Conservation data parameters for BIM enabled heritage asset management

Article

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Abstract

Key BIM concepts such as parametric modelling, database formulation and structured information management could offer huge benefits and efficiencies to the built historic environment in the operation and maintenance phase (O&M) of a building's lifecycle (lifecycle BIM), such as heritage asset management, and particularly conservation repair and maintenance (CRM) programming. Despite these potential benefits, practical examples of the use of BIM for O&M in a heritage context are limited in the published literature. This paper considers known barriers to the general implementation of lifecycle BIM, in particular the identification of critical information requirements, and introduces an Antarctic case study that sought to establish a framework of data parameters, limited specifically to BIM-enabled heritage asset management. Research findings suggest that while developing a framework of conservation data parameters is a relatively simple task, it is the retrospective compilation of historic building information for the development of a structured Asset Information Model (AIM) that presents more of a challenge. Furthermore, it is highlighted that adoption of the information management process is critically affected by socio-technical dimensions, and that working practices within the heritage sector need to be carefully aligned to a BIM philosophy for successful implementation. The key challenges and findings of this research should be considered when developing guidance for the implementation of BIM-enabled heritage asset management.

Keywords: BIM, Asset Information Model, Heritage BIM, Socio-technical, Digital Data Management, Asset Management,

1. Introduction

1.1 Building Information Modelling (BIM) and the built historic environment – Heritage BIM

Building information modelling (BIM) is a process of information production, management and delivery among project stakeholders. It facilitates collaborative working practices through defined processes and technology, offers the potential for improved performance and efficiencies and thus huge benefits to the construction industry. With the UK Government agenda to meet BIM level 2 compliance and the increasing use of BIM in design and construction, the application of BIM technology and procedures to existing and historic buildings, and the benefits this can offer for conservation management have been researched for the past decade [1, 2, 3]. Research has explored the emerging uses of BIM technology in the historic environment, generically termed Heritage BIM or HBIM, in design and restoration projects, and digital preservation and 3D visualisation for research, education and engagement. Although the list of potential benefits is impressive, practical examples of the use of BIM for operation and maintenance (O&M) in a heritage context are limited in the published literature [4].

BIM application in the heritage sector to date has had a heavy focus on digital documentation of heritage assets fuelled by technological developments in 3D data capture such as photogrammetry and laser scanning over the past few years. There are numerous exemplars of heritage assets being documented in this way [5] and the range of benefits in visualisation, structural and condition monitoring, education and research for conservation practice is becoming well understood. Research has considered the practical issues of data capture, subsequent 3D parametric modelling from point cloud data, automated data processing, pattern recognition, and the creation of object libraries [6, 7, 8]. The potential of BIM as a centralised data hub, facilitating the production, integration and management of required building information such as survey data, material, constructional and performance analysis, drawings, photographs, historical information and archival data, has also been the focus of much recent research [9, 10, 11, 12, 13]. Furthermore, key BIM concepts such as component based parametric modelling and associated data parameters, inventory and database development, and the extraction and transfer of structured data have been identified as beneficial in the operational phase of a building's lifecycle [14, 15], particularly for repair and maintenance.

Research often refers to the initial development of an enriched BIM model, usually developed to support a conservation or restoration project, noting that these can subsequently be used for the ongoing maintenance of the asset. For example, McArthur [16] uses a case study to present a BIM framework for the O&M phases of existing buildings but focuses on the modelling aspect and transfer of data from the model to computer aided facilities management systems. Similarly, the BIMLegacy and BIMExplorer web tools [17, 18] are research outputs for managing heritage interventions that focus on data capture and 3D modelling prior to data enrichment and the handing-over of information for ongoing heritage management. While modelling phases are reported for their difficulty, the need to identify information requirements for FM or ongoing maintenance are mentioned but not discussed in any detail, and no suggestions are provided for understanding information requirements. Furthermore, it is often acknowledged that data enrichment is an activity that can be conducted separately [e.g. 18], and that standardised data could *either* be used within the BIM model *or* managed separately in a spreadsheet [19]. Therefore it raises the question as to why none of this research has considered the need for a 3D model at all, or considered whether BIM modelling is one activity and data structuring a separate activity, both which form part of a BIM information management process but are not mutually dependent. An exception to the majority of reported research is Burak Cavka et al. [20], whose research did specifically consider requirements for asset management, as opposed to modelling techniques, and developed a conceptual framework through a longitudinal research and ethnographic study that proved useful in identifying computable requirements. As with most other research, they did not consider the requirements heritage buildings in particular, including the significant challenge presented by retrospective compilation that we address here. No other research has been identified that reports on issues as they relate to the heritage sector, including the dominance of analogue data without standardised storage and maintenance, and the structural difficulties of introducing an IT based process to a cash-starved sector that relies on traditional skills and volunteer labour. With a distinct lack of research, the study discussed here has focused on identifying critical information requirements and data structuring as part of a BIM information management process, for the limited and specific purposes of conservation repair and maintenance planning.

1.2 Heritage asset management – current practice

Where traditional asset management is driven by definitive lifecycle costs from creation or acquisition to disposal, the management of heritage assets is based on systematic, condition and significance-based conservation repair and maintenance (CRM). An understanding of significance and the principle of minimal intervention has been well understood as the most suitable and sustainable way of protecting heritage assets for centuries and this theory is well embedded within international building conservation legislative frameworks and charters [21, 22, 23, 24, 25]. In 2016 Historic England [26] published a case study report aimed at providing guidance to UK Local Authorities when developing asset management plans. The report acknowledged that heritage assets require their own management strategy with specific objectives where the emphasis is placed upon 'stewardship' and 'curation' and most importantly, in maintaining historic building fabric and cultural significance. As noted by English Heritage and Historic Environment Scotland in their own Asset Management Plans, heritage asset management should be underpinned by supporting principles such as multi-disciplinary, knowledge-based decision making based on comprehensive and current data; systematic and embedded processes; and explicit leadership and responsibilities. Information management, record keeping and integrated databases in a heritage context have been previously identified as themes requiring further development [27, 28], yet research suggests that today information is still too often document based, dispersed, inaccessible and unstructured, resulting in ineffective collaboration, duplication of work and poor management [15, 17]. In addition, there is no standard process or framework for heritage asset management.

