Stave off decay by daily care: Digitisation for the planning of conservation repair and maintenance of the built historic environment

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Abstract

The plea to 'stave off decay by daily care' promoted by major arts and crafts influencer William Morris (1834 –1896), in the seminal Manifesto of the Society for the Protection of Ancient Buildings (SPAB) referred to regular and preventative maintenance of buildings of all ages. In response, strategies were developed to manage the scarce resources available for the conservation repair and maintenance (CRM) of the UK's built historic environment. However, in practice, such strategies are failing. Focusing particularly on identified issues in information management, data fragmentation, and the analogue nature of the heritage sector, over 100 years after the publication of Morris' plea, this research finds the principle of 'daily care' to equally apply to the neglect of digital assets. Digitisation trends such as building information modelling (BIM), could offer huge benefits. Moreover, they are critical to prevent the decay of the historic building information that is vital to the protection of our historic assets. Despite this, within existing academic literature definitions of Heritage BIM vary considerably, and practical examples of the use of BIM for operation and maintenance (O&M) in a heritage context are limited. Additionally, a careful review of literature shows that current applications of BIM in a heritage context labour the use of 3D parametric modelling with little consideration of the nature of heritage stakeholders, and the lack of funding and digital skills within the sector.

A study of 3 key organisations and their asset management processes, across both heritage and non-heritage contexts, using a mixed-methods research approach offers a broad range of data presented and analysed in this thesis. Participant observation, active participation, interviews and document analysis is combined with a 'follow the action' approach adopted from an Actor Network Theory methodology to understand the challenges faced, and the opportunities presented by introducing digital, formalised processes.

Key research findings identify that developing a framework of conservation data parameters to support digitisation is a relatively simple task. However, it is the retrospective compilation of historic building information for the development of a structured Asset Information Model (AIM) to support CRM planning that presents more of a challenge. Furthermore, adoption of the information management process is shown to be critically affected by socio-technical dimensions, and that well-defined roles and responsibilities, such as the Information Manager, are critical in successful implementation.

While offering a significant academic contribution to the existing body of knowledge, this research also provides an important practitioner contribution. The relationship between BIM and the heritage sector is reconfigured, switching the focus from 3D parametric modelling used most often in relation to conservation intervention. Instead, a new approach is suggested relying on simple and effective information management (using BIM methods) to support longer-term asset management and CRM planning. This makes the asset management process more accessible to the full range of heritage stakeholders and aligns with the BIM Alliance 'Back to BIM basics' approach. A new 'Heritage Information Management' (H-IM) workflow is presented, which has been developed with the key challenges and findings of this research in mind. It is offered as a proposal to support digitisation for CRM planning, offering an opportunity to see improved adoption and efficiencies in conservation maintenance strategies for the UK's historic buildings.

Declaration of original authorship

Declaration: I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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Abbreviations

2D	Two-dimensional representation using coordinate values relative to the X and Y axes
3D	Three-dimensional representation using coordinate values relative to the X, Y and Z axes
AEC	Architecture, Engineering & Construction
AIM	Asset Information Model
AIR	Asset Information Requirements
ANT	Actor Network Theory
BIM	Building Information Modelling
CAD	Computer-Aided Drawing/Design
CAFM	Computer-Aided Facility Management
CDE	Common Data Environment
CIC	Construction Industry Council
CMMS	Computerised Maintenance Management System
COBie	Construction Operations Building information exchange
COTAC	Council on Training in Architectural Conservation
CRM	Conservation, Repair & Maintenance
EDMS	Electronic document management system
EH	English Heritage
GIS	Geographical Information System
H-A IM	Heritage Asset Information Model
HBIM	Historic Building Information Modelling
IDP	Information Delivery Process
IM	Information management
IMP	Information Management Process
O&M	Operation and maintenance
OIR	Organisational Information Requirements
OPEX	Operational Expenditure
UKAHT	UK Antarctic Heritage Trust

1. Introduction

This PhD is about the management of heritage assets, both physical and digital. In despair at the physical decay of materials and structures through neglect as he saw it in the 19th century, the great Arts and Crafts contributor William Morris called upon those responsible for buildings of all times and styles ‘to put protection in the place of restoration, to stave off decay by daily care [with the propping of] a perilous wall or to mend a leaky roof’ (Morris, 1887). Preventative conservation repair and maintenance (CRM) is now a well-established practice for the protection of historic buildings. Of course, over 100 years later the World has advanced and technological innovation continues to evolve. While Morris was of course talking in a fairly literal sense, what about digital assets?

The planning of CRM relies on current and accurate data, yet it is demonstrated that in much the same way as heritage buildings, the same neglect of digital assets results in loss of coherence and structure. If the data that informs CRM planning should lose its relevance, and become fragmented, the consequent ‘digital decay’ will put our historic buildings at even greater risk.

I have worked in the heritage sector for over 10 years, starting my career working in the stone masonry industry and focusing my research on the benefits of stone consolidants, in particular Nanolime, for the conservation of historic stone buildings. During my career I have become aware of the importance of robust conservation maintenance strategies for effective heritage asset management. I have witnessed bad CRM practice, including the use of incorrect materials, poor prioritisation of CRM projects, and in-efficient processes within heritage asset management practice. I have developed a passion for understanding heritage asset management strategies and how these may be improved to provide standardisation in the heritage sector, thereby improving the quality and effectiveness off CRM programmes.

In 2016 Historic England advertised this collaborative doctoral award with the University of Reading. The project title was ‘Heritage BIM – New ways of digital data management for the Built Historic Environment’. The initial vision of the research was to develop an innovative digital information model suitable for use in the heritage sector to record, display and conserve the historic built environment. It was suggested that BIM might meet this requirement, offering substantial potential as a tool for understanding and managing a broader range of existing buildings, including historic and heritage sites. Considering this vision in a more focused approach I selected to concentrate on the potential of a digital information management model suitable for use in the heritage sector to support conservation professionals with heritage asset management, and more specifically, the planning of CRM projects. I considered that such research could offer a significant contribution to the heritage field. Further, the project has led to me writing a new technical guidance document for Historic England which has been subsequently published for public access – BIM for Heritage: Developing the Asset Information Model.

This chapter presents the research context and rationale while presenting a synopsis of the PhD study, which includes the specific research aims and objectives, a summary of the adopted research methodology, an indication of the research study’s scope, and the thesis structure. The research context is considered next with a high-level overview of the key themes studied.

A review of built heritage in the UK presents a demographic context, illustrating the breadth and scale of the UK's built historic environment and the value of built heritage. The cost of maintaining these valuable assets, and financial resources and strategies for heritage asset management are considered. Information management is highlighted as a key area requiring research and development if the industry is to experience improvement in efficiencies in heritage asset management.

Digitisation, particularly Building Information Modelling (BIM), is demonstrated as offering significant opportunities within the AEC industry to improve issues with fragmentation of information, silo working and productivity or in-efficiencies. Considering similar issues experienced within a heritage context, particularly for the planning of heritage CRM, the question is raised as to whether BIM could offer similar potential to support conservation professionals.

1.1 The value of the UK Built Historic Environment

The UK's built historic environment offers a physical reminder of human activity that has taken place over thousands of years, from pre-history to the present day. Architectural endeavours, trade, industry and economy, population, political and social development are all evident in the man-made environment around us. From archaeological sites to post war buildings, designed landscapes, parks and gardens, historic battlefields (Creigh-Tyte, 2000) and war memorials or, seaside heritage and garden cities, the UK is abundant with built heritage. The built historic environment is easy to identify in terms of iconic sites and monuments such as castles, cathedrals and palaces. But this is just a small part of the much broader built historic environment that includes farm buildings and animal architecture, historic lidos, the homes of ordinary people, factories and cottage industry buildings. Together, this vast environment helps us to understand who we are and where we have come from as individuals and as a nation, and for this reason much of the UK's built historic environment is protected through statutory designation. Designation is based on criteria such as 'national importance', 'special architectural, historic or archaeological interest', and is graded based on significance.

Designation of different types of site or building comes under different pieces of legislation and as such there are a number of different designation systems used to record and manage heritage assets. Historic England are responsible for recommending historic assets for designation but the final decision for listing a building, scheduling a monument, or protecting a wreck lies with the Secretary of State for Digital, Culture, Media and Sport (DCMS). Historic England make the final decision when registering a Park, Garden or Battlefield. Historic England have produced a full suite of selection guides for various types of buildings and sites that are used when determining whether a historic asset should be designated.

Listed Buildings and Conservation Areas

Most historic assets are nationally designated under the National Heritage List for England (NHLE), 'the list', as listed buildings and are graded based on significance. Grade I being of the highest significance, Grade II* and Grade II of lower significance. Listing buildings comes under the Town & Country Planning (Listed Buildings and Conservation Areas) Act 1990. Local Planning Authorities also have a statutory duty to locally designate 'areas of historic importance' as Conservation Areas.

Scheduled Monuments

The Schedule of Ancient Monuments, ‘the schedule’, records archaeological sites as designated under the Ancient Monuments and Archaeological Areas Act 1979.

Wreck Sites

Wreck sites are protected under the Protection of Wrecks Act 1973, the Ancient Monuments and Archaeological Areas Act 1979 and the Protection of Military Remains Act 1986.

Registered Parks, Gardens and Battlefields

Historic England are responsible for the register of Parks, Gardens and Battlefields that have been designated under the Historic Buildings and Ancient Monuments Act 1953.

To give a sense of scale, the size of the UK built historic environment comprises;

- Over 377,000 listed buildings
- Almost 20,000 scheduled monuments
- Nearly 9,500 conservation areas
- Almost 16,000 registered parks and gardens
- 52 protected wreck sites
- Over 40 registered battlefields
- 18 World Heritage sites
- Over 400 sites in the National Heritage Collection

The map below illustrates the geographical spread of the National Heritage Collection across England.

Figure 1.1 Map of English Heritage sites - National Heritage Collection (Source: www.english-heritage.org.uk)

Listed buildings alone account for approximately 2% of English building stock. Furthermore, the UK 'is considered to have the oldest domestic building stock in the developed world with more than 10 million properties over 60 years old' (Historic England, p36, 2020c). 5.1 million of these properties are domestic homes built pre-1919 (Historic England, 2020c).

The built historic environment offers humans a communal legacy (Lowenthal, 2005), and understanding of personal, cultural and communal identity. In conservation practice, cultural value is referred to in terms of evidential, historical, aesthetic, and communal values. These are the conservation principles (English Heritage, 2008) used to think systematically and consistently about the overall heritage significance and play a key role in determining how the UK's built historic environment is designated through policy, managed and conserved as heritage (Jones & Leech, 2015). For reference, a summary of these are given below:

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 - it tends to be 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.

(English Heritage, 2008)

This valuation method, which is common in the conservation field, does not have an economic interpretation but instead is seen as an ‘expert judgement’ based on the information content or, significance, of a heritage asset (Ruijgrok, 2006). This type of valuation is key when designating assets as heritage or, in planning and conservation decisions however, it is not the only method of valuation that should be considered in the management and conservation of heritage.

In addition to cultural value there are a wide range of social, economic, and environmental benefits that are particularly important. To demonstrate this, figures from recently published documents are provided below (Historic England, 2020; Historic England, 2020a; Historic England, 2020c):

Social Value:

- Social cohesion and sense of identity – 35% of 8000 adults noted history as a factor that makes them proud of Britain.
- Improved wellbeing, learning and skills development through heritage volunteering - 5.5% of all adults who have volunteered in England have volunteered in heritage.
- In one heritage case, 75% of volunteers reported an increase in wellbeing after a year.
- Non-market value of churches (wellbeing value of volunteering, community services and church attendance) was estimated in 2019 as £10.0 billion

Economic Value:

- Estimated total gross value added (GVA) to UK economy of £36.6 billion in 2019.
- Direct and indirect employment for around 563,509 people in 2019.
- An economic driver for the tourism sector, generating £18.4 billion in spending in 2019.
- Repair and maintenance of historic buildings directly generated £6.7 billion in construction sector output in 2019.

Environmental Value:

- Protection of landscapes, wildlife and geodiversity through heritage (DCMS 2017).
- The conservation of heritage can help mitigate climate change –
  restoring coastal salt marsh is a cost-effective defence method that could capture an additional 300,000 tCO_2 e per year by 2050.
- Research using a Victorian property has highlighted that sympathetic refurbishment, compared to doing nothing or demolition and new build replacement, offers the greatest reduction of carbon emissions, making it the most appropriate pathway for meeting the UK Government’s net zero target.

1.2 The cost of built heritage conservation

Understanding the value of heritage assets is key to protecting them, and to support funding and investment in heritage conservation. While both the tangible and in-tangible values of heritage have been quite clearly identified, costs associated with the field of heritage management and conservation are not so well defined. Research in the field of cultural heritage value and economics has shown that while the cost of conservation is high, the economic value of heritage, defined as the amount of welfare or income generated for a society, surpasses these costs (Ruijgrok, 2006). Noting that ‘the end value of a property may be exceeded by the cost of acquisition, repair and conservation cost', Tomback (p 208, 2008) wrote about the 'heritage love factor'. In such cases, the love that people have for historic and unique properties outweighs the cost to acquire and maintain them.

The long-term, life-cycle maintenance costs (LCC) of heritage buildings comes at a huge cost (Forbes *et al.,* 2014). Standard LCC modelling in asset management considers the lifespan of building elements and materials to calculate repair or renewal costs over the building's life. However, the peculiarities of heritage assets, often uninhabited, roofless, or ruined means the impacts of external factors and exposure to the elements have an adverse effect on the expected lifespan of building elements which needs to be taken into consideration when considering the cost of maintaining them. Furthermore, standard repair or replacement is not an option for heritage assets. Instead, careful conservation repair and preventative maintenance using correct materials and traditional techniques is required (Macek *et al.*, 2019). Preventative maintenance can prolong the lifespan of building elements, but can these costs be supported by heritage owners and custodians?

The full cost of maintenance across the UK's built historic environment is unknown but, English Heritage noted in 16/17 that their annual expenditure on conservation projects (diligent maintenance) was £9.8 million (English Heritage Trust, 2016), whilst the National Trust reported in 17/18 that they had allocated £46.6 million to cyclical maintenance plans (National Trust, 2018). Both organisations note that investments are primarily directed at conservation, backlog repairs and presentation. In 2015 English Heritage valued urgent conservation defects across the national heritage collection (400+ sites) at £52 million (Department for Culture & Sport, 2013) and in 2019 reported that they were forecasting a spend of £118.6m on all conservation and maintenance between 2019 and 2023.

With acceptance that the financial cost of heritage may often exceed the economic value, how is heritage building conservation in the UK funded?

European initiatives such as Monumentenwacht in the Netherlands, Bygningsbevaring in Denmark, BAUDID (Bundesarbeitsgemeinschaft unab-hängiger Denkmal- und Altbauinspektionsdienste) in Germany and MAMEG (Maintainer Network of Hungarian Monument and Building Foundation) in Hungary provide maintenance grants, rate subsidies and subsidised building inspections to owners of historic buildings yet a similar incentive in the UK – Maintain our Heritage - never gained traction (Kutasi & Vidovszky, 2010; Dann & Wood, 2004; Forster & Kayan, 2009).

In the UK, heritage projects may receive funding from the Heritage Lottery Fund (HLF) following a robust application process. Grants are available from £3000 to £5 million and cover a wide range of heritage projects. Further organisations provide grants and loans, often to groups with charitable status or social enterprises, such as the Architectural Heritage Fund, the Wolfson Foundation or Church Care. Historic England provide grants and funding to large organisations and local authorities, but also offer repair grants for buildings at risk and war memorials. Grants are often only offered by Historic England where bids to other funding bodies such as the HLF have failed. Despite these resources, with the failure of an incentive such as Maintain our Heritage, there is no support to private owners of heritage buildings. Furthermore, it has been observed that funding granted to large projects often fails to allocate finances to the ongoing maintenance or risk control of heritage sites. This often results in a need for further funding at a later date which more commonly requires local solutions (Dimitriyadis *et al.,* 2012).

At this point, the relationship between cultural value (in-tangible value, social and environmental values) of heritage sites and economic value are important. Additionally, the range of stakeholders involved in heritage maintenance programmes is observed and should be considered further. Private owners, charities, tourists, and more are all involved in the management and maintenance of heritage and indeed, raising funding for these programmes. Whatever the value, the more value individuals place on something, the more they are willing to pay for it. The heritage love factor as described earlier is an example of how individuals are willing to pay for the repair and upkeep of privately owned historic properties. Further, tourists are willing to pay considerable amounts to visit significant historic sites, as demonstrated in the figures above. Throsby (2012) noted that it is perhaps 'public spirited benevolence' either from individuals or by governments on behalf of the nation that allows the best chance to preserve the built historic environment. Research has been conducted that builds upon this and seeks to raise massive outreach for heritage funding using mechanisms that mimic micro-funding (Dimitriyadis *et al.*, 2012). It is suggested that pre-screened projects, promoted through a specific web platform and through social media and websites of associated organisations such as tourist boards could accumulate minor individual contributions to achieve defined targets. This is an interesting area of research that has been considered, but for the purposes of funding heritage asset management programmes for heritage estates and national collections, has not been investigated further in this research. It is however acknowledged that this could provide a future research area for stakeholder engagement and heritage asset management.

Having observed that costs for heritage conservation are high, and that economic streams are limited it is vital that scarce resources are distributed effectively. Conservation maintenance strategies offer the best opportunity to manage funding carefully.

1.3 Conservation maintenance strategies

Conservation philosophy and practice for the UK's built historic environment has developed from international charters by organisations such as the International Council on Monuments and Sites (ICOMOS) and documents, such as the Society for the Protection of Ancient Buildings (SPAB) manifesto. An understanding of these charters and resultant philosophies are key to successful conservation action such as, conservation repair and maintenance, development, and regeneration.

Preventative conservation repair and maintenance (CRM) is a well understood approach to heritage asset management (Dann & Cantell, 2008) with concepts that are well embedded within international building conservation legislative frameworks and charters (The Venice Charter, 1964; Feilden, 1982; Earl, 2003; Forster and Kayan, 2009; Meul & Stulens, 2010; The Burra Charter, 2013; The Charter of Krakow, 2000). John Ruskin and William Morris, the founder of SPAB, identified maintenance as key to the survival of historic fabric as early as mid-nineteenth century. 'Stave off decay by daily care' (Morris, 1887) is a well-known phrase in conservation practice that acknowledges the importance of maintenance for the protection of historic buildings.

Further, established conservation philosophy offers concepts that must be considered in the practice of CRM. In a study on building conservation philosophy for masonry repair, Forster (2010a, 2010b) discusses such concepts, which fall within two categories:

- Ethics – authenticity, avoidance of conjecture, respect for patina of age, respect for contribution from all periods, relationship to setting and rights of the indigenous community
- Principles – minimal intervention, legibility/honest repair, use of 'like for like' materials, reversibility, documentation, sustainability

Ethical concepts are of course extremely important. In the context of conservation maintenance strategies, it is important to consider how these impact the planning and delivery of maintenance. Principles of minimal intervention, the use of like for like materials and reversibility will all impact the maintenance that is delivered and so are important considerations at the early stage of developing conservation maintenance strategies. With this in mind it is suggested that historic building conservation practice should be based on the following principles (Robertson, 2007; Forsyth, 2007):

- Uses traditional materials and methods of repair where possible
- Results are honest, appropriate and responsible
- Based on accurate and reliable information

Such principles are common in conservation guidance and training, and in general, in conservation practice, yet despite this it was reported that best practice conservation maintenance systems and strategies, with common structured and standardised processes, and related guidance specifically for CRM strategies are lacking (Forsyth, 2007; Dann and Wood, 2004; McGibbon *et al.*, 2018). Moreover, when such strategies are implemented, success is variable (Forster & Kayan, 2009). One reason for this could be related to the wide network of stakeholders involved in heritage conservation. Multiple groups or organisations involved in such processes results in a wide contribution to heritage systems (Heras *et al.*, 2012) which adds to issues of fragmentation and disparity. Further, the different uses of heritage assets, tourism and development for example requires a careful balance of the interests of different stakeholders (Chapagain, 2008) when developing conservation maintenance strategies.

