuals and reports, etc. Although relevant to the operation of a heritage building, a heritage AIM offers the opportunity to also include theoretical and heritage information: research material, photographs and scanned documents (Pauwels, Verstraeten, De Meyer, & Van Campenhout, 2008) relating to the use and development of the building over its existence. In doing so, a heritage AIM has the potential to not just be valuable to the operation of complex and unique heritage assets, but to also act as a structured historical record. It offers a new approach of visualising and managing historic and operational information for heritage buildings and estates, by offering efficiency and effectiveness in the conservation, long-term management and presentation of historic built assets. The key factors are (1) the 'parametric' and 'intelligent' potential of BIM; (2) the capacity of BIM to embed non-geometric information (specifications, material properties, reports, etc. along with unique theoretical and heritage information associated with heritage buildings); and (3) the accessibility and flexibility to access and utilise graphical and non-graphical data

3. Durham Cathedral

Durham Cathedral has dominated the City's landscape for almost 1000 years. Constructed over 40 years from 1093 to 1133, the cathedral stands today as the "largest and finest example of Norman architecture in England" (UNESCO, 2012), and was inscribed on the World Heritage List by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1986, to recognise its architectural and historic importance (UNESCO, n.d.). Furthermore, the cathedral is designated a Scheduled Ancient Monument and Grade 1 listed property, giving it the highest legal protection for the built environment.

Based on the typical plan of a Latin cross (figure 1), centred on the four substantial piers of the crossing, the cathedral today has been adapted, modified and refurbished over the centuries. The earliest most notable additions were the Galilee Chapel in 1170-1175 and the 13th century central tower. In the late 17th century, the cathedrals bishop, Bishop John Cosin (1660-72), embarked on the first major restoration and refurbishment of the cathedral. Post Cosin the next major rework of the cathedral took place from 1777, that saw a period of significant works that were to alter the physical character by what would today be considered at best bad conservation practice, when architect George Nicholson smoothed off much of the outer stonework face (Stranks, 1970). In parts as much as 75mm were lost, that not only altered the appearance but substantially shorthand the life span of the materials leaving a legacy of replacement for future custodians. Further restoration took place in 1858 of the cloisters by Anthony Salvin and of the cathedrals central tower in 1859-60 by the George Gilbert Scott. Conservation projects have continued into the 20th and 21st century, with the 1930's seeing the beginning of the restoration of St Cuthbert shrine to something that was to be more befitting to the pilgrimage and worship this was attracting, and more recently in 2017 work was undertaken to repair the central tower (The Chapter of Durham, 2019a). Conservation work is also planned for the central cloister in 2020, as part of a further 15-year repair and maintenance plan for the Cathedral and Precinct and develop appropriate opportunities to improve public access (The Chapter of Durham, 2019b).

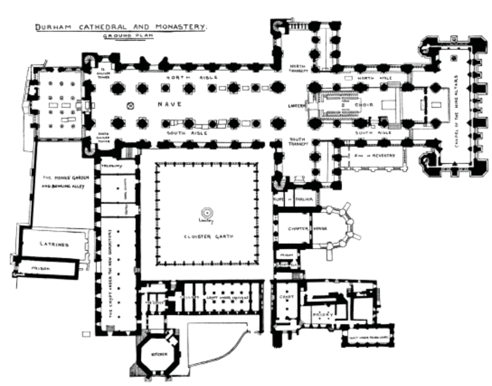

Figure 1: Durham Cathedral Plan (Bygate, 1900)

Throughout the adaption, modification and refurbishment over the centuries, the cathedral has been in constant use. Originally built as a monastic cathedral, it has long been a place of worship and pilgrimage, commemoration and culture; a place and a source of spirituality and inspiration. It has served political and military function being the seat of power for the Prince-Bishops and in 1650 saw the cathedral being used by Oliver Cromwell as a temporary prison holding around 3000 Scottish prisoners captured during the Dunbar (Durham World Heritage, n.d.). In more recent times the cathedral has been used as a movie and TV backdrop and been a centre piece of cultural arts and exhibition. This along with the World Heritage status has brought a new demographic of visitor, that has seen the addition of and improvement to public facilities including restaurant, toilets and retail shopping. Today the cathedral attracts approximately 700,000 visitor's pa, whilst still being used for daily services, which brings with it its own set of logistical challenges and adds to weekly running costs of £60,000 per week and the requirement of continual maintenance (Durham World Heritage, n.d.).