Building information modelling (BIM) might offer an effective solution to this problem. This, however requires testing in a heritage context [17] and would require implementation guidance for the heritage industry to facilitate adoption. Whilst BIM-enabled asset management, otherwise referred to as 'Lifecycle BIM' has been considered from a new build perspective, very little research considers this potential for built heritage assets. Research that does, has highlighted challenges affecting the slow adoption including a need to identify critical information requirements, provide practical guidance on incorporating information requirements into contract documentation and, defined information management processes [16, 29]. These barriers are not unique to the implementation of BIM-enabled heritage asset management [30, 20]. The uptake of BIM in the operations and maintenance (O&M) stage of a building's lifecycle for new build assets is also low, despite it being suggested that the most benefits from BIM processes are gained during this stage. In order to fully consider the potential of BIM-enabled heritage asset management, identified barriers must be addressed and more case study exemplars are required.

1.3 BIM information delivery cycle – the Asset Information Model (AIM)

Within a 'traditional' BIM workflow that begins with design and construction, information is produced and collated throughout the process as structured digital data sets within a project information model (PIM). This is passed to the building owner upon project completion to be transferred into an asset information model (AIM) and used for the ongoing management of the asset. In a heritage BIM workflow these early design and construction phases, and the consequent PIM, are absent due to the 'existing' status of the assets, and the emphasis is instead on producing, collating and maintaining asset information retrospectively. Principally this means the development of the asset information model (AIM) from which information can be drawn for heritage asset management, and to inform conservation repair and maintenance (CRM) activities. Furthermore, while a full BIM process may involve 3D data capture, subsequent parametric modelling and building information management, we have focused our research on the aspect of critical information requirements and structured data sets for CRM planning, rather than tackling the BIM process as a whole. The potential role of BIM in the management of the fabric of a heritage site and its associated data extends beyond CRM, but the scope of this paper is limited to that as perhaps the most significant activity, for the sake of producing a system that can be tested on a heritage site.

In the case of existing buildings, critical information for CRM planning may already exist rather than being produced during a design and construction phase. Identifying where legacy data can be found within the varied and fragmented documents however can be a little tricky. In the case of historic buildings, much of this information is archival and paper-based, requiring time and effort to compile. Data is often missing, possibly inaccurate, and must be brought up to date through survey work [31]. Thus, it is the *retrospective compilation* of historic building information and capture of up to date data that presents more of a challenge when adopting BIM information management processes for heritage asset management. Whilst this retrospective assembling of historic building information to create the AIM requires a certain level of resource as a basis for heritage asset management, and to provide a single source of data to be used to inform CRM activities, this could be hugely beneficial and a justifiable business case.

1.4 Producing structured datasets for the HBIM Asset Information Model – a framework of conservation data parameters

Traditional methods for the production of paper-based files or digital pdf documents in relation to a built asset can be difficult to manage and can be misused by individual project stakeholders. For the specific purposes of planning and programming CRM (conservation repair and maintenance) activities, information and documentation in this format does not facilitate efficient analysis, planning and decision making. Despite these inherent limitations, 'the use of textual documentation for the recording [and managing] of condition survey data…appears to be the norm in heritage sectors' [32]. This paper investigates the BIM concepts of component based parametric modelling, the application of data parameters to produce structured data sets, and BIM information management processes for the CRM of heritage assets. We have limited our discussion to focus particularly on establishing critical information requirements and thus data parameters, in order to produce structured data sets to be used within a BIM information management process. The research is intentionally limited to this specific task, which has been identified as a barrier to implementation, and aims to raise the profile of what is an under-researched topic in the BIM literature.

Structuring data using established conservation data parameters, such as element condition, significance and priority has a number of benefits. Where a BIM parametric model has been developed, data parameters can be added directly to the model and set as filters to be subsequently used as a visual planning tool within the model. However, where there is no initial requirement for a parametric model, it can be particularly useful to structure data sets within spreadsheets and databases using data parameters. This data may be immediately analysed and interrogated for CRM [33], and can be stored within the digital asset information model (AIM) for future retrieval. An AIM forms part of a BIM information management process but is not a 3D parametric (or BIM) model - it is a digital data repository and document management system relating to the operational phase of an asset. Typically an AIM includes both structured and un-structured information ‘containers’ comprising 3D models, 2D drawings, point cloud data, photos, spreadsheets, databases and a variety of document formats such as .pdf and .doc. , managed within a digital workspace, such as a common data environment (CDE).

The Construction Operations and Building Information Exchange (COBie) is the standard BIM method for exchanging information (as a subset of model information to be transferred into the AIM) in a structured format and uses standard spreadsheets (such as Microsoft Excel) to pull together key information in one format. Whilst COBie provides a format for exchanging asset data that is exported from parametric models, its role in heritage BIM where asset data is compiled outside of the parametric modelling process, is less clear. COBie does provide a useful template for structuring data but does not specify what information is to be included. PAS1192-3 provides generic guidance in establishing the information requirements of the AIM, however there is no current advice on establishing conservation specific data parameters for heritage BIM. Heritage BIM research has considered parametric modelling and associated data parameters with regards to the creation of historic architectural library objects [8, 34] however, research identifying and formalising data parameters for the ongoing CRM of an asset is limited, and has been more specifically researched in relation to new build facilities [19, 20] rather than historic buildings.