Information management (IM), record keeping, and integrated databases are historic themes identified as contributing to the failing of best practice conservation maintenance strategies (Major, 1999; Dann and Wood, 2004). Further, more recent research identifies that IM is still a critical area for improvement. Information is still too often largely textual, paper based, dispersed, in-accessible and unstructured resulting in ineffective collaboration, duplication of work and poor management and analysis in support of the development of CRM programmes (Simeone *et al*., 2018; Jordan-Palomar *et al.*, 2018).

1.4 Digitisation trends and information management (IM) for operation and maintenance of built assets

To improve ongoing issues of efficiency in the construction field, digitisation is identified as offering the biggest benefits to the sector across all processes (Berger, 2017). It is identified that the construction industry has been falling behind in the implementation of digital and information technologies (Hautala *et al.*, 2017) despite an acknowledgement of the benefits. Lack of investment in research and development into digital technologies in the construction industry (Dulaimi *et al.,* 2002; Agarwal *et al,.* 2016), minimal strategic planning for innovation resulting in experimentation rather than concerted efforts for implementation (Benmansour & Hogg, n.d.; Stewart *et al.*, 2002), and silo working and entrenched ways of working within the industry (Dulaimi *et al.,* 2002; Harty, 2005) are all considered barriers to implementation.

'Information is a key enabler to digital transformation' and effective information management (IM) has been considered critical in enabling a step change to the sector's productivity (KPMG LLP, 2021). Cost savings could be achieved through the use of IM and an ability to increase efficiencies and reduce risks. Further, revenue could be increased through the use of IM and better asset utilisation. Research commissioned by the Centre for Digital Built Britain (CDBB) has suggested that;

'The use of IM could potentially secure between £5.10 and £6.00 of direct labour productivity gains for every £1 invested in IM, and between £6.90 and £7.40 in direct cost savings (from reductions in delivery time, labour time and materials). We have also found evidence of cost savings at various stages of the asset lifecycle, ranging from 1.6% to 18%1, depending on the lifecycle stage' (KPMG LLP, p4, 2021).

Furthermore, effective IM is considered to increase social value, for customers, society and the environment. Modest investments in IM could offer significant social value.

Building Information Modelling (BIM) has been considered a necessity to improve collaboration, develop lean processes and increase UK productivity in the construction sector and is included in the Government's own strategy for digitisation. At its core BIM is about IM. The aim is to provide a framework and process for the collaborative production, management, and delivery of information in relation to a building's lifecycle. This is commonly illustrated with the BIM lifecycle model (Dispenza, 2010)

BIM information requirements, and the information delivery cycle, are key to the successful implementation of BIM as an information management tool.

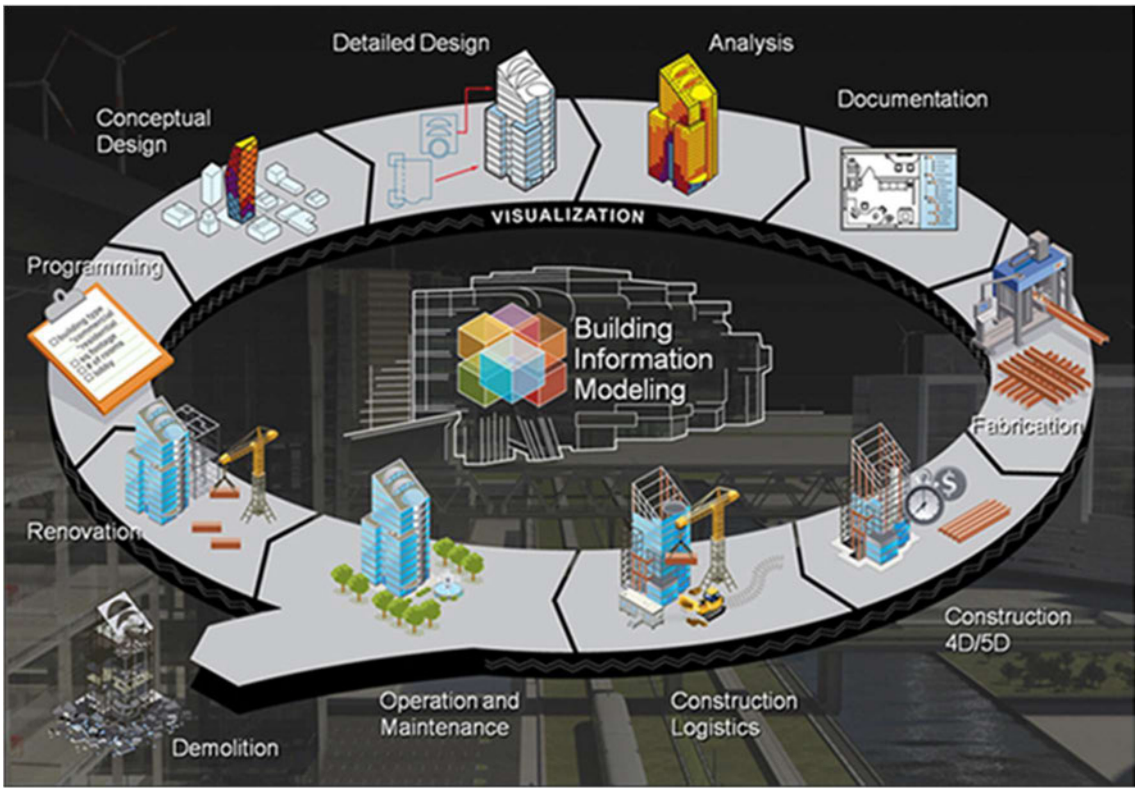


Figure 1.2 BIM Lifecycle Model (Dispenza, 2010)

Despite the Government agenda for the adoption of BIM across the AEC industry in general, adoption is low, definitions of BIM are confused, and literature and case studies fail to successfully 'analyse and quantify [the] universal benefits' (Barlish & Sullivan, p152, 2012) of

BIM. Research and literature tend to fall into one, or several, of four main themes, even if not specifically declared. These are further considered in the Chapter 2 literature review;

- Process
- Information
- Digital representation of a building or asset
- Building lifecycle

In relation to building lifecycle, BIM is identified as offering benefits across all processes and the complete lifecycle of a built asset however, the CRM of historic buildings is closely aligned with the O&M phase as opposed to design and construction. Literature that focuses on challenges identified in the O&M phase, and the perceived benefits of BIM in this particular phase (Becerik-Gerber *et al.*, 2012; Bosch *et al.,* 2015; Cavka *et al.,* 2017; Gao & Pishdad-Bozorgi, 2019) identified a potential for improved IM for O&M that could be equally beneficial for heritage CRM.

It is observed that fragmentation in the AEC industry is well reported and has led to building and estate owners and managers grappling with building data and the information required for operation and maintenance (Becerik-Gerber *et al.,* 2012; Bosch *et al.,* 2015.; McGibbon *et al.,* 2018; Miettinen & Paavola, 2014; Pärn *et al.*, 2017). Furthermore, the management of legacy data and tacit knowledge in the O&M stage is reported as a significant challenge (Gu *et al.,* 2014). Fragmentation, management of disparate data and interoperability between different management systems used by stakeholders in the O&M phase, such as computer aided facilities management systems or asset management databases, is estimated to cost the industry $1.58 billion per annum, signifying 'the importance of finding an efficient way to collect, access, and update building information' (Gu *et al.,* p1911, 2014).

Issues noted above are found to be shared by the heritage sector and are identified as contributing to failings in consistent approaches to heritage asset management and conservation maintenance strategies (Major, 1999; Gardner & Whitehead, 2003; Dann and Wood, 2004; Simeone *et al.*, 2018; Jordan-Palomar *et al*., 2018). It is demonstrated that the development of heritage management systems using computer technology and guiding principles deserves greater attention in the research. A review of the implementation of digital technology in the heritage sector illustrates a common theme that links development and experimentation of digital technology such as CAD and GIS in the heritage sector (Watrall, 2019). This theme is the digitisation of data, thus illustrating efforts within the sector to use digital technology and processes to manage issues of fragmentation and reduce inefficiencies with loss of data and duplication. This opens a particular line of enquiry for this research.

It is suggested that the potential benefits of BIM for the O&M phase, namely improved IM, may also offer a solution to issues of fragmentation, archival documentation and paper-based records commonly found within the heritage environment. However, in a similar vein to confusion around definitions and use of BIM identified in the wider AEC industry, literature has shown there to be considerable confusion around the term 'Heritage BIM', and a number of different definitions and uses have emerged. Where some research reflects on the benefits of parametric models to serve as a digital archive and navigable timeline of historical change (Fai *et al.*, 2011) which is particularly useful in a planning context, others are concerned with practical issues of data capture via laser scanning and photogrammetry and subsequent 3D parametric modelling from point cloud data which has proved difficult for existing and historical buildings. One definition that is the basis of much research is centred around the production of libraries of parametric objects built from historic data (Murphy *et al.,* 2009), or shared libraries of historic building elements to be used in parametric modelling (Oreni *et al.*, 2013; Baik *et al.,* 2015).

While the definitions and uses noted above could offer significant benefits to the heritage sector, it is observed that none relate to the planning of CRM. It is highlighted that BIM research focused on this topic is limited. The critical literature review identified that research in this arena was generally split between the recording and documenting of cultural heritage, and the management of cultural heritage (Stylianidis, 2016; Andrews *et al.*, 2015; Saygi and Remondino, 2013). It is the latter which is of importance for the field of heritage asset management. With known failings in the management of historic building information for the planning of CRM, and a lack of standardised approach, research in this domain is crucial if the sector is to see improvements in conservation practice and allocation of scarce resources.

Finally, if BIM for use in the heritage sector is to be researched further, particularly for CRM planning, observations around the range of heritage stakeholders as mentioned above must be considered. Research has noted that ICT and digital skills within the heritage sector have been demonstrated as limited (Vileikis *et al.,* 2012), and the impact of technology and digitisation within heritage fields, along with IT skills and training is a major theme that must be included in research (Duff *et al.*, 2009).

1.5 Research Problem

Through critical literature review, as detailed in Chapter 3, it is identified that formalised processes and frameworks for conservation and maintenance management of the built historic environment are lacking, and the success of implementation where processes are introduced is variable (Forsyth, 2007; Dann and Wood, 2004; Forster & Kayan, 2009; McGibbon *et al*., 2018). Moreover, information recording and management for subsequent analysis are key failings. Issues of fragmentation and inefficiency in the construction sector (Chapter 2) are mirrored in literature surrounding heritage management, in particular literature regarding recording, documentation, and IM for the heritage field.

Despite a clearly identified issue, literature around the topic is limited. The literature review in this area has relied heavily on just a few papers, highlighting a significant gap and area for further research. Having demonstrated the importance of CRM and heritage asset management activity to responsibly allocate scarce resources to safeguard the UK's built heritage, the challenges of heritage asset management require much greater research attention.

The use of digital technologies is seen to offer benefits to the construction industry to improve these issues and so consideration of how digital, formalised processes might support conservation professionals in the task of heritage asset management offers an avenue of research that offers a significant contribution to the field. Existing research around digital technologies in the heritage domain has considered topics of central repositories, GIS and heritage data thesauri, often used in archaeology or for heritage management more broadly, however research and proposals for the use of digital processes to support information management for CRM planning, or heritage asset management, are limited.

Research that investigates the role BIM can play in digitisation and IM for improved efficiencies in the construction sector, particularly in the O&M phase, shows promise as an area of research that could benefit the heritage sector also, particularly for the planning of CRM. It is demonstrated that BIM processes can facilitate the management of heterogeneous sets of data that are required to identify, prioritise and plan conservation and repair programmes such as; survey, material and constructional analysis, drawings, historic photographs and archival research (Bruno and Fatiguso, 2018; De Luca *et al.,* 2011), yet sufficient examples that consider the full range of benefits and limitations presents a significant gap in the literature.

It was identified that Heritage BIM research beyond the specifics of 3D parametric modelling has focused on potential benefits of the new technology, but with very little evidence to demonstrate these benefits, and no analysis of barriers to implementation or the reported low diffusion. Furthermore, consideration of the wide network of heritage stakeholders who care for and manage heritage assets, issues of digital skills within the heritage sector, and the impact this may have on the implementation of new processes or technology is lacking. This gap in the research offers a specific social perspective to be exploited.

1.6 Research Aims and Objectives

Taking the overall issues of fragmentation and inefficiencies of the construction sector, and proposed digital solutions such as BIM, this research aims to identify the potential of digital information management processes in meeting the needs of conservation professionals in the task of heritage asset management and CRM planning. In a similar plea to that of the great William Morris, Arts and Crafts Movement influencer and contributor, the research appeals for a greater focus on the regular maintenance of digital assets to prevent the ongoing decay of historic building information.

The question that the research seeks to answer is – What are the challenges of heritage asset management and how might digital, formalised processes, such as BIM, support conservation professionals with CRM planning?

In order to answer this research question, it is important to understand the following secondary questions and therefore, the objectives of the research are to answer these:

- How does conservation asset management differ from conventional asset management and what impact does this have on data management?
- How do people engage with formal process and guidance, and why don’t they always follow it?
- What features would Heritage BIM need to have to support conservation professionals with CRM planning?
- What are the specific challenges that conservation professionals face when engaging with information management and digital technology?

1.7 Key research contributions

This research offers a significant contribution to a number of existing research themes:

- Implementation of new processes and technology
- Conservation maintenance strategies
- Heritage asset management
- BIM for O&M
- BIM for FM
- Heritage BIM

It is noted that while the research offers a significant academic contribution to the existing body of knowledge, it also specifically provides an important practitioner contribution principally aimed at those responsible for the management of heritage assets, in particular, those responsible for the planning of CRM programmes.

Key research contributions are summarised as follows:

- Reconfiguring the relationship between BIM and the heritage sector
- Digitisation approaches for heritage asset management - drawing parallels from the wider AEC field
- The heterogeneity of heritage assets
- Translating academic research into practical knowledge and practitioner guidance
- Development of the BIM information delivery cycle for the heritage sector

The relationship between BIM and the heritage sector is reconfigured in this thesis, switching the focus from 3D parametric modelling used most often in relation to conservation intervention, to simple and effective information management using BIM methods to support longer-term asset management and CRM planning which is more accessible to the full range of heritage stakeholders.

A key contribution resulting from the research is the development of the BIM information delivery cycle and presentation of the 4 additional steps of the H-IM Workflow.

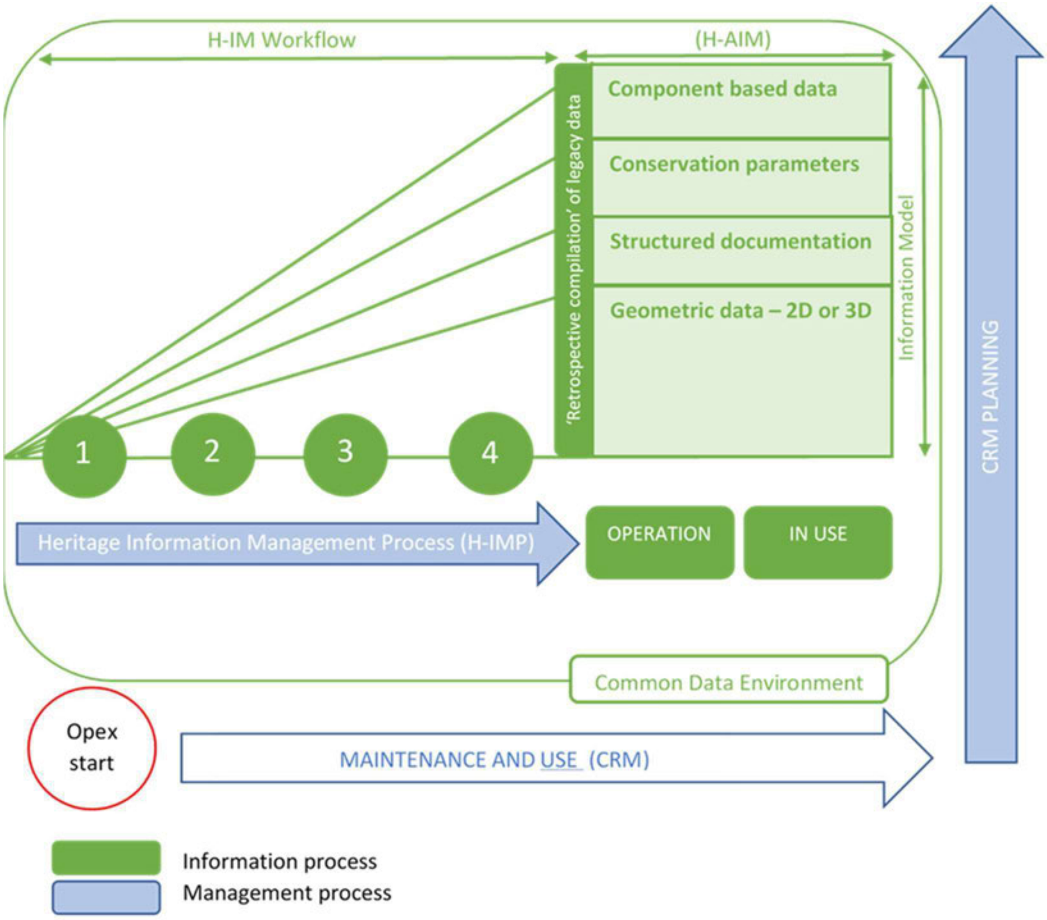


Figure 1.3 The Heritage Information Management (H-IM) Workflow developed by the Author.

The H-IM Workflow offers a significant contribution to the heritage field. It is proposed as an opportunity to implement an industry standard approach to heritage asset management and CRM planning. Further, the H-IM Workflow could be easily adapted for use in the O&M phase of existing buildings, heritage or otherwise, offering a standard approach to asset data management to a much wider audience.

Discussed in the next section, the research offers a significant contribution to knowledge regarding the implementation and adoption of new technology and processes due to the socio-technical networks-oriented method employed. It is noted that where heritage BIM or heritage CRM workflows have been proposed in other research, they rarely consider implementation or adoption and thus, do not provide clear understanding of effectiveness. This research fills this gap.

1.8 Summary of Research Approach

Chapter 4 is provided to explain and justify the research approach taken. Following critical literature review research objectives were developed in response to the research problem and to answer the research question - What are the challenges of heritage asset management and how might digital formalised processes, such as BIM, support conservation professionals with CRM planning?

The question, 'How do people engage with formal process and guidance, and why don't they always follow it?' illustrates a social element to the research that provides a significant contribution to knowledge that is currently missing in related research. A socio-technical networks-oriented method (Schweber and Harty, 2010; Sackey *et al.,* 2015; Miettinen and Paavola, 2014) is used in the research, focusing on 'interactions between social and material entities' (Schweber & Harty, p658, 2010), and offers a shift from research that privileges the technical, to a consideration of the social.