The picture is clear, the cathedral is a complex, unique and highly protected building, with layers of history imbedded in its structure, a collection of unique assets, a variation of uses by a range of different users, a constant program of maintenance and repair and a high running costs. Efficiencies need to be made to help manage and maintain the cathedral for future generations and to ensure limited budgets support the immediate and long-term running of this culturally and spiritually significant building.

4. A BIM solution for managing Durham Cathedral

Previously, the FM team at Durham Cathedral placed their reliance on architectural and sometimes artistic drawings from the late 20th century as a base for their decision making and assessment of condition of the fabric of the building. Their ability to maximize the use of the drawings to support operational processes was further hindered by their accessibility (often held offsite) and the fact that they were frequently misplaced, unorganised and inaccurate. There is no searchable way of accessing the information and there is a lack of indexing on the information that currently exists (Tapponi, Kassem, Kelly, Dawood, & White, 2015). This lack of accuracy and accessibility to the drawing material and supporting information has resulted in inefficient processes and increased costs to projects, with architects and contractors having to be paid to make bespoke studies per project, potentially duplicating effort, adding to the time and cost of a project. Furthermore, due to the lack of information about the structure's build-up, unless intrusive surveying was undertaken, it was difficult to determine typical measurements (thickness and volume) that are needed for the restoration process (Tapponi et al., 2015).

To investigate the potential of a BIM solution for heritage buildings, the Chapter House at Durham Cathedral was chosen. This project aimed to capture and model the historic structure to create a 3D digital model to support the improved management of the world heritage building. In doing so, the project aimed to gained an understanding on the potential advantages, disadvantages, challenges and drivers of HBIM adoption for facilities management across the heritage sector.

4.1 Scan to BIM

In undertaking a BIM solution for Durham Cathedral, the first stage required the need to identify a source of base data that could be used to support the modelling process. As existing drawings were deemed inaccurate, or were inaccessible, the team opted to utilize a laser scanning approach over traditional surveying techniques to create an up-to-date and accurate record of the cathedral. Accurate measured surveys have long been recognised as an important part of the renovation and redesign process and have a fundamental role in BIM of existing and heritage buildings. Laser scanning has proved to be a vital tool in the production of BIM surveys, and has key advantages over traditional surveying methods when being used to support BIM processes. BIM requires a much higher level of detail in the survey and most importantly it requires this in 3D (Historic England, 2017).

With an original focus on helping to capture and create accurate As-Built models of complex oil rigs and plant facilities, the last decade has seen an increasing application of laser scanning technology being applied within the wider architectural sector, as the technology becomes more affordable, accessible and portable. Today there are a range of scanners, designed to fit different demands, purposes and preferences of the user. Although specifications can differ most laser scanners follow the same principal. A laser scanner emits a pulsing or continuous laser beam from the scanning unit, towards the area being scanned. The laser bounces back when it hits a surface and the position (distance from the scanner) of that event is recorded based on the time of flight or the phase shift of the laser (Arslan & Kalkan, 2013) and the corresponding horizontal and vertical angels of the rotating laser. The process is repeated upwards of a million points a second, as the scanner sweeps horizontally and vertically over the surrounding area (Tapponi et al., 2015). As the process is based on line of sight from the unit, there may be a need to carry out more scans if the area to be scanned is greater than the unit's range, or if parts of the environment are obstructed by other elements. At each scan position, certain scanners can use built-in or external cameras to capture photographs to add colour to the survey data. This can be very useful when using the data to create BIM to help distinguish architectural features and material changes. The result of a typical laser scanning process is a collection of individual scans or point clouds of the area surveyed. To create a single representation of the entire scene, each individual scan can be registered with the others to create a single point cloud. Some modern scanners can do this on site during the scanning process, while others require an additional post-processing and registration process. The latter can be supported by using scan targets, which when located in each scan, are identifiable and linked together in the supporting software and by ensuring sufficient overlap of captured data between scans.