1.5 Implementing BIM information management processes in the built historic environment

Applying BIM information management processes for digital data management of the built historic environment requires people to change the way they work if such processes are to become part of standard workflows. Socio-technical network approaches [35, 36] have proven insightful in understanding the development and implementation of new technological innovations [37, 38] but very little research, if any, has been undertaken that looks at the implementation of BIM in a heritage context from that perspective. As discussed above, the majority of research into the potential for HBIM has focused on technical processes, and especially the production of accurate 3D models of heritage buildings. In a case study of the renovation of Durham Cathedral, whilst the primary focus is technical, there is a brief mention of the general issues that affect successful adoption of BIM in heritage. It is noted that heritage professionals tend not to be innovators and, it is recognised that relevant team members must be enrolled to support the vision [33]. Similarly, in a very recent paper that considers the development of a digitised process for CRM projects in Scotland, it is noted that SME's, particularly in the heritage sector, are reluctant in the adoption of new technologies [39].

The nature of digital data management is such that information needs to be structured in a carefully controlled and consistent manner to be useful for collaborative work and multiple stakeholders. For the heritage sector the range of stakeholders is generally broader than a standard construction project, and includes more people with lower IT skills. A conservation craftsperson, or traditional building surveyor is less likely to be familiar with modern information technologies, such as laser scanning or BIM, than employees of large construction companies with IT support systems in place. When considered along with the need for retrospective compilation of archival data, it is clear that the heritage sector is far more analogue than modern design and construction industries. This has important implications for the design and implementation of HBIM protocols and systems, since the starting point would need to assume a wide discrepancy between the digital nature of the data, and the digital skills of the people who are responsible for managing and using it. As will become clear in the case study reported below, these socio-technical issues are one of the most significant factors likely to affect the success of HBIM implementation.

2. Methods

2.1 Research Methodology

The task of establishing and testing a framework of conservation data parameters for BIM enabled heritage asset management is described in this paper through two layers of data collection and an iterative development approach. The research focuses on the critical heritage asset management activity of condition and significance-based conservation repair and maintenance (CRM). First, a study of policy documents that provide guidance on heritage asset management, heritage conservation repair and maintenance, and the UK listed building consent and scheduled monument consent process has been undertaken. Documents are analysed to establish the range of information required when undertaking conservation repair and maintenance (see 2.2 below). Secondly, a participatory action research study was carried out at a case study field site (see 2.3 below). Participatory action research involves not only observation but participation and intervention with the project. It involves a cyclical process of action and reflection that is extremely useful in a process of development such as that involved with the implementation of new technology or organisational processes. The approach tends to offer immediate contributions to practical concerns and as such is particularly useful for considering the potential of BIM-enabled heritage asset management [1, 40]. Over a period of 12 months, in the role of Heritage Programme Manager (HPM), one of the authors (JH) studied and managed the planning and delivery of a data capture and emergency repair project for the UK Antarctic Heritage Trust (UKAHT) at Base E on Stonington Island (part of the wider UK Antarctic Heritage Trust heritage asset management programme).

Academic research was conducted in parallel to the daily activities of surveying and recording. In addition to the quantitative data that was generated through these activities, the researcher maintained a flexible approach to documenting significant qualitative data. Without any a priori assumptions, the intention was to adopt typical socio-technical research methods, exemplified by the ANT advice to ‘follow the action’ [41]. The case study demonstrates common challenges faced by heritage asset owners/managers including; multi-disciplinary project teams, heterogeneous and fragmented data sets, traditional working practices and an unpredictable number of unknowns that emerge. The project allowed for the full range of stakeholders to be identified and to take into consideration the information requirements of the whole project team. The primary methods of data collection were a daily diary, alongside the results of the surveying and recording, project correspondence e-mails, project reports and other such documentation. Finally, the sets of data were compiled to provide one set of common information requirements. The requirements were then further analysed to identify computable requirements that could be used as BIM data parameters [20]. The result of this initial process was to devise a proposed framework of conservation data parameters that could be used as a baseline when implementing BIM-enabled heritage asset management.

2.2 Secondary data sources

Analysis of secondary data was carried out to establish the range of asset information, such as surveys, reports, drawings and photographs and, non-graphical data commonly required for conservation repair and maintenance. The aim was to consider the type of information and data available within different documents, establish data categories and understand how this information would be used in the CRM process. Documents that provided the most useful information include: the Scheduled Monument Consent Application Form; Heritage Assets Data Template as developed by Historic England; English Heritage Asset Management Plan 2011-2015 [42]; Historic Environment Scotland Asset Management Plan for the Properties in Care of Scottish Ministers 2018 [43], and the English Heritage K2 Basic User Guide. Data requirements identified from each of the documents were compiled in a spreadsheet under seven categories adapted from the Historic England ‘Heritage Assets Data Template’ (see Table 1). A key is provided below to illustrate which sources identified the different requirements. Many of the data requirements are shared by a number of sources and, those shared by 3 or more sources have been highlighted offering an initial set of requirements upon which to build for the framework of conservation data parameters. Source no. 1 offered a limited number of data requirements, illustrating the targeted purpose of this document and the specific requirements for schedule monument consent applications. Source no. 2, the Heritage Assets Data Template, has by far the broadest range of data requirements, indicating that this is aimed at the wider heritage management field and not purely for CRM. Sources 3, 4 and 5 which relate to the asset management plans of the UK’s leading heritage organisations and, the English Heritage asset management database, suggest a range of information requirements primarily aimed at CRM planning and therefore offer the best source of data.