A 'follow the action' method is borrowed from Actor Network Theory (ANT) (Latour, 2005) resulting in a multimethod research approach combining quantitative and qualitative data. Qualitative research methods are described in detail in Chapter 4 and include:

1. Participant Observation
2. Active Participation
3. Interviews
4. Document Analysis

Further, the use of the ANT 'process of translation' (Callon & Law, 1982; Callon, 1986; Shiga, 2006) offers a framework and terminology for critical discussion about how digital, formal processes such as BIM may be applied to the historic environment, and how the new technology may develop and how it will be used or adopted. Through this lens, actors are identified, associations are traced, and the range of negotiations and displacements that take place are considered and are described using the elements of the ANT concept of translation as follows:

- problematisation
- interessement
- enrolment
- mobilisation

The BIM research framework (Succar, 2009) is used to position this research within the BIM domain. The BIM process field is used, with CRM planning for heritage asset management selected as the BIM lens. The research also offers significant contribution to the heritage sector outside of the BIM domain. Here 'process' is used as the overarching lens.

The research approach has been structured by introducing the key organisations that were selected, and a description of how these were chosen. Each research method is described in detail, explaining why it was chosen, how it was used and the data that was gathered.

A number of case studies were completed across the three organisations. The way the various methods were employed across the case studies are described in detail.

1.9 Chapter Overview

This section offers a summary of the thesis chapters, providing the reader a clear navigation through the research. A short summary is provided with 3 key points for each chapter. These points are structured as follows:

- Chapter Objectives
- Chapter Theme
- Chapter Findings / Emerging Question

1.9.1 Chapter 2 – Digitisation for Operation and Maintenance within the Construction Sector

Chapter 2 is the first of two critical literature review chapters that considers current debates and state of knowledge on digitisation within the construction sector.

- Offers a critical review of wider research areas relevant to the PhD.
- Considers digitisation for the wider construction industry and more specifically for O&M.
- Digitisation and digital processes could offer huge benefits for the development of standardised heritage asset management processes, particularly CRM planning.

1.9.2 Chapter 3 – Management of heritage assets in the UK

Chapter 3 is the second of two critical literature review chapters that studies research with a specific value for the field of heritage asset management.

- Offers a critical review of heritage specific research areas relevant to the PhD.
- Considers the conservation of the built historic environment and the potential benefits of digitisation.
- Building information modelling (BIM) information management processes could offer an effective solution for CRM planning and standardised approaches to heritage asset management.

1.9.3 Chapter 4 – Research Approach

This chapter describes the multi-method approach used in this PhD and details the 3 key organisations and case studies used.

- Provides an explanation and justification for the research approach and methodology.
- Describes qualitative methods such as participant observation, active participation, interview and document analysis while providing an explanation of how an Actor Network Theory approach has been applied.
- A socio-technical networks-oriented approach was identified as offering a significant contribution to the research field.

1.9.4 Chapter 5 – Comparing asset management in conventional and heritage contexts

In line with the research question, to understand the challenges of heritage asset management it is first useful to consider the practice of asset management in different contexts.

- Understand how heritage asset management differs from conventional asset management and how this impacts data management.
- Describes how 3 organisations, 2 heritage and 1 non-heritage, undertake asset management
- The question that emerged from these findings is, 'What are the critical information requirements for CRM planning?

1.9.5 Chapter 6 – Establishing critical information requirements for CRM planning

This chapter builds upon the findings of Chapter 5 and considers the information required for CRM planning and asset management programmes, and whether heritage organisations have this information available, and how they use it.

- Define the critical information requirements for heritage asset management
- Describes and analyses 2 layers of data collection to define critical information requirements for CRM planning and propose a set of 'conservation data parameters'
- The chapter opens the question, 'How do people engage with formal process and guidance and, why don't they always follow it?'

1.9.6 Chapter 7 – Implementing the Process

Chapter 7 was developed as a direct result of the question that emerged from Chapter 6. In trying to establish new data management processes during the research case study at Stonington Island, an interesting network of actions followed.

Data from the studies conducted at English Heritage were further analysed to see what additional information presented itself with regards to how people engage with formal processes and guidance.

- Understand how people engage with formal process and guidance, and why they don't always follow it

- Identify the specific challenges that conservation professionals face when engaging with information management and digital technology?

- Data from studies conducted with UKAHT and English heritage are analysed to consider how people engage with asset management processes

- Findings suggest that for processes to be successful, consideration of the people involved, their needs and how they engage with the process is required

1.9.7 Chapter 8 – The Heritage Information Management (H-IM) Workflow

This chapter is explicitly different from data collection chapters; 5, 6 and 7. Instead, as a culmination of the data collection and research a proposed workflow is offered as a solution to the research problem.

As a research output, there are a couple of objectives to this chapter:

- Define the features required for Heritage BIM to support conservation professionals with CRM planning?
- Present a digital, formal process to support conservation professionals with information management for CRM.

Content and findings are as follows:

- Proposed workflows and protocols for Heritage BIM are discussed, with a review against the BIM research framework to allow comparisons to be drawn.
- The proposed Heritage Information Management (H-IM) Workflow is presented which positions this research as an original piece of work, offering significant contribution to the heritage sector and specifically for those involved in CRM planning.

1.9.8 Chapter 9 – Discussion and Conclusion

This chapter provides a detailed discussion of the research findings from each chapter, along with a personal reflection on the PhD journey and the thesis as a whole.

- Presents a detailed discussion of research findings.
- Answers the main research question – What are the challenges of heritage asset management and how might digital, formalised processes, such as BIM, support conservation professionals with CRM planning?
- Offers a reflection on the success in answering the research questions and the approach adopted, noting limitations and including challenges or issues faced.
- The contribution to the body of knowledge along with the research outputs are presented.
- Areas for future research are discussed.
- Concluding final thoughts observe the success of the research and significant contribution it offers to both the academic arena and for practical industry implementation.

2. Digitisation for the Operation and Maintenance of Built Assets

This chapter is one of two critical literature reviews describing key research areas relevant to the PhD. In this first chapter, literature is reviewed regarding the wider construction sector but focuses on key themes considered to offer a context that provides useful knowledge for this research.

The impact of digitisation in the construction sector

A broad overview of the increasing significance of digitisation (Berger, 2017) in the construction sector is reviewed, identifying common problems in the industry and the reported benefits.

Current state of the art – Building Information Modelling (BIM)

The current state of the art illustrates a particular emphasis on BIM and so, this area is explored further. It is noted that research does not always measure the benefits of BIM across the whole building lifecycle (Hautala *et al.,* 2017). The BIM research framework (Succar, 2009) was developed to help provide focus to BIM research and to position it to allow successful analysis.

Operation and maintenance (O&M) management

Using the BIM research framework, this PhD focuses specifically on the O&M phase in the building lifecycle, as this is where asset management takes place.

The benefits and limitations of BIM in the O&M phase

With the research question focused on CRM planning, the operation and maintenance phase, and asset management practice in the wider construction industry, offers an important body of knowledge that provides critical insights for this research. Typical issues are noted, specifically the management of building information in the O&M phase, and research that analyses the benefits and limitations of BIM in the O&M phase are critiqued.

Emerging technology – Digital Twins

Emerging technology, such as Digital Twins, are reviewed as they are proposed to meet some of the limitations of existing digitisation methods. However, having noted that barriers to implementation, slow adoption rates and skills shortages are ongoing and unresolved issues in the BIM field, this research is limited to BIM as a formalised, digital process, whilst explicitly excluding other technologies from the research.

The review considers the current state of knowledge on identified issues, and debates in these areas, and offers insights that are important in understanding how digital, formalised processes, such as BIM, may support conservation professionals with CRM planning.

This first literature review chapter is intentionally shorter, offering some wider context before a more detailed analysis of literature surrounding these themes more specifically within the heritage context. The summary of the literature reviews are combined and provided in Chapter 3, section 3.8, where the future of heritage asset management is considered.

2.1 The Impact of Digitisation in the Construction Sector

Dating back to the 1930's the AEC industry has highlighted a need for change. Matters of cost efficiency, low productivity, poor collaboration, lack of innovation and quality are raised in no less than 88 industry reports (Designing Buildings Wiki, n.d.). Most often cited are the Egan and Latham reports; 'Constructing the Team' (Latham, 1994) and 'Rethinking Construction' (Egan, 1998). As observed by Ashworth (2020), the reports 'paint a picture of an industry ripe for change' (Ashworth, p39, 2020). The construction industry could hugely benefit from innovation, with the opportunity to deliver 'better housing, improved living and working conditions, lower construction costs, effective environmental sustainability and a construction industry that is globally competitive and profitably sound' (Benmansour & Hogg, p680, 2002).

Digitisation is seen to offer the biggest benefits to the industry with some '93% of construction industry players agreeing that digitisation will affect every process' (Berger, p2, 2017). In the same report, Berger (2017) suggests that there is no alternative to digitisation. If construction companies are to see the step change required, they must catch up with other industries that are embracing digital trends such as media and finance that have seen rapid growth as a result of digital technology (Faltinsky & Tokunova, 2018). The construction industry has been considered to be falling behind in the implementation of digital and information technologies (Hautala *et al.,* 2017) with 'negative consequences on productivity and innovation' (Stewart *et al.,* p1, 2002). Faltinsky & Tokunova (2018) suggest that the construction industry has not 'utilised the available potential of digital transformation' as highlighted in statistics that note only 20% of construction projects are not completed on programme, and that 80% exceed budget. The McKinsey Global Industry Digitisation Index was developed to illustrate the level of penetration of digital technology in different economic sectors. As shown in Figure 2.1, except for Agriculture, Construction has seen the lowest penetration of digital technology, with ICT, media and finance having the highest digitisation.

In line with the numerous industry reports, Agarwal *et. al.,* (2016) further report that construction labour productivity in developed countries such as the UK and Germany has 'not kept pace with overall economic productivity' (Figure 2.2).

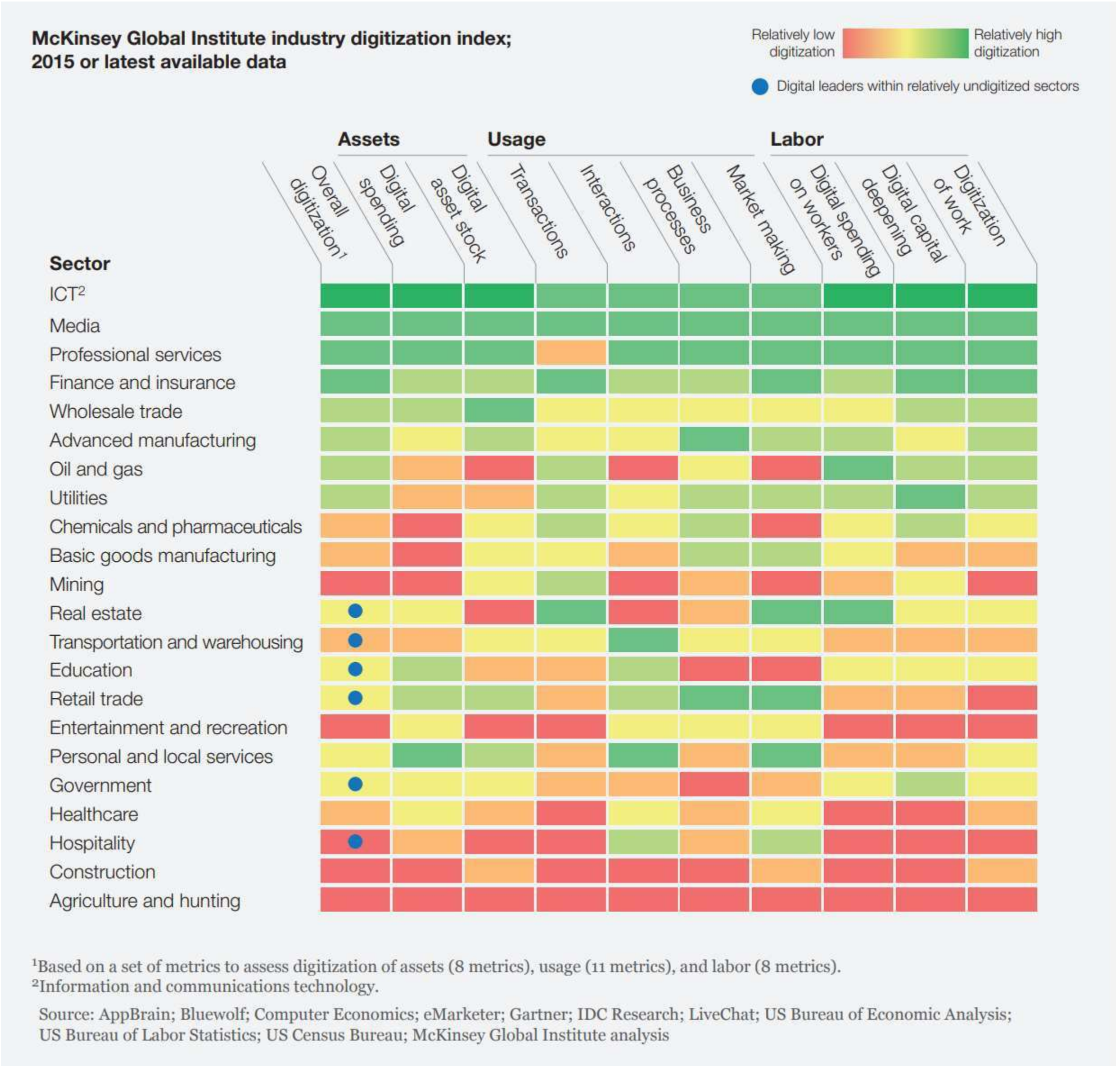


Figure 2.1 McKinsey Global Institute industry digitization index; 2015 or latest available data (Agarwal *et. al., p3,* 2016)

Figure 2.2 Labour productivity, gross value added per hour worked, constant prices (Agarwal *et. al., p3,* 2016)

Reasons for the lack of significant change in the construction sector, despite the acknowledged importance of innovation and digitisation, are discussed in the literature (Dulaimi *et al.*, 2002; Benmansour and Hogg, 2002; Agarwal *et al.,* 2016; Faltinsky & Tokunova, 2018). It is suggested that worldwide research and development investment (R&D) for innovation such as digitisation in the construction sector lags behind other global economic sectors. Dulaimi *et al.* (2002) summarise that reports in the UK (The Egan Report, 1998), Australia (The Building for Growth Report, 1999), Hong Kong (The Construct for Excellence Report, 2001), and Singapore (Construction 21 (C21) Report, 1999) have all recognised a lack of R&D investment to support innovation implementation. It is observed that some of the technological innovations that are implemented in construction come from other sectors, such as innovation in process and manufacturing, including automation in processing. While this has direct advantages for construction, the R&D costs are seldom linked to the construction sector. This results in a lack of financing for innovation in construction (Agarwal *et al*., 2016).

Additionally, the construction sector has been seen to 'experiment in innovation without making a sustained effort to incorporate it within their business' (Benmansour & Hogg, p1, 2002.). Research seeks to 'determine strategies to reduce or remove barriers to innovation', such a view will open up 'opportunities to improve innovation activities' (Benmansour and Hogg, 2002). This theme is discussed elsewhere in the literature where emphasis is placed on the need for strategic plans for the successful implementation of new and innovative information technology (Stewart *et al*., 2002). It is noted that in the construction industry an interest in strategic planning for innovation has only been seen in recent times.

While focused on the construction industry in Singapore, the issue of silo working and segregation of design and construction activities are considered as principle barriers to potential improvements offered by innovation and digitisation (Dulaimi *et al*., 2002). This could be further extended to the activities in operation and maintenance. In a similar vein, Harty (2005) described the complex context of construction, with existing and entrenched ways of working and collaborating complicating the adoption of innovation such as new tools and processes.

2.2 The current state of the art – Building Information Modelling

Despite the barriers and slow adoption discussed above, the literature is acknowledged as somewhat dated. As observed by Hautala et al. (2017), the rate of change is now generally accepted to be accelerating. They further state that digitisation is transforming the construction sector across whole asset lifecycles, from planning, design, construction, assembly, operation, and maintenance.

In recent times, with a significant focus from the wider AEC industry and the UK Government's own strategy for digitisation, Building Information Modelling (BIM) has been considered a necessity to improve collaboration, develop lean processes and increase UK productivity. The UK Government Construction Strategy was published on 31 May 2011 which announced its intention for BIM Level 2, (with all project and asset information, documentation and data being electronic) on its projects by 2016.

Table 2.1 Possible definitions of BIM (Ashworth, p104, 2000)

Source	Suggested definition of BIM
Lee et al, (2006, p758)	"the 'process' of generating and managing building information in an interoperable and reusable way".
Sabol, (2008, p13)	"representation of a building as an integrated database of coordinated, internally consistent, and computable information in design and construction".
Arayici & Aouad, (2010, p. 3)	"the use of ICT technologies to streamline the building lifecycle processes to provide a safer and more productive environment for its occupants, to assert the least possible environmental impact from its existence, and to be more operationally efficient for its owners throughout the building lifecycle".
Azhar, (2011, 242)	"a virtual process that encompasses all aspects, disciplines, and systems of a facility within a single, virtual model, allowing all design team members (owners, architects, engineers, contractors, subcontractors, and suppliers) to collaborate more accurately and efficiently than using traditional processes".
Teicholz et al, (2013, 17)	"describe the three-dimensional geometry, objects, and attributes of a physical facility. The core of BIM is building geometry, but BIM is also a structured information base of nongraphic data that provides detailed information about the building components"
Golabchi et al, (2013, p187)	"BIM is a value creating processes that involves the generation, management and exchange of knowledge of a facility forming a reliable basis for decision making throughout its life cycle from the conceptual, design and construction phases through its operational life and subsequent closure".
NBS, (2016)	"a process for creating and managing information on a construction project across the project lifecycle. One of the key outputs of this process is the Building Information Model, the digital description of every aspect of the built asset".
EU BIM Task Group, (2017, p. 4).	"a digital form of construction and asset operations. It brings together technology, process improvements and digital information to radically improve client and project outcomes and asset operations".
Eastman et al, (2011, xxi)	"a socio-technical system that ultimately involves broad process changes in design, construction and facility management"
Jackson, (2018, p. 7)	observes BIM models are often perceived as a 3D representation of a built asset. The model can be defined as "a digital representation of physical characteristics and functional characteristics of a facility or asset".
BIM Dictionary, (2019)	"a set of technologies, processes and policies enabling multiple stakeholders to collaboratively design, construct and operate a Facility in virtual space. As a term, BIM has grown tremendously over the years and is now the 'current expression of digital innovation' across the construction industry".
ISO, (2019, p5)	"use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions" **Note**: Built assets include, but are not limited to, buildings, bridges, roads, process plants.
Autodesk, (2020)	"a process that begins with the creation of an intelligent 3D model and enables document management, coordination and simulation during the entire lifecycle of a project (plan, design, build, operation and maintenance)".

The principal theme of academic literature that considers digitisation in the construction sector is BIM. In particular, the more intense collaboration between stakeholders and different disciplines offered by centralising and digitising all construction information, across all phases, in one single database. However, while the origins of BIM are traced back to object-based parametric modelling used in the manufacturing industry (Sacks *et al.,* 2018), there is often confusion surrounding the definition of BIM, as illustrated in research by Ashworth (2020) and Table 2.1 above.

Common themes that emerge from the definitions can be summarised as follows:

- Process
- Information
- Digital representation of a building or asset
- Building lifecycle

Of the 4 common themes noted above, digital representation of a building or asset is the one that is less clear. While some definitions state that BIM is an intelligent 3D model-based process, a definition aligned with the parametric modelling origins of BIM, others refer to representation of an asset. It should be considered that BIM concepts and outputs will vary depending on which stage in the building lifecycle BIM is being introduced, and which BIM maturity level is being adopted. A review of the BIM 'maturity levels' justifies this statement. BIM maturity levels were developed to support the gradual adoption of BIM. The transition from analogue working to fully collaborative digitisation will take time but can be measured against the maturity milestones.

Level 0 BIM is referred to as unmanaged CAD. For example, only 2D drawings are used, information is still transferred by paper or electronic files and there is essentially no collaboration. Much of the industry has already advanced beyond Level 0 with at least some collaboration.