Within this pilot study the team used a FARO Focus^{3D} S 120. This survey-grade 3D terrestrial laser scanner is a phase-based panoramic-type scanner equipped with a built-in tilt sensor, barometer, and magnetic compass. The scanner has the ability to accurately capture up to 305^{O} of an environment, at a range from 0.6m – 120m, up to 976,000 points per second, with a single survey point every 3.8mm, and to an accuracy of +/- 2mm from a 25m range (FARO, 2013). Over the course of two days, the team completed 42 scans to captured external and internal features of the chapter house. The result was a 250-million-point highly accurate point cloud of the site as well as a record of the intricate detail of the site's current condition (Figure 2). However, although very accurate and detailed, the resulting file size (8 gigabyte) was too large for efficient use within BIM based software. A key point for a scan to BIM process is to provide point clouds in both a file format and size that allows for efficient modelling work. The team opted to export the data as a e57 file, selected only the data required for modelling and exported at a density of 10%. The resulting file was significantly smaller in file size but retained more than enough points (10 million) to allow for efficient modelling to take place.

Figure 2: Example of captured laser scan data of Durham Cathedral

4.2 Model creation

The process of creating the BIM of the chapter house was carried out using Revit. This required for the point cloud data to first be imported into Autodesk Recap to create a compatible format, as there is no direct file link between the FARO software and Revit. Once imported into Revit, a variation of modelling approaches was taken to "trace over" the architectural features within the point cloud to create the final BIM (Figure 3). Due to the unique nature and high architectural detail of the historic features within the chapter house, it was not possible to use standard modelling tools (system families). Instead, the Generic Model tool was used, allowing the creation of bespoke components that were more closer in detail to real architectural features, and then manually adding any object-specific parameters to it (Kelly, 2018). Even though this approach allowed for a more accurate model to be created, limitations in Revit did restrict the modelling approach, creating inaccuracies in the final model. One such error can be found in the southern wall, that was shown in the point cloud to lean out by 300mm from the vertical at the highest point of the wall. In consultation with the estates team at Durham Cathedral, it was decided to straighten this wall vertically within the BIM, to add a note to the wall highlighting the discrepancy and to provide the estates team with the point cloud to support any measurement processes. After the geometrical model was complete, a process was undertaken to populate the model with provided non-geometrical information (reports, condition classifications, comments, etc.) and parametric data, creating a data-rich 'intelligent' AIM of the chapter house.

Figure 3: Point cloud data of Chapter House, Durham Cathedral and resulting BIM.

The creation of the AIM of the chapter house provided the estates team with an up-to-date, structured and accessible model from which traditional outputs such as elevations, sections and floor plans could be accessed, along with any attached non-geometrical information. The model also allowed the creation of condition surveys to interlink with the history of each element; maintenance schedules; accurate stone surveying; visual walkthroughs for virtual tours; scaffolding simulation for refurbishment planning; scenario planning (planning an exhibition inside a room); with field tools that utilise mobile technology being available to explore and update the model on site (Kelly, 2018) (Figure 4). One further advantage resulting from undertaking a BIM approach related to the identification of wall and ceiling thicknesses and volumes. The completed laser scanning survey captured the faces of the architectural elements. When the resulting void was modelled as solid geometry within Revit, it was possible to measure the thickness at any point and calculate the volume of any part of the AIM. For the first time, the estates department were able to accurately determine the thicknesses of walls, and the volume of concrete used in the vaulted ceiling. Therefore, demonstrating the ability of the process to reduce the need to undertake expensive, time-consuming and potentially intrusive surveying.