Key:
1 - Scheduled Monument Consent Application
2 - Heritage Assets Data Template
3 - English Heritage Asset Management Plan
4 - Historic Environment Scotland Asset Management Plan
5 - English Heritage K2 Basic User Guide

Owner/Occupier of Monument	**Monument Details**	**Identification & Location**	**Heritage Significance**	**Core Data**	**Management Action**	**Supplementary Information**
Name **(1)**	Name **(1, 2, 3, 4)**	Location Description & Plan **(1, 2)**	Categorisation of Asset **(2, 3, 4, 5)**	Occupation **(2)**	Description of Proposed Works **(1)**	Plans **(1, 2, 4, 5)**
Address **(1)**	Address **(1, 2, 5)**	National Grid Reference **(1, 2)**	Designation (Heritage Status) **(2, 5)**	Use **(2,5)**	History of previous action **(2, 5)**	Drawings **(1, 4, 5)**
Telephone **(1)**	County/National Monument No. **(1, 5)**		Conservation Area **(2,5)**	Area **(2,5)**		Statement on Presentation **(2)**
Email **(1)**	Unique Property Ref. No. (UPRN) **(2, 4, 5)**		Statement of Significance **(2, 4, 5)**	Value, cost, income **(2, 3)**		Information on Interpretation **(2)**
Tenure **(2,5)**	Elements **(3, 4, 5)**		Description of Asset **(2,5)**	Suitability **(2)**		Photographs **(2, 4, 5)**
			At Risk **(2)**	Condition / Condition Indicator **(2, 3, 4, 5)**		Details of fixtures & fittings **(2)**
				Sustainability **(2)**		Details of other contents - collections/artefacts **(2)**
				Performance **(2)**		Conservation Management Plan **(5)**
				Risk **(2, 4)**		
				Defect **(3, 4, 5)**		
				Defect Cost (to repair) **(3)**		
				Defect Priority / Urgency **(3, 4, 5)**		
				Minimum Standard of Repair **(3)**		

Table 1: Compilation of data requirements from secondary data sources

2.3 Case Study Site – Base E, Stonington Island, Antarctica.

Established in 1993, the UK Antarctic Heritage Trust (UKAHT) is tasked with the difficult mission of preserving the remains of over 70 years of British scientific exploration and research on the Antarctic Peninsula. Faced with the hostile conditions of the Antarctic climate; katabatic winds, freezing temperatures and sea ice, even getting the 5 plus tonnes of equipment required for a typical field season to these remote bases is an accomplishment. In the face of such adversities, UKAHT have taken on the challenge of managing six historic sites and monuments (HSM) and embarked on a comprehensive survey, conservation and maintenance programme of the buildings and artefacts - the UKAHT Heritage Management Programme (see Figure 1). The site used for this case study is on Stonington Island, first established as a base for exploration and research in 1946, and closed permanently in 1975. The British hut currently standing at Stonington (HSM no.64), is a steel-framed hut and the first two-storey building to be erected by the British Antarctic Survey, marking the beginning of modern construction techniques in Antarctica. As well as the main building, the station also comprises of a number of other structures: the generator shed, dog pens, emergency store, radio mast, water tank and the collapsed anemometer tower. The buildings remain in relatively good condition but only a few of the original artefacts remain on site.

UKAHT's portfolio of historic sites has been managed to date with what can be best described as ad-hoc maintenance work. Basic historic reports were used as guiding documents for conservation decisions and repair philosophy, and conservation work was recorded in annual worklists and end of season reports. However, recent management policy reviews led to the conclusion that a more informed and managed approach to the conservation of the sites within the portfolio and the way the trust executed their responsibilities, must be established. This state of affairs is not uncommon in the management of historic sites, since the resources available are much more limited than in commercial sectors, making this case study quite typical. Most importantly was the Trust's ambition to collate a comprehensive set of base data about the historic sites, including measured survey, condition survey, material sampling, photogrammetric digital recording and artefact audit. Central to achieving these aims would be the development of a new digital data management system and, the potential use of BIM technology and processes to meet the heritage asset management needs of the Trust. The result was a new UKAHT Heritage Management Programme, divided into 5 distinct phases (see Figure 1).