Level 1 BIM describes managed CAD in 2D and 3D. Concept designs are often developed in 3D but approval and production drawings remain in 2D. CAD and naming convention standards are used in Level 1 BIM and collaboration is seen through the use of common data environments for digital data sharing.

Level 2 BIM is characterised by full collaboration with all project and asset data and information being electronic, and defined information exchange processes that are specific to the project and are co-ordinated between all stakeholders and systems. In some cases, Level 2 BIM is referred to as a collaborative 3D environment. In relation to the full building lifecycle, it is agreed that design and construction should be managed through 3D discipline models which can be federated to ensure collaboration through all disciplines. However, where the building lifecycle is entered at the operation and maintenance phase (i.e. when applying BIM processes for existing buildings), the concept of 3D discipline models is less relevant as the design and construction phases have already passed.

Level 3 BIM is intended to include a single, collaborative, online, project model including construction sequencing, cost, and life-cycle management information.

Despite the government agenda for the adoption of level 2 BIM across the industry, it is noted in academic research within the BIM domain (Succar, 2009; Barlish & Sullivan, 2012) that both literature and case studies fail to successfully 'analyse and quantify [the] universal benefits' (Barlish & Sullivan, p152, 2012) of BIM. Whilst Barlish & Sullivan (2012) use a case study approach to empirically measure the performance of projects with both BIM and non-BIM application, using return and investment metrics, they acknowledge that BIM success can be affected by a number of internal and external variables that due to their subjective nature, could not be quantified within their research. Furthermore, the research is limited to an owner's perspective and does not consider the benefits realised by Contractors and Designers.

In addition to perspective, it is suggested that benefits claims 'include several mental constructs derived from organisational studies, information systems and regulatory fields' (Succar, p357, 2009). Moreover, with an increasing library of BIM guidance Succar (2009) demonstrates the need for a systematically defined research framework for the BIM domain. This is an important piece of work that analyses the following knowledge areas:

- BIM fields
- BIM stages
- BIM lenses

BIM fields include; technology, process and policy.

BIM Stages are defined as follows:

BIM Stage 1: object-based modelling

BIM Stage 2: model-based collaboration

BIM Stage 3: network-based integration

BIM stages are measured against a number of variables but an important one to consider here is project lifecycle phases, such as design, construction, and operations. It is important to define what variables are being measured when reviewing BIM stages.

Finally, the framework includes BIM lenses which allows to 'selectively focus on any aspect of the AECO industry and generate knowledge views' (Succar, p367, 2009). This framework can be used to position this research and is further discussed in Chapter 4 – Research Approach - where it is noted that the a 'heritage' lens (CRM planning) is used to position the research and its consideration of BIM within both the BIM and heritage fields.

Hautala et al. (2017) review the benefits of collaboration through technology and process using the lens of bridge building across Europe. The use of 'information models' that contain data such as survey and investigative information for early design stages, material specifications, conservation areas and adjacent buildings, unit costs etc, are considered to have benefits in early visualisation and improved accuracy and efficiency in the transfer of information to different stakeholders through the models. Despite the title of the paper the BIM stage demonstrated does not suitably demonstrate the benefits across the whole lifecycle. Benefits are measured against the design and construction phase with the O&M phase missing.

This PhD asks, 'what are the challenges of heritage asset management?', and 'how can digital, formalised processes, such as BIM, support conservation professionals with CRM planning?'. It is therefore useful next to look to wider construction industry research that considers common failings in asset management practice and the potential benefits that BIM offers. First a quick explanation of asset management as an activity with the construction operation and maintenance (O&M) phase is provided.

2.3 Operation and Maintenance (O&M) Management

The operation and maintenance (O&M) stage in the lifecycle of a built asset is the longest stage in which the most cost, resource and energy is placed (Ashworth, 2020). Buildings are valuable assets supporting organisational needs and providing homes, and ensuring they are kept safe, secure and comfortable is a complex issue in the O&M phase, costing around 80% of the whole lifecycle cost' (Lu *et al.*, 2020). In their report, 'An Anatomy of Asset Management' (The Institue of Asset Management, 2015), the Institute of Asset Management suggest that modern society relies on physical assets to function effectively. In the simplest of terms, businesses, educational establishments, healthcare, defence, justice and immigration, and transport organisations could not function without physical assets, buildings, infrastructure and so on. The report further suggests that while a range of apparent variants to the term 'asset management' exist; strategic asset management, property asset management, facilities asset management, and enterprise asset management, at the core asset management remains a process of co-ordinated activity to realise value (ISO 55000).

The terms O&M, facilities management and asset management are seen to go hand in hand. Asset and facilities management being the primary activities in the operation and maintenance phase and including two distinct tasks:

- Planned and preventative maintenance (PPM)
- Asset replacement

Lifecycle asset management is most common in the military and construction sectors and can be defined as the combination of management, financial and engineering practices over the life of a physical asset to provide required levels of service in a cost effective way (Giglio *et al.,* 2018). The management of large-scale assets, large built estates for example, requires organisations to maintain a good state of repair which relies on programmes of preventative maintenance, the timely replacement of assets, and good quality design and construction. Lifecycle asset management principles have been promoted in the private sector (Korpi and Ala-Risku, 2008) to support decision making processes, with Giglio et al. (2018) suggesting that the successful implementation of these principles can be attributed to contractual obligations and financial penalties faced by businesses when service requirements are not met. They suggest that lifecycle asset management is essential for cost effectiveness and long-term economic viability and that to defer maintenance, rather than a proactive or preventative approach, 'significantly increases costs associated with repair or replacement' (Giglio *et al.*, 2018).

They argue that the same principles should be adopted by the public sector, yet suggest there is little incentive for this approach based on a number of factors:

- Political support favours capital investment and the construction of new assets
- Media attention is higher for new construction than it is for maintenance

Despite these suggestions, research that considers the effectiveness of property asset management within Scottish councils (Ngwira *et al.,* 2012) notes a change in practice and motivation for lifecycle asset management. A need for strategic management approaches in the public sector is identified as a result of increasing public expectation and requirement for value for money. Three broad outcomes were used to evaluate the asset management arrangements within 32 councils. Within these outcomes, '*efficient and effective use of property assets'* included a requirement for a reduction in the levels of required maintenance. It is noted that programmes of planned maintenance contribute to efficiencies and reduction in maintenance yet Scottish councils have been unsuccessful in reducing maintenance requirements and costs (Ngwira *et al.*, 2012). The research further noted that similar issues were identified in English public sector organisations and the Scottish school estate, where maintenance backlog was increasing rather than reducing.

Following Lord Carter's (2016) 'Review of Operational Productivity in NHS providers', a focus was placed on NHS England's financial situation and the need for ongoing maintenance of the NHS estate. Strategic approaches such as asset management were identified as necessary for achieving sustainable management of backlog maintenance (Pantzartzis *et al.,* 2016). Through interview it was observed that NHS trusts generally have a clear understanding of the impact on the estate of accumulated critical maintenance backlog, and what they perceive as positive strategies or major difficulties in implementing sustainable maintenance strategies. Analysis of the interview data allowed the researchers to propose 6 balanced actions for sustainable maintenance management (Pantzartzis *et al.*, 2016). Actions such as *knowledge and accountability, appropriate methodology, shared performance metrics and service delivery strategies* all have a common requirement which while not specifically discussed in the research, are critical for success. This requirement is accurate data.

Obtaining maintenance backlog data in the first instance is critical if sustainable maintenance management strategies are to be employed. This might be thought of as data-driven asset management. While this might seem a simple task, research has identified differing definitions of maintenance backlog, when viewed from different perspectives and within different industries (Pantzartzis *et al.,* 2016; Rødseth & Schjølberg, 2017). Maintenance backlog could be considered the amount of planned maintenance not yet complete; this is common in petroleum and energy industries. Alternatively, maintenance backlog might be considered the cost of bringing an asset up from a current condition, to a defined condition level (Rødseth & Schjølberg, 2017). This approach is based on technical assessment and economic or financial analysis often seen in relation to road maintenance (Evdorides, Nyoagbe, & Burrow 2012; Rødseth & Schjølberg, 2017). It is therefore important to define clear strategies to understand data and information requirements. It will be important to refer to this discussion when considering conservation maintenance strategies and heritage asset management (Chapter 3).

From the discussions above it is observed that while asset management and planned and preventative maintenance could provide significant improvements to the O&M phase, there are a few strategy variations that should be considered. Methodology, key performance indicators and definitions should be well defined to establish information requirements.

Furthermore, issues such as silo working should be considered with proposals to mitigate the currently experienced challenge with regards to information sharing for improved maintenance planning (Rødseth and Schjølberg, 2017). Building and estate owners and managers have historically struggled to manage building data and the information required for operation and maintenance due to fragmentation in the AEC industry (Becerik-Gerber *et al.,* 2012; Bosch *et al.,* 2015; McGibbon *et al.,* 2018; Miettinen & Paavola, 2014; Pärn *et al.,* 2017) .

This fragmentation is well reported. Research suggests that data is often handed to building owners upon completion of a project to be uploaded, often manually, to a number of disparate systems – these include;

- computerised maintenance management systems (CMMS)
- computer aided facilities management systems (CAFM)
- electronic document management systems (EDMS)
- building automation or building management systems (BAS or BMS)

In addition to a range of systems, traditional methods for the production of paper-based files (analogue) or digital pdf documents referred to as 'operational documents' (Clayton & Al-qawasmi, 1998), such as O&M files, warranties, certificates, equipment and spare parts lists (East, 2007) can be difficult to manage and can get misplaced or missed by individual project stakeholders. Furthermore, information and documentation in this format does not facilitate efficient analysis, planning and decision making. To be handled manually is a time consuming and inefficient process (Becerik-Gerber *et al.,* 2012; Kassem *et al.*, 2015) and is a leading cause of knowledge loss in the sector (Pärn *et al.,* 2017). The huge amount of data produced during the O&M phase also requires ongoing management. Legacy data held in document archives and tacit knowledge are important sources of information that are not easy to structure or control adding further to the issues of inefficiency and data loss. It has been cited that fragmentation and lack of data due to interoperability between the disparate systems results in an estimated annual cost in the O&M industry of $1.58 billion, '[signifying] the importance of finding an efficient way to collect, access, and update building information' (Gu *et al.,* p1911, 2014).

While discussed in relation to developing owner's information required for 'BIM-enabled' project delivery and asset management, identifying information requirements *and* formalising them into some structure is considered a complex task (Cavka *et al.,* 2017). Issues of fragmentation and data quality are widely discussed but more important is to gain an understanding of what asset management professionals find so difficult about defining their critical information requirements. Asset and facilities management professionals require information based on the task they are undertaking and so this must be an important step when considering the information requirements. In a traditional sense, Cavka *et al.* (2017) suggest that as these tasks and the information requirements are not well-defined at the outset of a project, the information is often found to be missing after project handover. Through a 3 year longitudinal research project involving case studies of two large organisations, Cavka *et al.* (2017) looked to identify and structure critical information requirements for operation and maintenance tasks to improve the quality of handover documentation. Through an iterative approach they investigated data sources and personnel requirements. They considered the scale and scope of information requirements in the specific context of project delivery and asset management, and finally considered these in relation to a building information modelling approach.

Ignoring the project stage and handover of O&M information, a similar approach could be beneficial for structuring existing building information, and the ongoing management of such information. As suggested, a BIM approach to identify information requirements and manage this through a structured information management process could offer significant benefits in any of the building lifecycle phases.

2.4 The benefits of BIM in the O&M phase

A review of literature focused on BIM-enabled asset and facilities management (FM) in the operation and maintenance (O&M) phase (Becerik-Gerber *et al.,* 2012; Bosch *et al.,* 2015; Cavka *et al.,* 2017; Gao & Pishdad-Bozorgi, 2019) provided a useful overview of the perceived benefits of BIM in the O&M phase. These could be categorised into 3 main functionalities:

- Visualisation
- Analysis
- Improved data management

(Kassem *et al.,* 2015; Pärn *et al.,* 2017; Gao & Pishdad-Bozorgi, 2019).

BIM concepts such as component based parametric modelling and the application of data parameters offer benefits in visualisation in the O&M phase. The use of models to locate assets could offer time savings, as could the visualisation of data parameters within the parametric model rather than timely site visits or time spent searching through documents for certain pieces of information.

Visualising information within the model, and the opportunity to produce structured data sets directly from the model could also offer significant benefits when analysing building data for facilities and asset management planning.

However, benefits of improved data management presented by BIM information management processes are of particular interest to this research, especially where BIM is adopted in the O&M phase for existing buildings, and thus excluding the design and construction phase.

When adopting BIM for O&M, the ultimate goal is to develop a digital asset information model (AIM) that offers a single source of validated data to support facilities and asset management activities. Whilst there has been much focus in related research on the 3D modelling aspects of BIM for O&M it can be argued that the AIM is much more critical and so when using the BIM research framework, BIM Stage 2 for model-based collaboration needs to be considered in the widest sense. Within a common data environment, the AIM provides a digital data model of structured information required for facilities and asset management activities which may be developed alongside a 3D model if required. Creating an AIM supports efficient navigation through documents, and individual structured data sets, even in the simplest format such as spreadsheets, can be queried to improve facilities management activities and maintenance planning. In relation to maintenance backlog, digitisation and structured datasets could offer huge benefits in analysis and planning.

Key to the initial creation, and ongoing management of an AIM in the O&M phase is identifying data requirements, and effective data exchange between project stages and stakeholders. COBie is the standard method in the BIM process for exchanging information in a structured format (East, 2007). Using standard Excel spreadsheets, COBie offers standardisation, pulling key building information into one structured format that then allows the information to be transferred between software products such as Autodesk Revit or asset management and CAFM systems. While COBie provides a format for exchanging asset information, it does not specify what information is to be included or who should provide it. Literature has considered the use of COBie as the data handover tool in a BIM for FM or O&M context (Jawadekar and Lavy, 2014) considering benefits and limitations. Three research case studies are used to study the accuracy of data in the data exchange, and the compatibility of the BIM COBie data with the project's computerised maintenance management system (CMMS). Furthermore, interviews with project stakeholders were conducted to understand the benefits of COBie as a data handover tool such as time saving, and to get a detailed account of the accuracy of the exchanged data. Findings demonstrated that the longer-term strategy planning for IM and handover was not considered early enough in the design and construction phase, resulting in the re-creation of data once the building was handed over and, inaccuracies in data that then had to be rectified by maintenance staff.

The technical knowledge and capabilities of stakeholders was a further issue identified through the case studies. Personnel did not have the required knowledge or experience to ensure effective integration of the COBie data with the CMMS (Jawadekar and Lavy, 2014) and therefore in all cases, a consultant was appointed to manage the data handover and the ongoing IM and maintenance. Maintenance staff were not involved in the process and so there were ongoing issues with data accuracy.

The case studies demonstrate a failing in information handover that still results in re-work at the interface between the construction and O&M phase. Moreover, they do not consider data exchange as a result of ongoing maintenance or lifecycle replacement (the key activities undertaken in the O&M phase). Instead, the focus is on the handover of information for FM and asset management activities *following* design and construction. Research conducted by Gu, Ergan, & Akinci (2014) further highlights that the distinction between the construction and O&M phase requires further emphasis on understanding lifecycle BIM in the wider context of existing building stock. The construction industry does not rely purely on new build, design and construction. In the UK, new buildings account for only 1-2% of housing stock year on year and so, there must be much more emphasis on the adoption of BIM for existing buildings in the middle of the O&M phase, and the challenges presented by existing building information.

A look to the ISO19650 information management cycle diagram can help to explain the adoption of BIM information management processes at different stages in the building lifecycle further. The three outer bands illustrate the levels of information management and the quality management system used to control information. At the highest level, the outer band refers to organisational management. Next, specific asset or project management is considered and finally, information management. For each level, organisations should identify their information requirements.

Figure 2.3 ISO19650 information management cycle (BS ISO EN 19650)

In the centre of the diagram the green circle represents the building 'lifecycle' with both the delivery phase and the operation phase illustrated. Throughout this cycle, information is produced and collated. During the process of design and construction this information should be collated in the 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 on-going management of the asset. As stated in BS EN IS0 19650-1:2018 (BSI 2019a), the PIM and AIM are the structured repositories of information needed for making decisions during the whole lifecycle of a built environment asset. The letters, A, B and C in the centre of the diagram indicate points in the building lifecycle when organisations must consider information requirements.

When BIM is adopted in the O&M phase the design and construction phase is ignored. This means there is no development of a project information model. The focus of BIM adopted in the O&M phase is therefore based around the development of an asset information model. It could be suggested that in such cases an additional letter (D) should be added to the diagram as building owners will need to consider information requirements in the middle of the operational phase, rather than at the intersection between the delivery and operation phases.

Research that has considered this focuses on the development of 'as-is' building information models from heterogeneous existing information (Gu *et al.*, 2014). Key to their research, particularly considering the theme of this research, is that they intentionally ignore research that seeks to capture geometric and spatial data of existing buildings, using technologies such as laser scanning, in favour of two case studies that sought to create as-built information models for two legacy buildings, using existing data sources. Moreover, the information model is created in the middle of the O&M phase rather than post-delivery phase. The cases are extremely useful in understanding issues with legacy data; format, accuracy, cross over etc. However, the goal of the research was still to produce an intelligent 3D model and compare how the collated information compared to COBie requirements, rather than considering the information management during the O&M phase.

2.5 Limitations of BIM in the O&M Phase

The cases above identified a need for maintenance professionals to be involved in the process of integrating COBie data with CMMS or CAFM systems but didn't pay particular attention to identifying these information requirements. Ahn & Cha (2014) undertook on-site survey and interview with members of building maintenance teams and analysed maintenance works programmes to try and establish information requirements however, the focus was on building this information into a 3D parametric model rather than focusing on the foundations of creating organisational, asset and exchange information requirements (OIR, AIR and EIR). On the other hand, Cavka *et al.* (2017) have attempted to develop a conceptual framework for the analysis of BIM requirements and identification of OIR. Their aim was to help owners think about the information requirements for BIM-enabled asset and project management, as the area seen as offering the most value for BIM in O&M. They note that there are increasing reports of large owner occupiers, such as universities, that provide project teams with guidelines and required deliverables for the physical asset, but to provide the requirements for the digital data has proved more challenging due to the analogue nature of building documentation. Turning this information into a computable format and with sufficient detail, rather than generalised owner requirements (Mayo & Issa, 2014) was the focus of their longitudinal research project.

Despite the potentially disruptive impact of BIM on the AEC sector Berger (2017) notes there are still hurdles to cross. He categorised these as follows:

- Training
- Standards
- Governance

Further, Lu *et al.,* (2020) have considered specific limitations of BIM in the O&M phase. In addition to issues of identifying critical information requirements mentioned above, they note limitations that fall under four perspectives:

- Technology
- Information
- Organisation
- Standard

Although widely acknowledged that the future is digital, the problem lies with slow and hesitant implementation. In response to the slow rate of adoption The UK BIM Alliance launched the *Back to BIM Basics* initiative towards the end of 2020. The aim is to provide a series of educational videos, webinars and conferences to educate and inform the sector of the basic BIM principles and the benefits they offer to the industry. Instead of focusing on 3D parametric modelling, COBie and the complicated array of acronyms that flood the BIM playing field, such as BEP, OIR, AIR, EIR, IMP and IFC for example, the objective is to shine a light on BIM at its simplest – that it is a process for defining, creating, and delivering structured data and documents for the lifecyle of a built asset. The industry needs to realise that BIM is not reserved for specialists or experts, is not just about the design and construction process and does not have to be a costly exercise that results in little benefit in relation to the initial outlay. The emphasis of the initiative is that *any* step towards a BIM process, whether it be becoming aware, developing a strategy, formalising the use of digital, considering team and organisational structures, or developing standards, is a step in the direction of moving from analogue to digital.