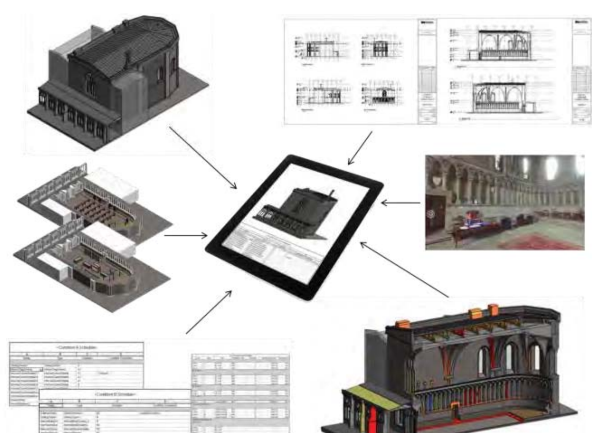

Figure 4: Resulting AIM and its features, running on a mobile device

5. Findings: Challenges and guidance

From undertaking the research, the team have been able to gain insight into the complexities of managing heritage buildings. It is clear that heritage buildings come with their own unique challenges, in relation to: the historical assets themselves; the accuracy and accessibility of current graphical and non-graphical information, and the processes and bureaucracy in place for managing historic buildings. However, it is through these challenges, where the opportunity of BIM can play a helping hand, although in doing so, it too presents new challenges. The undertaken project demonstrated the potential for BIM to improve efficiencies in managing heritage buildings, by offering an accessible platform that utilizes structured digital information and 3D models to deliver greater value. The resulting AIM creates a centralised point of access for information relating to the building and its historic assets. In comparison to modern buildings, this non-geometrical information can relate not only to operational information of an asset but could also include theoretical and heritage information relating to the use and development of the building over its existence. In doing so, a heritage AIM has the potential to not just be valuable to the operation of complex and unique heritage assets, but to also act as a structured historical record for preserving and maintaining information for future generations. However, the delivery of a heritage AIM creates some new challenges.

(1) **Level of detail.** The research has previously discussed the relationship between the architectural details of heritage buildings, the appropriateness of laser scanning in supporting data capture and BIM, and the capabilities of BIM tools to reproduce the geometrical detail. This process can be complicated depending on the complexities and detail of the historical features and assets and the needs of the client. Decisions will be required to establish a balance between geometrical accuracy, level of detail and the requirements of the model to support facilities management processes. Where accurate geometry cannot easily be created, supplementary data could be used. Within the case study presented, the team were able to provide the millimetre accurate point cloud and a virtual tour (a biproduct of the scanning process) alongside the AIM to help with measurements and visual reviews (at time of capture).

(2) **Access to information.** On completion of the geometrical model, the next stage in creating an AIM for heritage buildings would be to imbed the necessary non-geometrical information in a structured and useful way. For the pilot study, the team were provided with relevant information, however, one of the main drivers for the initial research was the lack of accessibility and poor structure of existing information. Correct BIM processes can support the structuring of the information, but a program of information identification and retrieval may be required to collate the required information and establish its capability to attach to the AIM.

(3) **Technical skills.** To be able to complete a base model that can carried forward, a combination of the adequate hardware, software and skillset is required to achieve the whole process from laser scanning to producing an 'intelligent' AIM. Although the initial process of data capture and BIM can be done using external subcontractors, there will be a need inhouse to utilise the model and keep the model up-to-date. As with any AIM, its value decreases if it is not kept up-to-date. On delivery of the model to Durham estates, it became apparent that all relevant team members who engage and support AIM would require a level of training and initial support in to how to utilise and update the model, in order to overcome any lack of technical knowledge.

(4) **Current culture and procedures**. The delivery of an AIM for the pilot study aimed to demonstrate and gain further insight into the capabilities of BIM in supporting FM processes for heritage buildings. It was clear from follow-on discussions with Durham estates, that a larger exercise was required to understand FM processes and how they can be aligned to a BIM workflow. Although the pilot study demonstrated that a wider implementation of a BIM workflow to support FM processes would have the benefit of reducing costs and increasing efficiencies and knowledge, the estates team were restricted by current processes and bureaucracy and allocated funding streams that were in place. Through the pilot study it was highlighted that current processes that generated the bespoke and then inaccessible drawings would be hard to step away from as they had been in place for decades. Furthermore, although there were funding streams in place to support the running and maintenance of the cathedral, all funds for several years to come had been already been allocated. Therefore, for Durham to escalate BIM adoption in the future, it was established that a further research was required to understand current FM processes, and a solid business case, based on the advantages from this pilot project and potential future applications, needed to be developed to demonstrate the efficiencies of a heritage AIM whilst justifying the improved upfront costs.

It is worth noting that the challenges identified for creating an AIM for heritage buildings are also relative for the creation of an AIM for any existing building. Authors have noted similar challenges in creating AIM for existing buildings (Kiviniemi & Codinhoto, 2014; Nical & Wodyński, 2016; Pishdad-Bozorgi, Gao, Eastman, & Self, 2018). One paper to note is Kassem, Kelly, Dawood, Serginson, & Lockley (2015) exploration of creating an AIM for a large university complex. Within the paper, the authors identify challenges in: workforce and process efficiencies; accuracy of records of geometrical information and implementation challenge and maintenance of models when creating an AIM for existing buildings. Although the titles of the challenges differ, the essence of the challenges are similar to those established from this study, with the author identifying organisational barriers, a lack of accurate and structured information and a need to agree LOD, as challenges to creating AIM for existing building. However, from the review of literature, it appears that although challenges are shared, the additional and bespoke complexities of heritage buildings amplify these challenges.