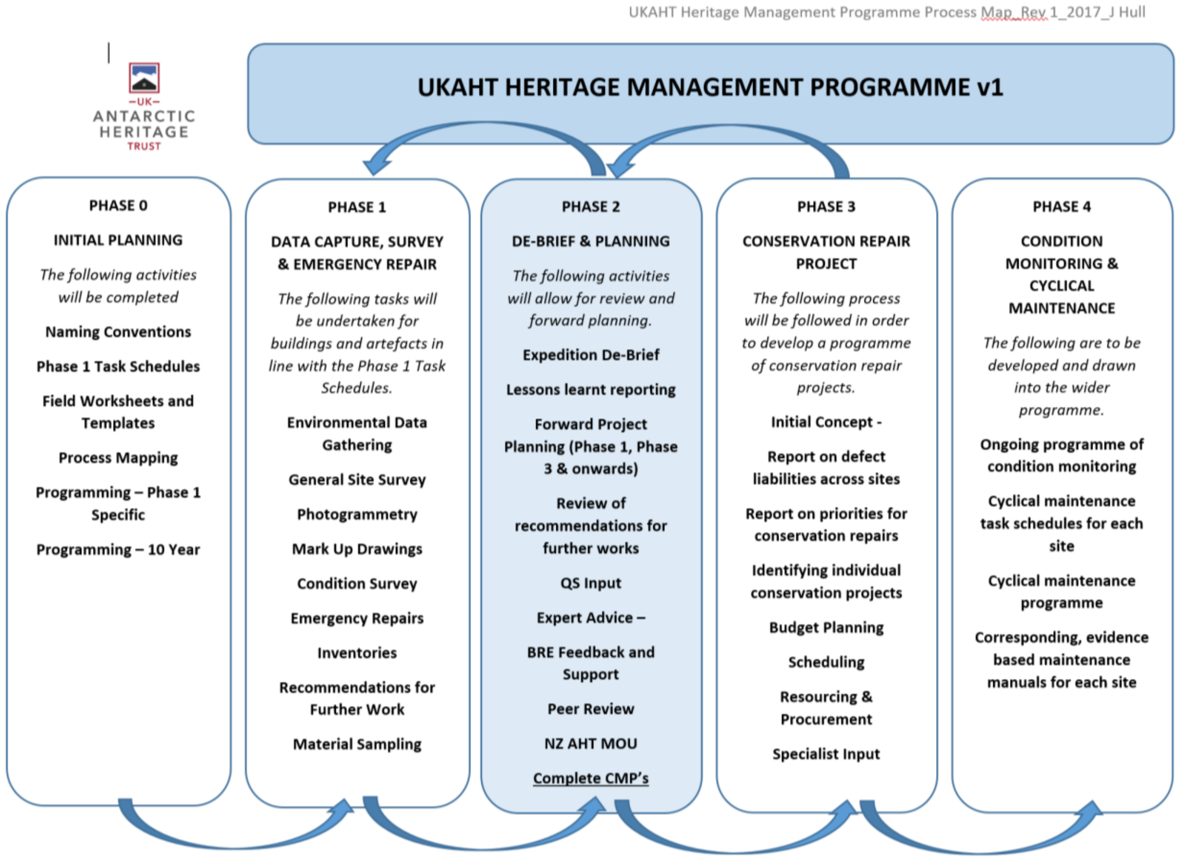

Figure 1: UKAHT Heritage Management Programme Process Map

Fieldwork was carried out at Base E, Stonington Island between 12th January 2018 and 17th March 2018 during which time a team of 6 people carried out data capture, survey and emergency repair work. The activities undertaken fell under Phase 1 of the heritage management programme process map and served to collate a comprehensive set of base data. Photogrammetric survey was conducted to provide an accurate digital record of the structures from which 2D plans and 3D models could later be developed and used in the planning of conservation repair and maintenance projects as so required. The emphasis was on capturing accurate asset data that would be added to an asset information model (AIM), rather than the process of BIM parametric modelling (Figure 2).