Given the slow pace at which BIM is being adopted by the industry, particularly in the O&M phase, it is somewhat surprising that newer emerging technologies are being considered to fill the void left by BIM in the O&M phase, particularly when the sector is still grappling with BIM technology and process. Statements suggesting the rising adoption of BIM for asset management (Lu *et al.*, 2020) have been shown to be unsubstantiated, and research case studies illustrate that the information richness and analytical capability of BIM is not always enough to support facilities and asset management. BIM 'lacks the functionality of assessing and forecasting the state of the built environment in real-time' (Stojanovic *et al.*, 2018). In their research Stojanovic *et al.* (2018) discuss that production of 'as-is' BIM data for O&M is a labour intensive process and needs to be constantly updated to give current information. It is possible that this is a further reason for the slow adoption in the O&M phase.

2.6 Emerging technology – Digital Twins

Digital twins are proposed as an emerging technology that can develop the limitations of BIM. These digital representations of a physical object, a building/buildings/or cities in a construction sense, integrate artificial intelligence, machine learning methods and data analytics to improve FM tasks.

Through a thorough literature review of BIM-enabled asset management research, (Lu *et al.*, 2020) provided a 'comprehensive summary of limitations and gaps in current research and standards for achieving smart asset management in the O&M phase' (Lu *et al.*, 2020). Note the addition of the term 'smart'. Identifying that producing, managing and updating 'as-is' information is a labour intensive, manual task that leads to in-efficiencies, error and in-accurate data, smart asset management seeks to use technology to automate these processes where possible. Their proposed framework for digital twin (DT) enabled asset management takes advantage of DTs ability to integrate various data sources and is proposed based on 4 main requirements;

- *Intelligence –*
  a shift from traditional manual and labour-intensive asset management to more active and automated approaches (e.g. automatic monitoring process, data driven approaches and knowledge-led methods).

- *Efficiency –*
  the ability to manage assets in the O&M phase using effective ways with fewer resources required (e.g. time, cost, FM professionals and computational cost).

- *Integration –*
  addresses that all assets (including data, technology and models) can be compatible, integrated and further collaborative.

- *Interoperability –*
  describes how DT-enabled asset management can coherently deal with various activities and seamlessly co-operate with other systems/people.

(Lu *et al*., 2020)

A key benefit of BIM for FM or O&M is the opportunity to 'centralise access to digital documentation for stakeholders' (Stojanovic *et al.*, 2018), and processes for data management and sharing. However, unless this information is updated it provides no benefit. BIM information management processes can improve information management roles and responsibilities offering significant opportunity to improve O&M process and the accuracy of 'as-is' data but digital twins offer the potential to automate these processes through the use of point cloud data and machine learning, therefore offering centralised access to the *current* operational state of a building (Stojanovic *et al.*, 2018).

Emerging technologies such as Digital Twins have been considered in the literature review as they are an ongoing area of research that cannot be ignored. In relation to the heritage lens of this research, and digitisation for CRM planning, digital twins have been ignored given the ongoing barriers to implementation and adoption of BIM methodologies. They are considered an area for future research.

3. Management of heritage assets in the UK

This chapter is the second critical literature review describing key research areas relevant to the PhD. Following the review of current trends in digitisation, particularly BIM, in the operation and maintenance phase of the wider construction sector, this chapter focuses on literature more specifically related to the heritage field, and the management of heritage assets in the UK.

To help answer the research question, this second critical literature review is required to offer a deeper understanding of the heritage field. In addition to common research themes shared with Chapter 2, such as digitisation, information management and the benefits of BIM, this chapter provides analysis of conservation and protection of the built historic environment and the heritage asset management activity of conservation repair and maintenance (CRM).

Unlike Chapter 2, due to the wider review, each of the key areas discussed has been sub-divided to provide the reader with a clear journey through the literature and demonstrate the reasoning for each subsequent theme.

The key areas reviewed and considered to offer useful knowledge for this research are as follows:

- Heritage conservation repair and maintenance (CRM)
- Information management in the heritage sector
- Digitisation in the heritage sector
- Defining Heritage BIM
- Implementing digitisation in the heritage sector
  (including sub sections – stakeholders, skills and funding)
- The future of heritage asset management

Closely aligning with the structure of Chapter 2, an introduction to the heritage asset management activity of CRM is discussed through a review of literature. O&M in a heritage context has some differences to the traditional O&M construction phase. For example, the emphasis is more on asset management, conservation repair and maintenance (CRM) of historic building fabric, structural monitoring, building fabric degradation and so on, as opposed to traditional FM that is very much focused on the operational performance of a building and its associated plant. Heritage assets are often ‘attractions’ supported by ‘operational’ buildings and so the FM and asset management requirements differ.

Key themes identified through the literature are used to structure the section on heritage CRM as follows:

- Strategic management
- Financial management
- Information management

As in Chapter 2, where operation and maintenance management is discussed, and includes the challenges of managing building information in the O&M phase, a critical literature review on the subject of information management in the heritage sector is provided. The literature highlights the importance of accurate and reliable information to inform planning and the correct use of funds, noting information management as a key factor in the effectiveness of heritage CRM. Moreover, these activities are identified as a key challenge within the heritage sector and so justifies this field as one requiring further research.

While Chapter 2 had begun with a literature review on the impact of digitisation in the construction sector and the current state of the art with regards to BIM, these discussions are added to this chapter once the heritage sector itself, CRM processes and information management specifically within the heritage sector have been discussed. This sets the scene of the heritage asset management context before considering the impact of digitisation specifically for heritage and CRM activities.

Innovation and engagement with digital technology in the heritage sector is a developing field and so, critical literature review in this arena is extremely useful. The common link between all innovation with digital technology in the heritage sector is that all aim to improve digital data management. While the purposes of digital data management may vary, for public consumption, museum archiving etc, it is noted that for heritage management, or CRM more specifically, BIM could offer solutions to the highlighted issues of information management and improve efficiencies in CRM planning. Literature that focuses on the use of BIM in a heritage context is analysed to help provide some definitions of ‘Heritage BIM’.

In Chapter 2 some limitations of BIM and barriers to implementation and adoption of BIM were discussed. With this literature in mind, section 3.6 expands on this reading to analyse the implementation of digitisation in the heritage sector. From the literature review a number of themes were identified that may have a particular effect on such implementation. These are summarised as follows and are used to structure the discussion within section 3.6:

- Stakeholders
- Skills and attitudes towards digital technology in the heritage sector
- Funding and resource

Finally, section 3.7 considers the future of heritage asset management using a summary of the literature from both Chapters 2 and 3.

3.1 Heritage conservation repair and maintenance

This section has been divided into 4 areas. First, the activity of preventative conservation repair and maintenance is considered as the primary asset management activity in the O&M phase of heritage assets. Next, key themes affecting successful maintenance management in a heritage context are illustrated:

- Strategic management
- Financial management
- Information management

3.1.1 Preventative conservation repair and maintenance

Preventative conservation repair and maintenance (CRM) has been well understood as the most suitable and sustainable way of protecting heritage assets for centuries (Dann & Cantell, 2008). These concepts are well embedded within international building conservation legislative frameworks and charters (The Venice Charter 1964; Feilden, 1982; Earl, 2003; Forster and Kayan, 2009; Meul & Stulens, 2010; The Burra Charter, 2013; The Charter of Krakow, 2000).

Despite conservation legislation that offers a framework for conservation best practice, it is acknowledged that heritage conservation activity has not always followed such frameworks, and so the importance of governance, and mechanisms such as Listed Building and Scheduled Monument Consent, is extremely important. Conservation action in its widest sense is more complex than simple or strict preservation, instead part of a broader vehicle for regeneration and economic development (Delafons, 2005). The integration of the conservation of the historic environment with environmental concerns and sustainability are key issues that must be further considered in the development of conservation philosophy and practice and subsequent conservation action. A commentary on the changing role of heritage conservation observes a need for conservation 'to be interrelated more systematically with other physical, economic and social regeneration programmes' (Strange & Whitney, 2003).

For the purposes of this research, whilst heritage conservation has been acknowledged in the widest sense, further discussion is limited to preservation through planned and preventative conservation repair and maintenance, as an activity of heritage asset management.

It has been reported in research that best practice maintenance systems, industry guidance and common structured processes for heritage CRM are lacking (Forsyth, 2007; Dann and Wood, 2004; McGibbon *et al.*, 2018), and when implemented, success is variable (Forster & Kayan, 2009). Research has explored how organisations approach and manage the maintenance of heritage assets and undertaken analysis to consider why the practical implementation of preventative conservation and maintenance theory is failing.

Research undertaken by Dann *et al.* (2007) considered that whilst non-heritage organisations have adopted aspects of best practice, and heritage organisations are becoming increasingly aware of preventative maintenance, 'there is a need for a step change to ensure that the retention of cultural significance and minimal intervention set the context for maintenance management strategies and implementation' (Dann *et al.,* p97, 2007). Following a comprehensive review of literature and subsequent analysis, a framework of key themes for conservation maintenance best practice were identified and tensions and omissions were highlighted (Dann and Wood, 2004). Maintenance management areas were identified as follows:

- Corporate objectives and maintenance strategy/policy management
- Management processes, conservation plans and management plans
- Programmes and prioritization
- Condition surveys, inspections and stock data
- Information management
- Financial management and performance measurement

3.1.2 Strategic Management

In Chapter 2, section 2.3, lifecycle asset management was discussed, noting the importance of strategic maintenance management approaches (Ngwira *et al.,* 2012). It was suggested that understanding maintenance backlog data and the organisation's defined maintenance strategy are key to effectiveness. A postal survey and semi-structured interviews were used to gain knowledge on existing maintenance practices in both heritage and non-heritage organisations which revealed that there is a lack of strategic framework for maintenance within heritage organisations meaning there is no coherent way to evaluate the effectiveness of maintenance activity, and that financial resources are not effectively targeted (Dann *et al*., 2007).

The wide range of industry bodies, organisations and suppliers involved in the heritage sector, and resultant silo working, have made it difficult for a clear and consistent lead in process and practice in the industry (McGibbon *et al.*, 2018). Furthermore, there was a lack of evidence that surveys and inspections conducted as part of heritage management programmes adequately considered issues of significance and vulnerability of historic assets and building fabric. Cultural significance considers the aesthetic, historic, scientific or social value of an asset, for past, present or future generations and is a key concept in modern conservation practice (The Burra Charter, 2013). A full appreciation of this concept allows the conservation practitioner to make judgement of the value of places and therefore provides an aide in the process of deciding the best course of action when conserving fabric in an historic building. Heritage assets may of course have a range of values, and a subjective judgement by the parties involved with the project should be made in each case (Worthing & Bond, 2008, p.71), or frameworks developed.

The English Heritage document, Conservation Principles (2008) asks that 'the effects on authenticity and integrity' (English Heritage, 2008, p.45) are considered. It suggests that not only the fabric is of value but, design and function too, therefore allowing flexibility in conservation approaches, as long as whatever is proposed is justified. As it suggests, 'retaining the authenticity of a place is not always achieved by retaining as much of the existing fabric as is technically possible'. (English Heritage, 2008, p.45). Without evaluation of these key concepts of conservation philosophy within survey and inspection processes, the protection of cultural significance is not suitably considered within maintenance practice, meaning organisations are falling short of best practice.

In addition to lacking strategic approaches in maintenance practice, the construction industry as a whole is seen to lag behind in innovation, with limited resource for R&D and slow adoption of new technology and approaches (Dulaimi *et al.*, 2002). Strategic planning for innovation is required if the industry is to see innovation become embedded in practice and to experience the benefits. The same can be said for the heritage industry and strategic planning for innovation should be embedded into wider heritage asset management strategies.

3.1.3 Financial Management

Financial management was identified as another key area of maintenance management in which heritage organisations were falling short of best practice (Dann *et al.*, 2007). Whilst some organisations were fairly certain of budgets for shorter term programmes of maintenance, most had no certainty over funding for longer term projects. The unique nature of heritage assets, often uninhabited, roofless or ruined means the impacts of external factors and exposure to the elements have an adverse effect on the expected lifespan of building elements which needs to be taken into consideration when considering the cost of maintaining them. Furthermore, standard repair or replacement is not an option for heritage assets. Instead, careful conservation repair and preventative maintenance using correct materials and traditional techniques is required (Macek *et al.*, 2019). A recent report in the Insurance Times noted that increased costs of traditional building materials such as stone, hardwood and handmade bricks has pushed up the cost of conservation repair and maintenance by 3.4% (Ruel, 2019). The high cost of maintaining heritage assets is considered a universal issue (Forster & Kayan, 2009) with the expense of maintenance putting heritage assets at risk.

Research has demonstrated that the cost of regular preventative maintenance compared to the cost of occasional restoration projects after years of neglect is a more economical option (Kutasi & Vidovszky, 2010) yet, unlike other European countries, funding for maintenance grants is not commonplace in the UK. Incentives such as maintenance grants, rate rebates and subsidised buildings inspections offered by organisations such as Monumentenwacht in the Netherlands, Bygningsbevaring in Denmark, BAUDID (Bundesarbeitsgemeinschaft unab-hängiger Denkmal- und Altbauinspektionsdienste) in Germany and MAMEG (Maintainer Network of Hungarian Monument and Building Foundation) in Hungary were trialled through a pilot study in the UK. Despite the benefits seen in other European countries, 'Maintain our Heritage' did not catch on in the UK, further illustrating a culture that does not value maintenance of heritage assets as a priority (Kutasi & Vidovszky, 2010; Dann & Wood, 2004; Forster & Kayan, 2009).

3.1.4 Information Management

Fragmentation of building information is often discussed as a typical problem associated with the wider architecture, construction and engineering (AEC) industry (Chapter 2, section 2.3), as well as the heritage sector more specifically, (Miettinen & Paavola, 2014; Ciribini *et al.,* 2015; Pärn *et al.,* 2017; McGibbon *et al.,* 2018; Bruno & Fatiguso, 2018), resulting in in-efficiencies and poor quality. 'The effectiveness of asset management in the O&M phase will heavily rely on continuous information on asset condition' (Lu *et al.*, 2020), performances, specifications and documented historical change, repair and maintenance. Structured information, dedicated communication channels and process are necessary for optimum effectiveness.

From a heritage perspective, multi-disciplinary teamwork within the sector, and across a building's lifecycle, have resulted in 'severe problems related to data acquisition and management' (Parato *et al.*, 2011). Collaboration between stakeholders and the introduction of information technology could be the answer to improving efficiency (Maxwell, 2017).

Owing to the significant impact that information management has on effective O&M, and to answer the research question asking what the challenges of heritage asset management are, the next section is dedicated to the subject of information management in the heritage sector.

3.2 Information Management in the Heritage Sector

Issues of fragmentation as noted above are shown to be a global issue across the entire AEC industry, including the heritage sector. It has been stated that the field of heritage management more broadly is data rich, but information poor (Gardner & Whitehead, 2003). That is, there are lots of facts and details in the form of text, images, number, sound or video but, it is very often unstructured, without context and not in a format that makes it useful information for heritage management. For heritage maintenance management more specifically, it has been historically reported that information management, record keeping and integrated databases are themes requiring further development (Major, 1999; Dann and Wood, 2004), yet research suggests that today information is still too often largely textual, paper based, dispersed, in-accessible and unstructured resulting in ineffective collaboration, duplication of work and poor management (Simeone *et al.,* 2018; Jordan-Palomar *et al.,* 2018).

It is clear from the published literature that the development of heritage management systems using computer technology and guiding principles deserves greater attention in order to examine the potential for recent digital technologies to improve heritage data management. In 2002 a Getty Conservation Institute group of experts known as RecorDIM (Recording, Documentation and Information Management Initiative) identified a number of issues that required principles and guidelines to be published. In the resulting publication, Letellier (2011) suggests that the recording, documenting and management of historic building information is the basis for monitoring, management and maintenance of a heritage asset and therefore, solutions to these issues should be sought. It is noted that conservation should be based upon informed decisions and that documentation and recording tools can provide the information required to make these decisions (Letellier *et al.,* 2011). The publication identified twelve guiding principles for the recording, documenting and management of historic building information. These can be reviewed in the publication but a summary is provided below:

- Heritage information is required to understand heritage assets in order to promote interest and inform management and long-term maintenance and conservation.
- It should be gathered when compiling inventories or creating a heritage information system, when critical decisions are made, when historical evidence is revealed and when changes are made as a result of conservation work.
- Heritage information should be kept in a central repository.
- Legacy data should first be reviewed before new records are prepared.
- Heritage information should include metric, quantitative and qualitative information including; values, significance, condition and risks.
- Standard formats and unique identifiers should be used to aide retrieval of data.

While the publication provides a number of exemplar cases of documentation and recording, it does not prescribe any particular method. Instead it is suggested that the guiding principles as summarised above should be followed.

When considering methods for capturing as-built information for operation and maintenance functions from existing data sources, as would be the case with heritage buildings, Gu *et al.* (2014) note the unique challenge presented. Information may be duplicated in numerous data sources or may overlap across different documents. Furthermore, multiple data values such as condition record or maintenance certification for the same information may be collected over time resulting in issues of data reliability (Gu *et al.,* 2014). Their research considered the available existing information for operation and maintenance from two case studies and compared it to information required to generate building information models specified by Industry Foundation Classes (IFC) and COBie. Unfortunately, the primary focus of the paper is on the ability to create an as-built BIM model from existing data sources and to compare the existing information to the requirements outlined by IFC and COBie rather than considering how the central repository of building information might be developed for the heritage industry or, defining standard format and processes for information storage, retrieval and analysis.

Heritage data management systems often focus on delivering information to an expanding range of stakeholders all who have very different needs, the primary function being; information sharing and dissemination. As noted, the heritage sector is broad and as such the numerous stakeholders play many roles and require a varied range of information and data. To provide such a range of data is often beyond the capability of the system (Gardner & Whitehead, 2003). Furthermore, these systems are often accessed, used and contributed to by a variety of stakeholders and organisations, each with their own ways of organising data (Heras *et al*., 2012). Where the centralised hub of data is to be used as a single source of dissemination for research purposes, it can be a useful tool. A collection of maps, plans, photos and all manner of other archive material in one place makes the life of the researcher far simpler. However, the way information is organised is still a concern offering no improvement to the way information is retrieved. Furthermore, a system that does not seek to prejudice one data source over another, therefore providing a whole plethora of information that is not specifically structured, can add to the problem of finding the data required to carry out a particular task. Despite heritage data management being an essential task to support the use and dissemination of information (Letellier, 2007; Heras *et al*., 2012), heritage management demands a multi-disciplinary knowledge base (Fai *et al*., 2011) which inherently presents some challenges when trying to manage, integrate and disseminate the wide range of data produced and consumed by the sector meaning there is no 'one size fits all' approach.

To provide some consistency and structure a number of systems have been developed using heritage standards and thesauri (FISH). Several papers have discussed standards such as the Dublin Core (Kakali *et al*., 2007) Cidoc and the UK standard; MIDAS Heritage (MIDAS Heritage v1.1 (2012), 2012) along with the London Charter (Denard, 2009; Denard, 2012; Gea *et al*., 2013), The Seville Charter and the ICOMOS Sofia Principles 1996 (Stylianidis and Remondino, 2016). However, there is no standard approach or rather, methods of standardisation for heritage data management are not being consistently used for the digital data management of the historic built environment or, for conservation, maintenance and facilities management of historic sites. It is understood that the wide range of data and uses is a barrier to the development of a single solution however, it is not clear why a standard approach for digital data management for heritage CRM is yet to be developed.