5.1 The need for a Heritage Information Requirements (HIR)

The challenges identified can be split into two distinct areas (1) information requirements (level of detail and access to information) and (2) current culture (technical skills and current culture and procedures). The latter is a significant barrier to implementing BIM workflows into heritage buildings, and one that needs further research before recommendations can be made. However, based on the research undertaken, it is possible to make recommendations in relation to supporting the challenges that fall within the area of information requirements. Current BIM processes for new developments follow three distinct stages (1) **understanding** the client's needs and project team's capabilities and (2) the **development** of a BIM to support collaborations, communication and coordination throughout the design and construction phases, and (3) **application** within construction and/or more increasingly to support facilities management purposes (Figure 5).

Figure 5: Simplified BIM Workflow

These three stages are similarly applicable to heritage buildings, however it is often the 2nd and 3rd stages that take focus. This study has demonstrated the technical capabilities and solution in creating an AIM for heritage buildings, but in doing so established the importance of the first stage in order to drive the project and get value out of the resulting AIM. Within the application of BIM on a modern development, the project would be driven by documentations such as Organisational Information Requirements (OIR), Asset Information Requirements (AIR) and the Employers Information Requirements (EIR). These key documents set out what is required from the BIM process and any resulting AIM. However, due to the complexities and uniqueness of historical assets, along with the potential for a heritage AIM to include theoretical and heritage information, these documents themselves may not deliver the supporting foundation for a HBIM process. Although further research is required, it can be proposed that for heritage buildings, in addition to the OIR, EIR, and AIR, there is a requirement for heritage organisation to create a Heritage Information Requirements (HIR) that details specific information requirements relating to the historic assets and the unique theoretical and heritage information associated with heritage buildings, to deliver a coherent and relevant HBIM approach.

6. Conclusions

The focus of this study has been to gain an insight into the potential application of BIM workflows in supporting facility management processes of heritage buildings. Through the application and reflection of a pilot study at Durham Cathedral the paper has aimed to provide a narrative on the creation of AIM for heritage buildings and identify challenges and provide guidance for those wishing to develop this initial research. From the research undertaken, it is clear that heritage buildings are complex and unique structures. Although the research focused only one case study, the extreme nature (processes, uses, scale and size, etc.) of the cathedral has been able to provide a valuable insight into the complexities that heritage buildings. It can be surmised that unlike modern buildings, for which BIM is comfortably applied, heritage buildings have unique architectural details, layers of history imbedded into their structure, a requirement for constant and complex programs of maintenance and repair and have high running cost. For such buildings, it is important that efficiencies in management, maintenance and repair and use are needed to help reduce costs and preserve the historical assets for future generations. The processes and ethos promoted by BIM has been shown within this paper to have a potential to support. Through a process of laser scanning and modelling, the team were able to deliver a working prototype of an AIM for heritage buildings. They were able to successfully demonstrate the capabilities of the model to present graphical views (plans, elevations, sections, etc.) on request and imbed and provide access to non-graphical data (specifications, material properties, reports, etc. along with unique theoretical and heritage information associated with heritage buildings). In doing so, showcase the potential of BIM to provide an accessible, accurate and visual database for supporting facility management processes. However, it was through this process that key challenges and areas of future research were identified. Although identified challenges are relative to creating AIM of existing buildings, the challenges are amplified by the bespoke complexities of heritage buildings. It was established that there is a need to further understand the culture in managing heritage buildings, to understand not only the technical capabilities, but the processes and bureaucracy in place for making decisions and implementing changes that have been created by their protected status. A greater understanding is needed to understand these processes and to establish how BIM can support. Another key challenge relates to the information requirements for heritage buildings. Due to the complexities and uniqueness of historical assets, along with the potential for a heritage AIM to include theoretical and heritage information, alongside operational information, it can be proposed that in creating an AIM for heritage buildings, in addition to the OIR, EIR, and AIR, there is a requirement for heritage organisations to create a Heritage Information Requirements (HIR) that details specific information requirements relating to the historic assets and the unique theoretical and heritage information associated with heritage buildings, to deliver a coherent and relevant HBIM approach.

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