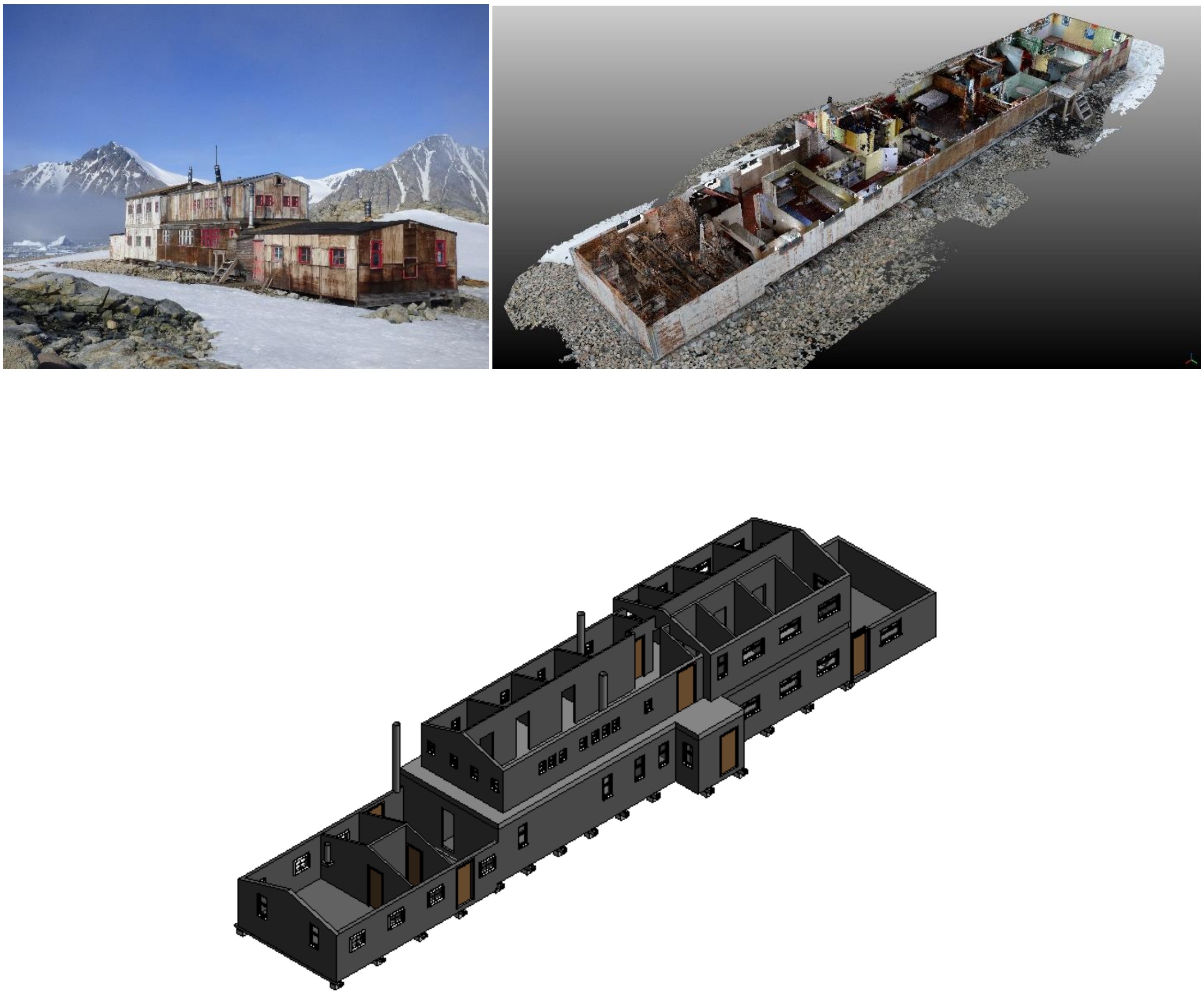

Figure 1: HSM no. 64, Base E, Marguerite Bay, Stonington Island, Antarctica – a collection of asset data to be added to the asset information model (AIM)

2.4 Analysis of information requirements

Establishing the critical information requirements for the planning of future conservation repair and maintenance projects was carried out by reviewing the information requirements data gathered from secondary sources (see Table 1) and, in consultation with key project stakeholders, critical pieces of information required for the effective planning of CRM work were identified. Phone calls, Skype calls, meetings/interviews and informal discussions were conducted with all the identified project stakeholders to gain an understanding of where this information could be found. For example, one of the conservation carpenters had previously been a Base Leader himself and, having worked for the Trust for many years, he had extensive knowledge of the types of information that were recorded in end of season reports. For effective CRM planning, analysis of building components, materials and condition is paramount. Moreover, and what sets CRM planning apart from general building repair and maintenance, is the need to understand the significance of the assets. The Government of the British Antarctic Territory (BAT) note in their headline strategy for the conservation and protection of British Heritage in the BAT (delivered in partnership with UKAHT) that conservation action will be prioritised on the basis of the historic significance of the site and, the material state of any structure or artefact. In order to achieve this, conservation management plans (CMP) were to be developed for each site, a task that had been assigned to the project Architects. The CMP is a comprehensive document that includes the significance of each site and the conservation principles and philosophy for repair and maintenance work. In addition, to provide the material state data, a current condition survey of the assets was also required.

As stated in guidance such as PAS1192-2, a BIM information management process begins with establishing organisational and asset information requirements and the development of an asset information model (AIM) within a Common Data Environment (CDE). The AIM should comprise of two parts. First, a file store containing 'published' files such as documents, reports, surveys, drawings (or, information) and where appropriate or at BIM Level 2, geometric 3D federated models. Second, a data store comprising of non-graphical structured data such as a relational database or in simple terms, structured spreadsheets. This non-graphical structured data for the AIM data store is the primary focus of this research.

The set of data outlined in Table 1 acts as a guide to the broad range of information requirements for the management of heritage assets. However, this range of activities goes beyond the scope of this paper as an initial consideration of BIM specifically for conservation repair and maintenance (CRM). So whilst Table 1 suggests the type of data that might be required for activities such as record keeping, heritage designation, consent and ownership, and facilities management, we are restricting our scope to CRM. Information noted in Table 1 might meet organisational and asset information requirements and thus would be considered a requirement for the AIM file store. The column titled 'Core Data' however provides an outline framework from which a set of structured data parameters for CRM planning of heritage assets could be developed. Combined with the primary consultation with project stakeholders, we were able to define the parameters that are decisive for protection and maintenance of heritage assets, such as the component material, the condition indicator and the significance code (see Table 2 below). The development of an asset data capture spreadsheet that used this framework of data parameters, following the concept of COBie as a template to structure data rather than specifically as a way to exchange data, provides the non-graphical structured data that would be found in the AIM data store.

3. Results and Discussion

3.1 Documentation and Structure

Building material, repair and condition information had been provided in end of season reports that were available through the British Antarctic Survey (BAS) archives, or were stored without formal structure in the 'SharePoint' electronic document management system (EDMS). As the project architects commented, scouring these documents to pull out information on the buildings and their condition in order to plan for repairs & maintenance was neither efficient nor precise. During the 2016/17 field season, steps had been taken to structure the data collected on site using template documents produced by the architects. These included a gazetteer, room data sheets, a conservation worksheet to record completed works, a building material sampling spreadsheet and a window and door schedule. As a result, condition survey information was recorded as a snapshot within the architects' suite of documents, and future recommendations were recorded in the end of season general report, as had been done historically. This did not provide a suitable structure for analysing data to document and plan CRM activities.