3.3 Digitisation in the heritage sector

3.3.1 Innovation and engagement with digital technology in the heritage sector

Innovation and engagement with digital technology in the heritage sector, particularly archaeology, dates back as far as the 1950's and in general has followed 3 particular topics of study:

- Computer Aided Drafting (CAD)
- Geographic Information Systems (GIS)
- Digital data (storage, retrieval, analysis and modelling)

(Watrall, 2019)

While these topics have remained constant in the literature, each has seen development in more recent years with the introduction of even newer technologies and increased integration and interoperability leading to a rise in the number of digital projects taking place across a range of heritage settings (King *et al.,* 2016). In their research King et al. (2016) aim to learn lessons from both successful and less successful digital projects, an area that they consider to often be overlooked in critical literature (Champion, 2008) in (Kalay *et al.*, 2008). In considering how digital technology and processes might support conservation professionals, this critical review of digital application in the heritage sector is crucial.

As noted in section 2.1, digitisation in the construction sector is often a result of experimentation with innovation without significant attempts to embed this into practice. However, as described below, it is not true that all innovation has not been well embedded. CAD and GIS are both innovations that have been extremely successful, especially in a heritage context.

CAD

Computer aided drafting (CAD) as an application of digital technology in the heritage sector has seen much development, particularly as a basis to 'virtual heritage', defined by Champion (2008) as the recreation of the past through 3D modelling, and subsequently virtual reality (VR) and augmented reality (AR) applications (Arayici, 2008). Going beyond the well embedded use of CAD for 2D drawings used as architectural records and across all construction phases, digital documentation and visualisation of heritage assets in this way has been fuelled by technological developments in 3D data capture such as photogrammetry and laser scanning over the past few years (Hull & Ewart, 2020) which has made 3D modelling processes much easier. Champion (2008) suggested that the re-creation of heritage assets in the digital world should not be simply about reconstructing the appearance but should also convey the meaning and significance of heritage artefacts and assets. He suggests that it is often claimed that virtual heritage environments lack meaningful content and considers what this meaningful content should be. The evaluation is considered from a user-experience point of view and specifically about how users engage with the virtual environment. It considers ways to layer interpretations so that cultural heritage is fully understood as a projection of a shared idea of reality, and suggests the use of 'new media', defined by Champion (2008), as user-centred, personalised data that is not constrained by one type of hardware device to achieve this. Similarly, King *et al.* (2016), note research that has centred around engagement activities that complement physical visits and add meaningful content to virtual heritage environments, such as user generated content and online communities. Historic England adopted ideas of user generated content when they launched their 'Enriching the List' project which allowed users to create their own online account and add contributions such as photographs, information and stories about the heritage assets that are registered on the National List for England, albeit this was not in a 3D virtual environment.

As an application of digital technology in the heritage sector, there are numerous exemplars of 3D virtual reconstructions used to document heritage assets (Historic England, 2017; Watrall, 2019) and the range of benefits in visualisation, structural and condition monitoring, education and research for conservation practice is becoming well understood. CyArk and the Rae Project (Scottish Ten) have developed an archive of digital models of historic sites that are available via Google's Open Heritage. This digital documentation offers a number of benefits in education and research, outreach and engagement, and post-disaster conservation and conservation monitoring. The use of 'new media' may be beneficial to these applications but it is important to consider the meaningful content from a wider range of perspectives and for more task-based activities. For example, if semantically-enriched 3D building information models could support conservation professionals (M. Murphy *et al.*, 2017) for specific tasks in conservation repair and maintenance activity, would the meaningful content be the same and would 'new media' meet the requirement?

GIS

Following the development and widespread use of CAD in the archaeology and heritage sector, the ability to create detailed maps and illustrations on 'desktop computers facilitated the spread and adoption of geographic information systems (GIS)' (Watrall, p348, 2019) which can be considered one of the most important applications in digital archaeology. Of note is the 'standards based framework 'for sharing spatial archaeological data, maps, and tables' (Watrall, p348, 2019) provided by GIS. This success and the potential of GIS to handle and process large amounts of heritage information at different scales has led to experimentation in the use of GIS for heritage information management systems (Berg, 2007; Heras *et al*., 2012; Saygi *et al*., 2013; Tracey *et al.,* 2016). Heras *et al.* (2012) discuss a summary of reports from the International Symposium on Heritage Recording & Information Management in the Digital Age (SMARTDoc Heritage) held in Philadelphia, USA, in 2010, which identified that most GIS projects in the heritage field tend to be based on large scale data for archaeological monitoring or landscape applications, rather than smaller scale data management for individual building and building elements. Databases have seen development for the storage of heritage information, such as MAKSin, developed by Monumentenwacht a non-governmental institution in Belgium (Meul and Stulens, 2010) but, these have not yet been developed for the processing and analysis of data (Heras *et al.*, 2012). The aim of the research is to develop a Heritage Information System (HIS) capable of handling large amounts of heritage data which may then be processed at different scales. The research follows a use-based approach rather than data or software driven. This is an important approach mirrored in my own research. Importantly, the research notes that 'the choice of database system was constrained by the type of databases currently used in the institutions dealing with and managing heritage information, the type and nature of the data [which varied considerably within the same institution], the knowledge and capacity level of personnel, and the technical problems most institutions face' (Heras *et al*., p56, 2012).

Heritage information management systems are commonly developed for research purposes or to maintain historic asset registers and historic environment records. Such systems provide a central repository of data about a heritage asset, often using a combination of geo-spatial information (GIS) technology and structured query language (SQL) database, to which historic building documentation and media can be added. Such examples are used by Historic England or, the national systems for cultural heritage management in Norway; "Askeladden" and "Kulturminnesok" (Berg, 2012). GIS approaches are discussed in a number of papers, (Vileikis *et al.*, 2012; Foietta no date; Kokalj *et al.*, 2007; Brizzi, 2005) , in which GIS is referred to as a repository of structured data that allows users to view and retrieve data that has been geo-located. In other words, layers of data can be gathered and managed and, visualised and analysed using maps. Many local authorities manage their heritage data in a similar fashion, allowing users to access maps and retrieve information about listed buildings and conservation areas. These heterogeneous sets of data about an historic asset can provide invaluable information to help understand a monument or site, its history and significance. Access is commonly available via open-source software (Open Heritage, HEROS, Arches).

While both experimentation and developments with CAD and GIS are providing benefits to the heritage sector in a number of ways, neither yet offer a solution for the digitisation of heritage asset management. That is, neither offer a complete solution for the storage, modelling, retrieval and analysis of heritage data required in the process of CRM planning.

3.3.2 Digital Data Management- BIM and Digital Twins

The common theme that links development and experimentation of digital technology, such as CAD and GIS in the heritage sector is digitisation of data. If we think about museums as a portion of the heritage sector, their main aim is to digitise their collections; documents, images, photographs of artefacts for example, and make them publicly accessible. This could be expanded into the different heritage stakeholders and their requirements. Of course in all cases, digitisation is aimed at the regular maintenance of data. Digitisation in heritage could be categorised as follows:

- Data digitisation for public consumption
- Data digitisation for outreach and engagement
- Data digitisation for heritage management

The latter is a broad theme that for the purposes of this research, and to answer the specific research question, has been narrowed down to data digitisation for heritage asset management – this particularly focusses on the conservation, repair and maintenance programmes that are developed for the management of heritage assets.

Digital methods such as BIM - 'a new approach to design, construction and facilities management, in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format' (Sacks *et al.*, 2018) have been suggested to provide benefits in *visualisation, analysis and improved data management* (Kassem *et al.,* 2015; Pärn *et al.,* 2017; Gao & Pishdad-Bozorgi, 2019) that could benefit the O&M phase and potentially, heritage asset management. With the widespread use of GIS in the heritage sector, but noted limitations surrounding the management of information at a 'building' level, the roles of BIM and GIS are often discussed together (Zhang *et al.*, 2009; Osello & Rinaudo, 2016; Vileikis *et al.*, 2012).

It was suggested that the ability to retrieve and analyse building information in a 3D environment could be of significant benefit, particularly with the possibility of locating building components more efficiently. Additionally, the potential to access data through a single, unified graphical interface could offer further efficiencies. An example in which building components within the 3D model are linked to building information and documentation from and electronic data management system (EDMS) and works orders and asset information from a computer aided facilities management (CAFM) system (Becerik-Gerber *et al.*, 2012) shows great promise and would certainly provide benefit to the industry.

Building information is inherently fragmented and so the paradigm shift in the way this information is managed (Pärn *et al.*, 2017) using BIM to co-ordinate consistent, computable building information throughout the building lifecycle (Becerik-Gerber *et al.*, 2012) is of great interest. BIM information management principles such as the development of an Information Delivery Plan (IDP), Organisational and Asset Information requirements (OIR and AIR) and the Asset Information Model (AIM), offer benefits and efficiencies to information management in the O&M phase that require greater attention in the research. Clearly, these functionalities and processes would be equally beneficial in the heritage sector for asset management and conservation repair and maintenance (CRM) planning.

Further, in addition to assessment of BIM benefits, limitations should be considered. As noted above, issues surrounding data richness and analysis of data using BIM have been identified and so the use of digital twins to bridge the gap is considered. This research acknowledges that future research should consider the benefits of digital twins to support heritage asset management, especially given the sector's advances in the use of 3D surveying and point cloud generation. Difficulties identified in the generation of 3D parametric models of heritage assets could be overcome where point clouds can be used as the basis for a digital twin (Stojanovic *et al.*, 2018).

It is clear from the discussion above that BIM processes could support heritage professionals with a number of activities, for a range of users and stakeholder groups, and in a number of different ways. Unfortunately this has led to some confusion in the literature around the term 'Heritage BIM'.

3.4 Defining Heritage BIM

Described instances of Heritage BIM (HBIM) application have demonstrated some confusion over the definition of HBIM resulting in a number of themes, or definitions. Most commonly, HBIM case studies relate to the retrospective development of parametric models of historic buildings, with associated data to inform conservation intervention on a large scale. For example, models may be developed to aid the planning and management of individual conservation projects such as that at the Glasgow School of Art, or to serve as a digital archive of accurate documentation and a navigable timeline of historical change (Fai *et al.*, 2011) and a particular focus on visualisation in a planning context.

Primary considerations in the literature are around the practical issues of data capture via laser scanning and photogrammetry and subsequent 3D parametric modelling from point cloud data which has proved difficult for existing and historical buildings. Libraries of parametric objects within the software are most suited to new build design and therefore, developments were required to accommodate the complexities of modelling existing or historic buildings (Oreni *et al.* 2013; Dore 2017). A definition of HBIM was provided by Murphy *et al.* (2009) following research carried out by the Dublin Institute of Technology and a number of papers co-authored by Murphy as; '*a library of parametric objects built from historic data'*. It is around this definition and associated difficulties that many papers are written and, the focus of most is to reach a conclusion to deal with these limitations. Research from the Dublin Institute of Technology has been quite dominant within HBIM discussions and as such, Murphy et. al.'s research has developed between 2009 and 2017 (Murphy *et al.,* 2009; Murphy *et al.*, 2017; Murphy *et al.*, 2017; Murphy *et al.,* 2013; Dore & Murphy, 2017). Where the earlier papers were focused on data collection and designing library objects, the later papers go on to discuss BIM workflows and identify the benefits of BIM processes such as; the ability to manage information (not just graphics), the opportunity to add detail to the objects within the model such as methods of construction and material composition and, supporting a controlled common data environment. In other words, adding intelligence to laser and image-based surveys.

Other papers focus on the lack of a 'shared library for historical [building] elements' (Oreni *et al.,* 2013) to be used when developing parametric models of historic buildings, due to software limitations and the unique form of historic architectural features. Furthermore, the impact this has in time, resource and subsequent benefit to heritage conservation projects is discussed. The output of this research is to develop libraries of architectural features to support the adoption of HBIM. The library of vaults and wooden floor beams, that are common structural systems found in historic buildings in Northern Italy, is developed using historic architectural drawings, and manuals and guides on historic construction technologies (Oreni *et al.*, 2013). Similarly, the

Jeddah Historical Building Information Modelling process (JHBIM) is a case study example of the development of historical architectural object libraries to support parametric modelling of historic buildings in Jeddah. The 'Hijazi Architectural Objects Library has been modelled based on the Islamic historical manuscripts and Hijazi architectural pattern books' (Baik *et al.,* 2015). In both cases, library objects are semantically enriched with information such as:

1) the material used in the composition of the building's parts

2) the historical context of building

3) the history of reparations that took place in the building

(Baik *et al.,* 2015)

Others use the HBIM definition for monitoring and simulation data in heritage buildings. The use of BIM models enhanced with weather forecasting models on a case study at Jewel Tower, London allowed possible patterns of degradation to be visualised and used for maintenance planning (Pocobelli *et al.*, 2018). Specifically, 'the model is then integrated with moisture data, organised in spreadsheets and linked to it via parametric objects representing the points where measurements had been previously taken. The spatial distribution of moisture is then depicted using Dynamo' (Pocobelli *et al.*, 2018). The research demonstrates the potential of different types of software, such as Dynamo, for condition reporting in a 3D visual environment. The primary focus in these existing case studies is on visualisation and the use of the 3D parametric modelling aspect of BIM. This causes barriers to implementation, especially in the heritage sector where digital skills and resources for these complex, timely and costly processes are limited. It is acknowledged that this is an important area of research but is intentionally ignored here to allow research that focuses on the critical foundations of information management that are known to still require development, before advancing to the use of technological innovation for visual planning of CRM.

In their paper, Fai *et al.* (2011) acknowledge the importance of digital data management for conservation of the historic environment, in line with findings reported in Chapter 2. They note that leading documents on information management in this field (Letellier *et al*., 2011; Bryan *et al.*, 2013) do not refer to the advantages that BIM processes may lend to this field and, that technical research thus far 'does not fulfil the need for data-rich documentation of heritage buildings'. Since 2011 more recent publications have begun to note the potential benefits of BIM processes in the 3D recording, documentation and management of cultural heritage (Stylianidis, 2016; Andrews *et al.*, 2015; Saygi and Remondino, 2013). Analysis of the literature suggests that there is however, a distinction between HBIM research that refers to 'recording and documenting' and, that which refers to 'management'. In Dore (2017) for example, recording and documenting refers to the technical capacity for accurate records of European classical architecture through the developed HBIM procedural modelling workflow. Research that investigates the role that BIM can play in the renovation or restoration of historic buildings on the other hand tends to lean more towards how BIM processes can facilitate the management of heterogeneous sets of data that are required to manage renovation or restoration processes such as; survey, material and constructional analysis, drawings, historic photographs and archival research (Bruno and Fatiguso, 2018; De Luca *et al.*, 2011). Here, the use of the BIM research framework (Succar, 2009) in the HBIM context would provide clarity and focus to the research.

Using the renovation of Durham Cathedral as a case study, Tapponi et al. (2015) define HBIM as a digital toolkit that can help the understanding and management of historic assets more efficiently. An interesting aspect to the paper however is that whilst it focuses primarily on the technical capabilities, there is a brief mention of the general issues that affect successful adoption of BIM in heritage. These are noted as follows:

- *Heritage Managers are not early adopters or innovators*
- *It is necessary for all relevant team members to engage and support use in order to reap the benefits*
- *A strong commitment is required in order to overcome the 'significant cultural challenge' including the technical and procedural shift required to incorporate BIM workflows.*

(Tapponi *et al.*, 2015)

This shift from research that privileges the technical, to a consideration of the social, is an important contribution to the field of HBIM research that has been explored to inform the proposed workflow presented in Chapter 8. Where the majority of papers investigate the potential of BIM for use in the heritage sector, the emphasis is generally based on trying to make the technology fit the context or vice versa. Sackey et al. (2015) suggest that such deterministic approaches 'over-simplifies the process of technology design and use'. This research attempts to put emphasis on BIM technology as a socio-technical network, contributing to a wider discussion about how a BIM 'approach' may be applied to the historic environment, and acknowledgement that a social perspective must be considered in order to understand how the new technology may develop and how it will be used or adopted.

3.5 Implementing digitisation in the heritage sector

Having considered digitisation across the heritage sector, and for the purposes of the research narrowed this down to digitisation for the planning of preventative conservation repair and maintenance, it is important to consider factors that impact the implementation of new innovation such as digitisation. Earlier sections of this chapter have considered barriers to implementation from different perspectives. First digitisation in the AEC industry in general was reviewed. Next barriers to implementation of BIM, as a specific approach to digitisation, was considered. Issues affecting the O&M phase were noted and the heritage sector in particular was studied. Factors affecting implementation of digitisation are summarised in Table 3.1 overleaf for reference:

Table 3.1 Barriers to implementation of digitisation

AEC in general	BIM	O&M Phase	Heritage
Lack of funding and R&D	*Case studies fail to quantify universal benefits*	*Fragmentation*	*Fragmentation*
Silo working	*Failure to identify critical information requirements*	*Analogue nature*	*Analogue nature*
Fragmentation	*Lack of skills, training, standards and governance*	*Range of stakeholders*	*Range of stakeholders*
Existing & entrenched ways of working	*Limitations of BIM to meet users needs*	*No 'one size fits all' solutions*	*No 'one size fits all' solutions*

As illustrated in Table 3.1 above, the heritage sector shares factors with the O&M phase and therefore these should be considered when considering implementation. Three key areas identified through the literature are selected and further literature review for the heritage sector specifically was conducted. This section has been structured using these key themes.

3.5.1 Stakeholders

The range of stakeholders in construction, and particularly the O&M phases is broad. Research often uses specific stakeholders as a lens within which to frame their findings. Research that sought to understand the factors affecting cost performance in construction projects considered this through the roles of three key stakeholder groups identified as Clients, Consultants and Contractors (Doloi, 2013). Research analysed in Chapter 2 that considered a BIM research framework also identified stakeholders as a key lens and categorised them under one of three BIM fields: Policy, Technology and Process (Succar, 2009). For the purposes of this research, the activity of heritage asset management or preventative conservation repair and maintenance falls under the process field so this is considered further. Similar to the Doloi (2013) research, Clients, Consultants and Contractors fall into the process field however, a wider range of stakeholders are identified. This was reviewed against the range of BIM stakeholders (Butt *et al.*, 2015) to draw comparisons and consider the implications on BIM implementation.

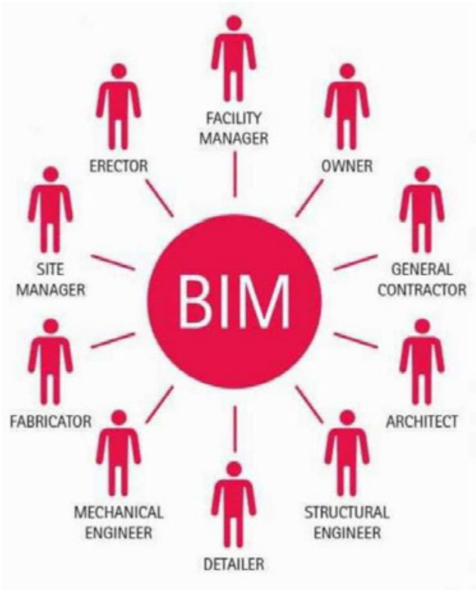


*Figure 3.2 Diverse Stakeholders (*Butt *et. al, p561, 2015)*

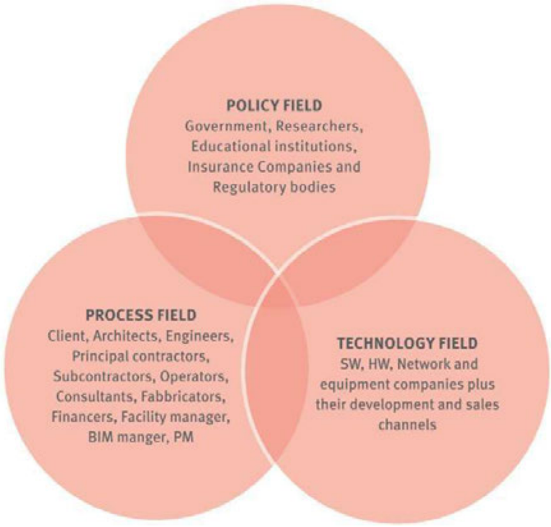


Figure 3.1 Stakeholders in the BIM research frameworkd fields (Succar, p361, 2009)

When considering stakeholders for heritage asset management it is important to understand how these compare with those in the wider construction industry and, across the building lifecycle, if implementation of digitisation is to be successful.

Heritage conservation is primarily aimed at preservation. As discussed earlier, conservation practice is a result of statutory protection to preserve cultural heritage for future generations. However, tourism and development also play a part in heritage conservation and as a result, there is a need to balance often conflicting interests between different stakeholders (Chapagain, 2008). Chapagain notes that heritage stakeholders may be categorised as follows:

International Stakeholders – such as UNESCO

National Stakeholders – such as Historic England

Local Stakeholders – such as building and heritage trusts, local planning authorities & volunteer groups

In the context of this research and the processes for heritage asset management, while International and National stakeholders may have been involved in the wider process of designating heritage assets, defining significance, providing funding and so on, it is local stakeholders that are involved directly in the process of preventative conservation repair and maintenance. When considering these local stakeholders in the heritage context we see a difference from the wider AEC industry. Building and heritage trusts and volunteer or 'friends of' groups are not structured in the same way as construction organisations and so the Architect, Project Manager, Facility Manager, Site Manager roles that are seen in both construction and BIM processes may not always be present in the heritage context. This must be taken into consideration when looking at implementing new formalised processes. How does the process fit with the existing stakeholder group and what changes are required to aide implementation?

3.5.2 Skills and attitudes to digital technology in heritage sector

As demonstrated in the previous section, heritage stakeholders are diverse and do not necessarily align with standard construction or BIM stakeholders. As such, the range of skills across stakeholders is varied. Although not directly quoting the digital knowledge base of heritage or conservation professionals, in their proposed application of GIS and content management systems (CMS) for the documentation of World Heritage Conservation, Vileikis et al. (2012) consider the solution as a 'user friendly' option where 'ICT skills are limited'. In a study of the impact of technology on museum studies the researchers considered IT skills and training of stakeholders as one of the major themes (Duff *et al.*, 2009). In the museum context the public are considered a primary stakeholder and as such the wide range of IT skills across all ages has a significant impact on the development of museum systems. Due to the vast range of stakeholders and use of technology it is difficult to select specific literature that considers the specific skill levels in a CRM context but the general sense is that digital skills are lower in this industry than the wider AEC sector. This is further justified in the fact that there are specific initiatives that focus on improving digital skills in the heritage sector.

The National Lottery Heritage Fund is responsible for the 'Digital Skills for Heritage' initiative that is designed to raise digital skills and confidence across the heritage sector. In response to the Digital Attitudes and Skills in Heritage (DASH) survey, they have developed a number of digital resources along with free digital skills training which includes The Digital Heritage Lab (online workshops, training events, digital bootcamps and a 9 month bespoke, digital skills academy), and a further digital skills programme – Heritage Digital. The Lab will provide bespoke digital mentoring support to 60 UK based small to medium sized heritage organisations from September 2020 until June 2021. Along with Heritage Digital that will provide free training to over 700 heritage organisations up to July 2021 these initiatives could have a big impact on the heritage sector.

The results of the DASH survey however provide some concerns around heritage professionals attitudes and understanding of how digital methods may help their organisation. Of the 388 digital uses that were suggested by over 200 participants, 8 categories were identified as illustrated on Figure 3.3 below.

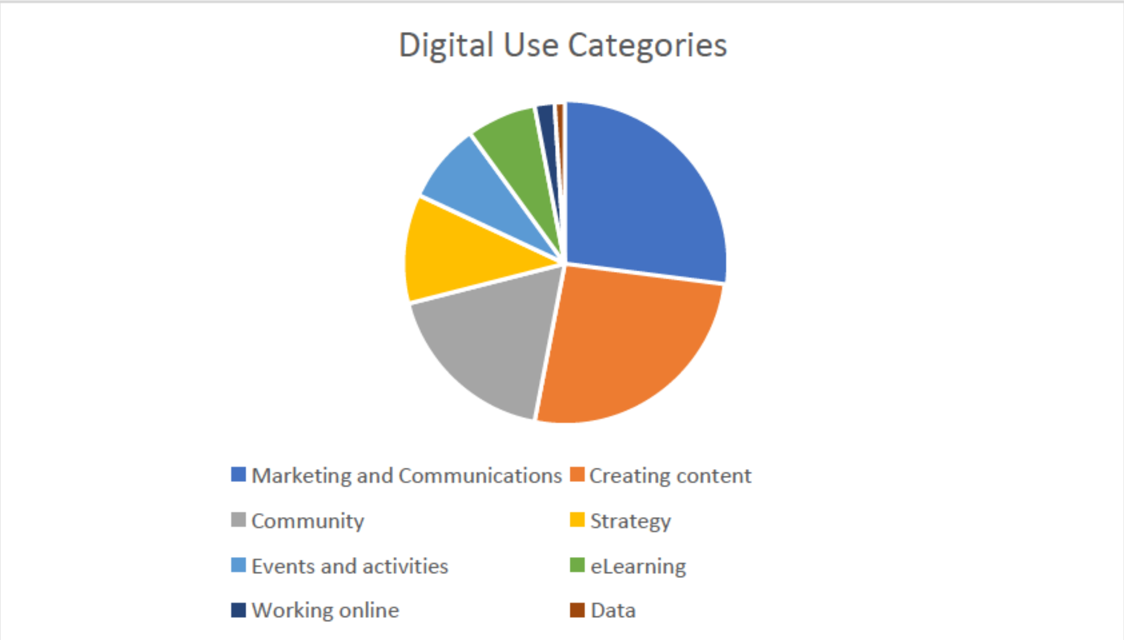


Figure 3.3 Digital use categories identified during survey of heritage professionals (www.heritagefund.org.uk)

The strategy category suggested organisations were keen to ensure digital methods assisted them in delivering their organisational objectives and included tasks such as digital training and support for staff, and evaluating the impact of their use of technology. Unfortunately this category only formed 11% of responses. Even more concerning was the response to data, where just 1% of the organisations suggested a desire to understand how they can better use their data.

Watrall (2019) suggested that with the heritage sector primarily focusing on the specific domains that it has, it has 'cut itself off from the much wider practice that has evolved in the digital humanities' (Watrall, p140, 2019). Digital skills, methods and techniques are not developing within the sector in line with other humanities and 'heritage professionals are facing digital challenges [for which] they have little or no training to address' (Watrall, p140, 2019). His research was centred around the development of scholars, and communities of practice in the use of digital methods and computational approaches to archaeology and heritage through a number of initiatives including a new Institute on Digital Archaeology Method and Practice, and a Cultural Heritage Informatics Initiative Graduate Fellowship Programme. Qualitative and anecdotal evidence from both initiatives suggests that participants have gained 'critical new perspectives with the potential to transform the way they work' (Watrall, p150, 2019).

Whilst there is no doubt that such initiatives have a positive impact on developing attitudes to digital methods and improving skills, with only 20 funded and 10 unfunded applicants accepted into the Institute, the impact will be limited. Investment in scholars and professionals is only half of the battle in a sector that relies heavily on traditional skills, crafts people and volunteer labour (Orr, 2006). When considering the volunteer demographic, the suggestion that the majority are retired, seeking volunteer opportunities as leisure activities rather than work experience (Holmes, 2003) highlights an even further disconnect with the developing digital needs and requirements.

3.5.3 Funding and Resource

With developments in digital technology offering new opportunities to the heritage sector, research has considered the cultural value of this digital engagement alongside practical challenges such as funding and capacity (King *et al.*, 2016). Through online survey of heritage professionals, emerging themes were compared to primary discussions from the academic literature. It was identified that funding to support implementation of digital technology in the heritage sector is limited, providing challenges that must be a primary consideration of any new application or process. Moreover, through this cultural value lens, the researchers consider the important connection with economic value. Where funding is obviously scarce, findings show that money 'is often wasted through underfunding of projects' (King *et al.,* p83, 2016), is spent in the wrong areas or, successful projects are not provided with ongoing support to allow them to continue.

Digitisation more specifically comes with its own challenges. With 'increasingly diverse data formats, larger file sizes, changing media types, distributed databases, networked information and transitive metadata standards, how are today's heritage specialists to plan for such an uncertain virtual future?' (Ashley *et al.,* 2007). This research asks a number of important questions that ultimately relate back to funding and resource:

- *Which data should we keep and how should we keep it?*
- *How is this data to be saved to ensure access in five years, 100 years or 1,000 years?*
- *Who will pay for all this?*

(Ashley *et al.,* 2007)

In section 3.1.5 the 'cost of heritage' was discussed. Whilst difficult to establish the full cost of heritage a number of areas, or associated costs, were considered with the principal focus on the cost of CRM. The costs discussed however were directly related to CRM tasks themselves and do not consider associated costs of additional resources and development in process such as digitisation to support CRM processes. Furthermore, while cost is discussed, as the question raised by Ashley *et al*, it must be considered where funding will come from and, the impact that available funding will have on digitisation.

In a paper that studies the economic and political challenges of UNESCO's World Heritage Convention 40 years after its inception, lack of funding is considered a 'major and permanent problem in the World Heritage system' (Meskell, 2013). The World Heritage Centre is the administrative body within UNESCO and is responsible for organising the annual World Heritage Committee. 'The Committee' is made up of 21 state parties who are responsible for implementation of the World Heritage Convention. 'It defines the use of the World Heritage Fund and allocates financial assistance upon requests from States Parties, has the final say on whether a property is inscribed on the World Heritage List, and examines reports on the state of conservation of inscribed properties and asks States Parties to take action when properties are not being effectively managed' (Meskell, 2013). State parties make compulsory contributions to the World Heritage Fund and other income is derived from sales of World Heritage publications or 'funds-in-trust' donations, given by countries to support specific projects. Funding may be used for such purposes as defined by the Committee as summarised below:

1. studies concerning the artistic, scientific and technical problems raised by the protection, conservation, presentation and rehabilitation of the cultural and natural heritage, as defined under the terms of the Convention ;
2. provision of experts, technicians and skilled labour to ensure that the approved work is correctly carried out ;
3. training of staff and specialists at all levels in the field of identification, protection, conservation, presentation and rehabilitation of the cultural and natural heritage ;
4. supply of equipment which the State concerned does not possess or is not in a position to acquire ;
5. low-interest or interest free loans which might be repayable on a long term basis ;
6. the granting, in exceptional cases and for special reasons, of non repayable subsidies.

(UNESCO, no date)

A number of concerns are raised and discussed in the paper that can be related specifically to funding. With more and more sites being inscribed onto the World Heritage, demonstrating historical development and a more representative inventory list, the convention must maintain a credible status. Meskell (2013) quotes Bokova's plea, and describes the trend in Committee decisions regarding inscription diverging from the 'scientific opinions of the Advisory Bodies toward a political rather than heritage approach to the Convention' (Meskell, 2013). Such political approaches have resulted in the withdrawal of US funding to UNESCO on a number of occasions. Most recently as a result of UNESCO's recognition of Palestine and the inscription of the Church of the Nativity and historically including the political decisions over national interest and cold war conspiracy which cost UNESCO 'some $43 million in lost revenue' (Meskell, 2013). Political issues between state parties and financial contributions will threaten the future of the World Heritage Fund and the amount of funding available for projects worldwide.

In contrast to the grim picture painted in relation to funding for World Heritage, there is a more positive outlook on heritage funding more specifically to the UK. Funding for heritage projects is overseen by the Heritage Lottery Fund (HLF), the largest dedicated grant funder of the UK's heritage. Founded in 1994 the HLF is responsible for distributing funds to good cause projects centred around arts, sports, heritage and community. 'By setting up a separate organization for heritage, the government ensured that heritage was not competing with other good causes that had their own funding bodies' (Clark, 2014). The HLF has provided funding to the value of £8bn since 1994 but with a large amount of money at its disposal, and the opportunity to fund a broad range of projects a robust system needed to be developed to ensure money directed to the right projects and minimising the potential for damage to be caused by spending money incorrectly (Clark, 2014). It was partly as a result of this funding system that conservation management plans and significance based assessment became so entrenched in conservation practice in the UK.

The HLF noted they could fund physical work, such as repairs and site management; new facilities, such as car parks and visitor centres; but also activities, such as interpretation, education programs, and volunteering (Clark, 2014). While skills, training and digital projects are not specifically mentioned it is encouraging to note that the HLF funding priorities for 2021-2022 in response to the COVID 19 context include skills and organisational resilience. Both of which could be considered to accommodate digitisation projects.

The overarching message however is the dependency on funding in the heritage sector. With limited funding for research and development, and limited and highly demanded funding streams with robust prioritisation and awarding processes, cost and benefit analysis of digitisation programmes or the implementation of digital technology will be critical when developing strategies.

3.6 The future of heritage asset management

To answer the research question; *What are the challenges of heritage asset management and how might digital, formalised processes, such as BIM, support conservation professionals with CRM planning,* a critical literature review has been conducted and is presented in Chapters 2 and 3. This is now summarised to consider the future of heritage asset management.

The literature review began in Chapter 2 with the impact of digitisation in the construction sector, owing to popular opinion that this will have the biggest impact across all activities and sub sectors of the AEC industry, including heritage. The slow adoption of digital technology and digitisation in construction, compared to other industries, is discussed with issues of R&D funding, lack of strategic planning for innovation, silo working and fragmentation, and existing and entrenched ways of working proving to be significant barriers to implementation. The current state of the art is considered, specifically a review of the UK Government agenda for digitalisation and the implementation of BIM. Confusion surrounding BIM terminology is discussed with an attempt to focus this research on the information management methodology of BIM and how such digital, formalised processes might support heritage asset management.

It was noted that both literature and case studies fail to successfully 'analyse and quantify [the] universal benefits' (Barlish & Sullivan, p152, 2012) of BIM, and that success can be affected by a number of subjective internal and external variables. This was an important insight for this research and so time was spent considering a defined research framework for the BIM domain that can be applied to position this research.

The application of BIM more specifically in the O&M stage is then discussed as this is the specific BIM stage considered when thinking about heritage asset management. Case studies reviewed provided useful insight into information requirements for O&M and, collating legacy data for existing buildings. They highlighted failings from a personnel perspective, not involving the right people in the process at the right time and not defining information requirements at the outset which led to failings in data handover. Issues in identifying information requirements and research that sought to establish frameworks to support building owners were studies as this could provide valuable lessons when considering the future of heritage asset management and the potential of BIM to support such activity. More recent initiatives to improve BIM implementation are reviewed and importantly, smaller, simple steps that are accessible to all AEC stakeholders are considered. With BIM adoption in the heritage sector in its infancy, it will be these more accessible milestones that will see increased knowledge and thus practical implementation.

Finally, the review of digitisation in the construction sector looks at the limitations of BIM, particularly in the O&M phase, and emerging technology that seeks to fill these gaps. The benefits of digital twins are discussed but, owing to the timeline of this research, the relevance in terms of asset management practice in a heritage context and the ongoing barriers to digitisation, they are ignored as an application to support conservation professionals in this research. Instead, digital twins are identified as an area for future research.

Chapter 3 opens with a wide review of literature around the conservation and protection of heritage assets, and more specifically looks at statutory protection within the UK. Such protection of heritage assets impacts heritage management and particularly CRM processes. It was noted that in the wider construction context, operation and maintenance management results in two distinct tasks;

- Planned and preventative maintenance (PPM)
- Asset replacement

This is focused further with a review of PPM in a heritage context, specifically conservation repair and maintenance (CRM) as an asset management activity. For the purposes of the research, CRM is identified as the key heritage asset management activity to be studied. Aligning with issues in the wider AEC industry that have been the focus of many industry reports, and ultimately leading to the agenda for digitisation, best practice maintenance systems, industry guidance and common structured processes for heritage CRM were identified as lacking (Forsyth, 2007; Dann and Wood, 2004; McGibbon *et al.*, 2018), with variable success in implementation (Forster & Kayan, 2009). Key themes affecting successful maintenance management are drawn out of the literature and used to structure the chapter section;

- Strategic management
- Financial management
- Information management

Of the three areas, information management was identified as a typical challenge associated with the wider architecture, construction and engineering (AEC) industry, as well as the heritage sector more specifically, (Miettinen & Paavola, 2014; Ciribini *et al.,* 2015; Pärn *et al.,* 2017; McGibbon *et al.,* 2018; Bruno & Fatiguso, 2018), resulting in inefficiencies and poor quality. To further focus the research, and aligning with the potential benefits of digital, formal processes such as BIM, information management is used as the primary focus of the research.

Initially a literature review surrounding information management in the wider O&M phase was completed and presented in Chapter 2. Equivalent identified issues of fragmentation and disparate systems for the collection and management of building information were subsequently identified through a review of information management in the heritage sector more specifically (Chapter 3). This review looked at the heritage sector in the broadest sense, the range of stakeholders and data uses. The section concluded that there is no standard approach for heritage data management, and while it is understood that the wide range of data and uses is a barrier to the development of a single solution, it is not clear why a standard approach for digital data management for heritage CRM specifically is yet to be developed.

Having considered digitisation more widely, and specific issues of information management in the heritage sector, Section 3.5 uses a literature review of digitisation in the heritage sector to consider current state of the art and further potential for digitisation to meet some of the information management challenges, particularly in support of heritage asset management – focusing on the conservation, repair and maintenance programmes that are developed for the management of heritage assets. An overview of CAD and GIS is given, identifying how this experience could be further developed. BIM information management principles such as the development of an Information Delivery Plan (IDP), Organisational and Asset Information requirements (OIR and AIR) and the Asset Information Model (AIM), are considered to offer the biggest benefits to the heritage sector for asset management and conservation repair and maintenance (CRM) planning. Finally the potential of BIM to support heritage asset management is considered, reviewing the earlier discussed limitations and barriers to implementation.

Barriers to implementation are key to understanding how successful a new technology or process might be. From the literature it becomes apparent that the technology cannot be considered in isolation and factors that impact the implementation of a new innovation need to be considered. These barriers were categorised into key themes that informed the subsequent literature review regarding implementing digitisation in the heritage sector. Themes were found to be common across the AEC industry; Stakeholders, Skills and Attitudes and Funding & Resource.

Using the BIM research framework identified in early literature review, stakeholders are an important factor in the BIM process lens. Research drew comparisons between AEC and BIM stakeholders and so for this research it is important to draw similar comparisons with heritage stakeholders. These were categorised as International, National and Local. When considering local stakeholders in the heritage context we see a difference from the wider AEC industry which must be taken into consideration when looking at implementing new formalised processes. Lack of knowledge in digital uses and a high volunteer demographic in the heritage sector are further identified as issues that might impact the success of digital, formalised processes. Finally, funding and resource is considered. The lack of funding for R&D has already been mentioned, and the lack of digital skills in the heritage sector increases the need for skills and training funding. The associated costs of digitisation are also considered, raising questions about how much data can be saved, how will it be saved and who will pay for it. This demonstrates a critical need for cost and benefit analysis when developing digital, formal processes for information management and heritage asset management.

3.6.1 Digital, formalised processes for heritage asset management

Digitisation 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 (Historic England, 2017) 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 (Garagnani and Manferdini, 2013; Oreni *et al.,* 2013; Dore, 2017). 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 (Murphy *et al.,* 2013; Dore & Murphy, 2017; Stylianidis, 2016; Saygi and Remondino, 2013; Bruno and Fatiguso, 2018).