In addition, whilst there was now some structure to the documents, they had been stored in SharePoint with no naming convention or file structure and were still quite difficult to locate. The data collected thus far, along with archive information, was reviewed and gaps in the data were identified to establish the requirements of the Stonington Island 2017/18 data capture field season. Finally, the information requirements were considered to establish which could become a computable BIM data parameter. The second step for the project team was to review the existing template documents and the structure of these. Component-based BIM concepts were taken into consideration allowing the data structure to mirror existing practices within a BIM philosophy and provided consistency across the BIM information management process. The project team decided to break the built assets down into building components and use Uniclass 2015 to classify and structure the data. In collaboration with the project team and taking into consideration existing field season processes and documentation, two templates were developed to be used during survey and, to capture the missing data; the current condition of the assets (recorded at a component level within the gazetteer document) and, required repairs and the materials needed to complete these (referred to as the 'recommendations for further work' worksheet). Finally, the 'asset data capture spreadsheet' was developed which would act as the overall 'database' in which information from visual condition survey and the supporting reports would be entered and would be used for data analysis and interrogation for condition and significance-based CRM planning by the management team. The bespoke asset data capture spreadsheet was developed using the concept of COBie as a template to structure data at component level using defined data parameters (see Table 2), rather than specifically as a mode to exchange data as would be the case in a traditional BIM workflow. This approach provides a method by which the asset data could be compiled retrospectively, effectively interrogated and used by heritage professionals in CRM planning, but also structured in such a manner that allows for the future option to transfer the data into a BIM parametric model. While it is intended within the wider field of lifecycle BIM that structured asset data will ultimately be imported to and used within computer aided facilities or asset management software, this is not yet the 'norm' in heritage practice and, there is no specific CRM software. Data management practices within the heritage sector rely on relatively simple IT, such as excel spreadsheets, that can be interrogated to inform and plan CRM activity. This does work effectively while also offering the potential to be incorporated into higher level systems of digital data management if required and thus, the development of simple but effective structured data sets that form part of a developed asset information model (AIM) effectively meets a BIM information management philosophy.

Key information / data requirements for CRM planning	Where to find key pieces of information	Missing data / Data capture requirements	Computable BIM Data Parameter
Unique Identifier / Building Name / Reference / Location	Historic Plans / Drawings	Agreed naming convention	Unique identification reference
	Historic Documentation		
	MODES database - references		
Construction type / detail / building components	Historic Plans / Drawings	Current Building Survey	Individual components / entities
	Historic Photos / Photos		
	Base Reports / Diaries		
	Existing Surveys		
Dimensions / Areas	Historic Plans / Drawings	3D data - point clouds	Dimensions - length, area, volume
	Base Reports / Diaries	Measured Survey	
Layout / Floorplan	Historic Plans / Drawings	Verified/Current Drawings	
	Historic Photos / Photos	3D data - point clouds	
	Base Reports / Diaries		
Building Materials	Historic Photos / Photos	Material Sampling	Component material
	Existing Surveys		Material analysis reference
	Base Reports / Diaries		
	Material Sampling		
Condition	Existing Surveys	Condition Survey	Overall condition indicator
	Base Reports / Diaries	Scope of works / recommendations	Known defect - free text
	Existing Photographs		Priority reference / code
Significance	Statement of Signifance / HSM Listing	Conservation Management Plan	Significance reference / code
	Base Reports / Diaries		
	Historic Photos / Photos		
Current use / Occupation	HSM Listing		Use / code
	UKAHT records		
Minimum standard of repair		Conservation Management Plan	Minimum standard of repair / code

Table 2: CRM data requirement findings from secondary data sources and longitudinal study

3.1 Practical realities

During the course of the Stonington Island field season a number of challenges associated with the introduction of new processes and data capture objectives of the project were encountered. As soon as BIM was mentioned the focus from a number of team members appeared to turn towards the 3D data capture/modelling aspect. The HPM had to work hard to explain the potential of BIM as a way of structuring and managing building data. Getting people on board, understanding the process and crucially, understanding the bigger asset management/CRM picture was difficult. Tensions arose during the season around completion of the templates (for survey and data capture). The field season is relatively short and can be affected by bad weather conditions. The conservation carpenters were therefore keen, as would be expected, to focus on the emergency repair and maintenance work whilst the weather was good and leave reporting (data capture) for days on which the weather made it impossible to work outside. The season happened to be blessed with good weather and there were only a few days during the 9 weeks on site on which outdoor work was not possible, this therefore reduced the amount of reporting that was completed. The concern of the HPM was that if information was missing from the reports, the structuring of data in the asset data capture spreadsheet and thus, forward planning of CRM would not be effective.

Laptops were used to process and file digital images, to record all survey data and, to complete the template documents. They were powered by two methods - generator and solar panels. On the journey south, two days into the crossing of the Drakes Passage, it was identified that the team's fuel supply was missing. In the re-formatting of the Bills of Laden the number of fuel pallets had been recorded incorrectly and as a result a pallet of fuel filled jerry cans was still sitting in a fuel cage on the harbour side. With a number of e-mails back and forth, the team were able to collect a supply from Rothera Research Station during a planned stop. Solar Panels, once set up on site, were extremely efficient at providing power for the camp and charging electronic equipment. It was the austral summer so nearly 24-hour sunlight was seen at the beginning of the season. This however changed towards the end of the season, the days were getting shorter and much more cloud cover and snow was experienced. The effectiveness of the solar panels dropped and the team were more and more reliant on the generators.

Only two laptops were provided to the team of six and as a result, most team members worked on their personal computers. During the season, team members experienced difficulties with these. An issue had been raised during the 16/17 field season that the laptops provided (Macs) did not operate well in the cold temperatures and lots of issues with batteries were encountered. As a result, different laptops known to cope better with the cold were provided (Asus). Some of the personal laptops and hard drives were however Mac, and thus experienced the same charging issues as had been seen previously. In addition, incompatibility between the different laptops and hard drives caused a number of issues around data exchange between team members. When issues were encountered with poor battery charging the two supplied laptops had to be shared between the team, leaving even less time to work on survey and data capture tasks.

3.2 Data capture challenges and surprises

One of the data collection tasks was the completion of a window schedule that would be incorporated into the master asset data capture spreadsheet. The first step with this was to number the windows. As the conservation carpenters were carrying out a task to remove window shutters it was decided that they would number the windows (and the related shutters) at the same time. This would be the first task that highlighted the unknowns and surprises that can be encountered when surveying or recording building information. Whilst the HPM (a building surveyor) assumed that windows would all be numbered with a 'W' prefix, which was the case for the numbering carried out on the window shutters, the plans were actually returned with an orientation prefix before each number such as 'N' for North and 'S' for South. While both approaches made sense, in the wider scheme of data collection, this is not consistent, prevents differentiation between window numbers and door numbers and, does not fit with the structure of the asset data capture spreadsheet. Furthermore, surveying conventions in heritage practice would begin numbering windows from the North elevation, but as this was not made explicit, inconsistencies crept in. As such, the data was collected in the way that felt most appropriate to the person carrying out the task. It became apparent that the way windows were numbered had a further impact on the way other data was recorded such as material samples on the material sampling spreadsheet. The structure of this template required windows to be numbered with a 'W' prefix, which had to be re-numbered to ensure accurate data.

Another of the surprises to present itself was in the general act of recording itself. Whether it was the location, a lack of equipment, a common 'industry' practice, or the general nature of people, the way information was initially recorded was varied, and novel! Despite there being paper based and digital recording templates, information was rarely entered directly into these. Instead notes were handwritten on sample bags, white boards or sheets of ply before being passed on to the HPM for further processing (Figure 3). Furthermore, although standard naming conventions for recording information had been established prior to the field season, these were rarely used when the information was initially recorded.

Figure 3: Novel and unstructured ways to record building information

These conventions would either be added at a later date when the information was typed up in documents by the various project team members or, would be added by the HPM during data management. For example, material samples were often initially collected with a scribbled record of the contents. This information then had to be re-recorded using the standard conventions on both the sample bag/tag and, within the material sampling spreadsheet/database.

3.3 Summary

The UKAHT conservation team spent nine weeks on Stonington Island, Antarctica, amongst other things, collecting the data required for the planning of ongoing CRM activity. Ethnographic research and participant observation provided an excellent opportunity to study the implementation of new processes, follow the action and record day-to-day activity. Through the lens of a socio-technical network approach, it becomes clear that the factors that influence the success of a HBIM process go beyond the challenges usually reported on. Digital technologies are problematic due to their complexity and continual rapid development, often requiring specific skills to manage, but to prioritise these issues at the expense of the social and practical issues such as those described above is likely to lead to long-term problems and ultimately failure in the implementation of a HBIM system. The high winds and cold isolation of the Antarctic would be expected to cause greater difficulties than in many heritage sites, but this research has demonstrated that it is the relationships between the social and technical systems that are significant in successful implementation, rather than either separately. The heritage sector is populated by enthusiasts with many years' experience in dealing with conservation issues, but with limited investment and limited expertise in IT, so the quirks of practice described above are not uncommon and need to be acknowledged as a specific requirement of a HBIM system, in ways that the better financed professionalism of the AEC sectors do not. A number of challenges have been recorded in this paper as they provide the best opportunity for analysis however, that is not to say that there were not successes. Data was collected that met the critical information requirements providing the Trust with an extremely useful resource. Much of this data is in a structured format, therefore providing a better chance of successful interrogation and planning of future conservation projects. The Trust can now build upon the processes that have been developed for future data capture field seasons thus constantly improving their asset data.

4. Conclusion

Lifecycle BIM has been proposed to offer the most benefit during the O&M phase of a building's lifecycle. This could be hugely beneficial for heritage asset management, yet the potential has been largely unexplored. Whilst this paper has focused specifically on conservation repair and maintenance (CRM) data parameters for BIM-enabled heritage asset management, preparatory project work identified that the production of structured data sets, the use of naming conventions and, common data environments are all elements of a BIM process that would offer significant benefit to heritage asset management more generally.

The two sets of data collected allowed a framework of conservation data parameters to be established, tested in the field and considered in the development of a wider BIM-enabled heritage asset management implementation framework. In contrast to reported barriers to implementation, establishing the critical information requirements, and thus a framework of conservation data parameters for BIM-enabled heritage asset management, is shown to be a relatively simple task.

The essential and fundamentally important point to highlight in this research is that HBIM cannot be seen as a simple extension of traditional BIM. Significant differences between traditional concepts of BIM and the data management requirements for CRM of heritage buildings were drawn out. The case study identified that the *retrospective compilation* and structuring of data required for CRM planning provides a significant challenge within a HBIM process. Producing, updating, collating and structuring historic building data retrospectively in order to adopt an HBIM information management philosophy, and subsequent parametric modelling, requires processes and standards to be established and implemented that, whilst 'default' in a new build BIM approach, are not well embedded in heritage practice. We strongly refute the idea that BIM processes and technical systems are suitable, as they stand, to be useful to the heritage sector in their efforts to introduce BIM to conservation repair and maintenance planning. It was illustrated that even with processes in place, collecting and structuring the data within this heritage context was critically affected by a diverse range of surprises and unknowns. Implementation of the designed data management processes identified a range of socio-technical challenges and surprises that included differences in working practice, the analogue nature of conservation craftspeople and building surveying practice, the effects of technology on designed processes and the impact of external factors. It would be a mistake for heritage professionals to assume that BIM is flexible enough to be able to accommodate their existing CRM practices without some significant changes to working practices, a wholesale re-thinking of their data management strategies, and formalising roles and responsibilities, especially that of Information Manager. For successful adoption and implementation of BIM-enabled heritage asset management these factors must be taken seriously and measures to mitigate the challenges should be drawn into industry guidance.

Whilst this case study uses empirical investigations to study the micro-level dynamics within a specific project, it should be acknowledged that this provides a basis for learning at macro-level, such as for the overall UKAHT Heritage Management Programme, the heritage sector, the HBIM community and, the wider field of asset management for existing buildings, historic or otherwise.

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