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, allow for the development of a comprehensive knowledge base that could be extremely beneficial in the operational phase of a building's lifecycle (Penttila *et al.*, 2007, Simeone *et al.*, 2018), particularly for repair and maintenance. Furthermore, the use of ontology based modelling that considers the representation of entities in terms of knowledge components (Carrara *et al.,* 2009, Nieto *et al.*, 2016) could be extremely useful for conservation of the built historic environment. In the book 'Heritage Building Information Modelling' (Arayici *et al.,* 2017) the varying approaches that have formed the origins of Heritage BIM are reviewed. Four distinct themes that set the scene for Heritage BIM, and result in a variety of definitions are identified; restoration philosophies in practice, data capture and visualisation for repair and maintenance, stakeholder engagement, and building performance.

Repair and maintenance is identified as the focus of this research, with the emphasis on information management rather than data capture per se, or visualisation. The literature review has demonstrated that a BIM methodology for information management, using the BIM process lens for the O&M BIM stage offers a suitable framework within which to position the research.

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). In 2016 Historic England published a case study report aimed at providing guidance to 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 (Historic England, 2016). 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, multidisciplinary, 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 historically identified as themes requiring further development (Major, 1999, Dann and Wood, 2004) 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 (Simeone *et* *al.*, 2018, Jordan-Palomar *et al.,* 2018). In addition, there is no standard process or framework for heritage asset management.

Following extensive literature review it is suggested that building information modelling (BIM) could offer an effective solution to standardise heritage asset management and the information management process for the effective planning of CRM. Whilst BIM has shown some promise in the O&M phase, this requires testing in a heritage context (Jordan-Palomar *et al.*, 2018), taking into consideration the specific factors as discussed within the literature review, and would require implementation guidance for the heritage industry to facilitate adoption.

From the literature review the following research objectives were identified;

- How does conservation asset management differ from conventional asset management and what impact does this have on data management?
- How do people engage with formal process and guidance, and why do they not always follow it?
- What features would Heritage BIM need to have to support conservation professionals with CRM planning?
- What are the specific challenges that conservation professionals face when engaging with information management and digital technology?

Each thesis chapter is based around a case study or specific data collection that was designed to answer one or more of the research objectives. The methodologies adopted to collect data and how each data set is analysed and used to answer the research objectives is now described in detail in the following chapter; Chapter 4 – Research Approach.

4. Research Approach

4.1 Introduction

This research is the result of a collaborative doctoral award between Historic England and the University of Reading. At the outset, the aim of the project was to investigate how BIM may be applied as a tool to record, manage and interpret historic built environments. Following extensive literature review it is suggested that building information modelling (BIM) could offer an effective solution to standardise heritage asset management and the information management process for the effective planning of CRM. It was identified however that Heritage BIM research, beyond the specifics of 3D parametric modelling, has focused on potential benefits of the new technology but with very little evidence to demonstrate these benefits, and no analysis of barriers to implementation or the reported low diffusion. The heritage sector is heavily dependent on a wide network of stakeholders who care for and manage heritage assets. Furthermore, whether in the specific fields of heritage asset management or heritage data management, the literature has shown there to be a lack of industry guidance and a tradition of loosely controlled management.

The research question has thus been developed to consider the challenges of heritage asset management and how digital, formal processes such as BIM may be applied to support conservation professionals in the recording, management and analysis of historic building information for CRM planning. From the literature review the following research objectives were identified;

- How does conservation asset management differ from conventional asset management?
- How do people engage with formal process and guidance and, why do they not always follow it?
- What features would Heritage BIM need to have to support conservation professionals?
- What are the specific challenges that conservation professionals face when engaging with BIM?

The objectives above clearly illustrate a social element to this research. 'How do people engage with processes and why do they not always follow them?' is a question that cannot be answered without observing people, and without this understanding it is not possible to fully understand how new technologies and processes are best implemented for successful adoption. Further, to understand the features required to support conservation professionals, and the challenges that conservation professionals face when engaging with BIM, one must take time to observe, question and understand the people, processes and technologies involved.

A relatively large amount of research has been carried out that looks at the implementation and uptake of new technologies, including BIM, but similar research in the heritage field is limited. Existing research demonstrates the positive contribution of a socio-technical networks approach (Schweber and Harty, 2010; Sackey *et al.,* 2015; Miettinen and Paavola, 2014) as an analytical tool or method. Consideration of elements within a network, problems they cause, and how the network responds to solve them is an extremely useful way to analyse implementation and uptake. In a socio-technical networks approach, network elements (or components, actors or actants) may be human, technical, social or natural. Not one element is fundamental to the structure of the network or privileged in any way, and in order to resolve issues within the network, the pattern of relations between all the different types of elements as they bring up problems or solutions must be traced.

It is observed that the focus on 'interactions between social and material entities' (Schweber & Harty, p658, 2010) in the socio-technical networks approach offers a shift from research that privileges the technical, to a consideration of the social, which is an important contribution to the field of Heritage BIM research. The majority of papers investigating the potential of BIM for use in the heritage sector focus on trying to make the technology fit the context or vice versa. Sackey *et al*. (2015) suggest that such deterministic approaches 'over simplifies the process of technology design and use'. Moreover, the work of Callon (2012) criticises the idea of innovation or technological development as a linear process, instead commenting on the complexity and 'seamless web' of technical, scientific, economic, social, political and cultural factors that are bound up in the process of technological development.

The social-technical network oriented approach is therefore considered an important contribution to knowledge in the field of heritage, and particularly for the implementation of new technology and processes such as BIM. It offers a framework for critical discussion about how digital, formal processes such as BIM may be applied to the historic environment, and acknowledgement that a socio-technical perspective must be considered to understand how the new technology may develop and how it will be used or adopted.

Noted above, the range of network elements, the problems that develop and how the network responds to find solutions must however be traced. The 'follow the action' method as presented in Actor Network Theory (ANT) (Latour, 2005) is a useful tool for such a purpose. As described by Harty (2005; 2010), there are some key points to an ANT approach that make it very well suited for studying processes of change that involve the interactions of many human and non-human actors (Callon, 2012).

- ANT concepts allow for an account of multiplicities (interactions, influences, negotiations, alignments) as innovations are developed and implemented.
- The extent of an actor network is not defined 'a priori' and, is unbounded (not restricted by organisational or project boundaries for example).
- ANT emphasises the dynamic nature of organisation and alignment (Suchman, 2000). Redesign, renegotiation and reconfiguration takes place through the interactions between the actors until stabilisation of the network is reached.

(Harty 2005; 2010)

As can be seen from the key points above, ANT can be seen as a method and mobilised within the research, rather than considered a theory as the name suggests. Latour (2005, p.12) suggests that one must 'follow the actors themselves… to learn from them what the collective existence has become in their hands'. The task for the researcher is to trace the associations but, 'the task of defining and ordering the social should be left to the actors themselves' (Latour, 2005, p.23).

For information management systems and processes, such as BIM, to support conservation professionals and become accepted in practice there needs to be some acknowledgement of the negotiations and reconfiguring taking place throughout the development that impact on final outcomes or, temporarily stable networks. Similar research that has considered the development, implementation and adoption of new technology and processes concluded that a cycle of continuous learning and experimentation is key to success.

The ANT 'process of translation' (Callon & Law, 1982; Callon, 1986; Shiga, 2006) is adopted in this research as it offers a lens through which actors are identified, associations are traced, and the range of negotiations and displacements that take place are considered. It offers a framework and vocabulary with which to explain how the particular interest or goal is rejected, transformed or, results in the temporary stabilisation of the actor network through a process of persuasion and negotiation in which actors become enrolled to support or adopt the vision. As noted by Shiga (p40, 2006), the ANT concept of translation offers an 'alternative framework for the role of artifacts in every day life'. This approach is particularly useful when considering the introduction of a new technological artifact, process or system, and subsequent adoption.

The elements of the ANT concept of translation are introduced here and are used to analyse the data presented in this thesis. The interests of each actor must be identified and either met or transformed to hold the associations together. Defining actors in such a way that they become indispensable to a network is known as problematisation (Callon, 1986)

The ANT concept of interessement considers the actions employed by the author of the problematisation to define, impose and stabilise the identity of the other actors in the network (Callon 1986). These actors may choose to accept the given identity and integrate with the network, thus achieving enrolment, or define their own identity and goal.

When actors are enrolled and a particular definition or problematisation is performed in reality, mobilisation through a single course of action is achieved (Shiga, 2006).

The ANT follow the action approach adopted in this reasearch has led to a multimethod approach, combining quantitative and qualitative data. The qualitative research methods described in this chapter were selected for their ability to collect data in relation to the research objectives, while offering a social perspective to the data. Ethnographic research and participant observation (Canagarajah, 1993; Bryman *et al.,* 2012; Pearson, 2012; Ingold, 2014) have been common methods to study the development of new technology and processes from this perspective, demonstrating the positive contribution they can add to this research. A summary of the methods is provided below:

1. Participant Observation
2. Active Participation
3. Interviews
4. Document Analysis

A mix of these methods were used across a number of case studies. Outline case studies were identified in line with the research objectives but these were not restricted, allowing new directions (or action) to be followed if and when presented.

Finally, in order to position this research within the field of BIM research, the BIM research framework as proposed by Succar (2009) is used. With an increasing body of BIM research, the BIM research framework more specifically positions research within 3 areas:

- The BIM field:
  - Technology
  - Process
  - Policy

- The BIM stage:
  - BIM Stage 1: object based modelling
  - BIM Stage 2: model based collaboration
  - BIM Stage 3: network based integration

- The BIM lens:
  - Selected aspect of the AEC industry

Of the three identified BIM fields, this research sits within the BIM process field, focusing specifically on digital, formalised processes to support conservation professionals with the activity of heritage asset management. BIM Stage 2 most closely matches the research as it focuses on process, information management and collaboration rather than object based modelling or network integration. The heritage sector is selected as the BIM lens but this is specifically defined as CRM planning for heritage asset management. Issues of barriers to implementation and adoption of BIM, specifically in the heritage sector are key to the research but this has been limited to an 'information' perspective.

The chapter is structured by describing the key organisations studied and the methods used. Methods are described using a clear structure explaining:

- why the research methods were selected
- how they were used
- the data that was gathered through each method
- limitations of the various methods and how these were overcome
- a reflection on each methods success and failures

A roadmap illustrating the research steps and methods used in the data collection chapters is provided below. Some data collection chapters were developed in response to questions that emerged as the research developed rather than a direct response to the research objectives outlined above. The diagram helps to explain this and clarify the relationship between the research methods and sub-questions addressed in the data collection chapters.

Table 4.1 Roadmap illustrating research steps and methods

Chapter	Research Objective	Research Step	Research Methods
5	Understand how asset management differs in heritage and non-heritage contexts	Sub-questions identified to decide what information was required during data collection	Active Participation Interviews Document Analysis
6	Understand how asset management differs in heritage and non-heritage contexts	Sub-question emerged from the findings of Chapter 5 used to direct data collection	Document Analysis
7	Understand how people engage with formal process and guidance and why they do not always follow it	Empirical vignettes described from the case studies and used for data analysis	Participant Observation Active Participation Analysis of interview data Document Analysis
8	Identify what features Heritage BIM would need to have to support conservation professionals and, identify the specific challenges that conservation professionals face when engaging with BIM	Data from the previous data collection chapters is re-analysed from a different perspective	Analysis of collected data

4.2 Key Organisations

Three key organisations were selected during this research within which the main case studies were conducted. These included two heritage and one non-heritage organisation. The network was traced to identify organisations based on the following criteria:

- An organisation responsible for asset management or heritage management
- Accessible to the researcher
- Provides an opportunity to observe digital, formalised processes
- Provides an opportunity to observe digital technology used by heritage professionals
- Typical examples from which lessons can be learnt and analysis and proposals can then be applied to the wider field

The UK Antarctic Heritage Trust

The UK Antarctic Heritage Trust (UKAHT) is a British charity tasked with the almost impossible mission of preserving the remains of over 70 years of British scientific exploration and research on the Antarctic Peninsula. 'Initially working to support the New Zealand Antarctic Heritage Trust (NZAHT) in raising funds for the conservation of heroic era huts in the Ross Sea Region of Antarctica, in 1993 UKAHT was born through the vision and energy of founding Chairman John Hamilton, who was inspired by the need to recognise and conserve Britain's long and distinguished history of exploration and scientific research' (UKAHT, no date). Following a conservation survey of several abandoned British bases, undertaken in 1994 by the British Antarctic Survey (BAS), on behalf of the Foreign and Commonwealth Office (FCO), four bases were designated as Historic Sites and Monuments (HSMs) under the Antarctic Treaty. In 2009 following UKAHT's increased work on the Antarctic Peninsula, a further two bases were designated as HSMs. In total, 85 sites that 'echo human's' first contact with the continent, and of Britain's pioneering role in the heroic age of Antarctic exploration' (British Antarctic Survey, no date) have been designated. These include rock cairns, monuments, flag poles, crosses, tractors and boats and of course, huts or former research stations. The former research stations are owned by the British Antarctic Survey (BAS) and are managed by UKAHT under a Memorandum of Understanding. The Trust's vision is to ensure that the legacy of pioneers in British Antarctic science and exploration is preserved for a global audience and future generations to enjoy. Physical heritage of human endeavour is managed through a sustainable conservation programme (UKAHT, 2020).

Katabatic winds, freezing temperatures and sea ice on the remote Antarctic peninsula are just some of the hostile conditions faced by UKAHT. Despite such adversities, the Trust have taken on the challenge of managing 6 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 (later named the Antarctic Peninsula Heritage Conservation Programme). With the appointment of a new CEO in 2014, it was decided that a more informed and managed approach to the conservation of the historic sites within the portfolio, and the way the trust executed their responsibilities, must be established. Ad hoc maintenance, the use of incorrect materials and a lack of conservation philosophy to support maintenance and repair decisions was not acceptable conservation practice yet was not an uncommon position for the Trust to find themselves in. Dann & Wood (2004) and Dann *et al.* (2007) have previously discussed the lack of common structured processes for conservation repair and maintenance, and Forster & Kayan (2009) have discussed that when processes are implemented, they are not always successful. The reason for this is something that needs to be explored further.

In October 2017 the Author was appointed by the UK Antarctic Heritage Trust as a Heritage Programme Manager/Building Surveyor on a 12 month contract. The scope of the contract was to oversee and coordinate the UKAHT Heritage Management Programme, to manage the design team, project architects, conservation team and external Consultants, Contractors and volunteers. The role allowed for active participation in heritage asset management and the development of processes to support this activity, along with coordination of the collection of geospatial data, and use by the project architects.

The English Heritage Trust

The English Heritage Trust (formerly English Heritage) was formed in 2015 as a result of 'The New Model'. 'The New Model' resulted in English Heritage being split into two organisations – Historic England and The English Heritage Trust.

Historic England is an executive, non-departmental public body sponsored by the Department for Digital, Culture, Media and Sport (DCMS). They are the government's statutory advisor on the historic environment, championing historic places, and helping people to understand, value and care for them. Historic England are responsible for protecting historic places through the listing system and they publish an extensive range of expert advice and guidance available publicly and free of charge, to help individuals care for and protect historic places.

The English Heritage Trust is a charitable trust who are responsible for the management of the National Collection, which remains in public ownership. Following the formation of the 1913 Ancient Monuments Act, which gave the Government powers to take historic buildings and sites into public ownership, hundreds of historic sites and monuments have been acquired creating the National Heritage Collection which includes over 400 sites and monuments:

59 Prehistoric sites – including Stonehenge
56 Roman sites – including parts of Hadrian's Wall
116 Castles and forts
32 Houses and gardens
90 Ecclesiastical sites
Industrial heritage – such as J W Evans silver factory in Birmingham
58 Statues and monuments
34 Domestic medieval buildings
Historic bridges, great barns, deer houses and cold war bunkers.

The registered charity is overseen by a board of trustees and the day to day running of the organisation is delegated to a senior management team. The aim of the Trust is to bring the story of England to life to over 10 million people each year. The charitable purposes of the Trust focus on the stewardship, conservation and public enjoyment of the National Heritage Collection in line with the National Heritage Act 1983. Securing the conservation of the National Heritage Collection is managed through the Asset Management Plan (AMP) and delivered by the English Heritage Trust Estates team. The Trust have embarked on the largest conservation programme in their history.

The researcher was employed by The English Heritage Trust as a Conservation Maintenance Project Manager when this research began in October 2016. This role involved the delivery of conservation projects under the asset management programme. The researcher had been employed by the Trust since 2013 and in a previous role had been involved in the development of the organisation's asset management database. The role allowed active participation in heritage asset management and the development of processes to support this activity. Relationships with the organisations also contributed to later access for research.

Organisation A

Organisation A is a global, public service provider managing 100's of contracts worldwide and employing tens of thousands of people. In this research one particular UK contract where Organisation A provide a total facilities management (FM), including Hard and Soft FM, is studied. The estate comprises buildings ranging from listed buildings to mid twentieth century military buildings and large modern facilities. Hard facilities management (FM) refers to physical structures such as buildings, plant and services and includes preventative and reactive maintenance including regulatory maintenance requirements under the Workplace (Health Safety and Welfare) Regulations 1992. Such contracts also include asset renewal or replacement programmes, otherwise referred to as asset management. For the purposes of this research, only the Hard FM elements of the contract that relate to asset management are studied.

The Hard FM contract studied includes:

- planned and preventative maintenance (PPM)
- a reactive maintenance service to the Customer
- the delivery of service variations such as building refurbishments and capital investment projects
- lifecycle asset replacement/management for the estate

Organisation A is typical of many public service providers who offer a range of Hard and Soft facilities management across large estates with a range of building types. Such organisations might be responsible for asset management for University, Hospital, Retail or Government estates. In contrast to the Trusts responsible for heritage estates, these private companies are large, profit making organisations managing many different contracts and estates. Often these organisations have central/head offices setting company or group operating models and standards, with separate teams managing individual contracts in line with the group operating standards and procedures. Outsourcing of FM services is not uncommon in the public sector, and in the growing FM academic discipline the benefits of in house or outsourced FM services has been widely discussed (Haugen & Klungseth, 2017). Matters of improved efficiency in the management of resources contribute to management strategies that seek to outsource such services and as such, private FM providers 'have begun to redevelop and rebrand their various range of services as a way of attracting interests from prospective Clients' (Ikediashi & Okwuashi, p60, 2015).

Active participation in the delivery and development of asset management projects and processes was undertaken with Organisation A between November 2018 and November 2020.

4.3 Participant Observation

Participant observation is a qualitative data collection method often used in the social sciences. It allows researchers to experience human behaviour in particular contexts through immersion and observation. Through literature review it was observed that the implementation and adoption of digital, formal processes such as BIM is often hampered by silo working, failure in collaboration and entrenched ways of working (Dulaimi *et al.,* 2002; Harty, 2005). It was further noted that understanding barriers to implementation are key to understanding how successful a new technology might be. Key themes relating to such barriers were identified through the literature and included; Stakeholders, Skills and Attitudes and Funding & Resource. Existing research that has considered the adoption of new technological innovation, or digital, formal processes in the AEC industry and beyond uses participant observation to gain further knowledge of organisations, their existing operations and processes, the organisational structure and resource, and how new processes are adopted and used (Linderoth, 2010; Davies & Harty, 2013;Cresswell *et al.,* 2011). More specifically, while observation has also been used to analyse required information for O&M, FM or asset management, and how information is used and managed, this is conversely noted as often missing from research that seeks to propose new processes or workflows (Cavka *et al.,* 2017), along with observation of engagement with new or proposed processes. Identified as a critical approach to understanding the challenges of heritage asset management and how digital, formalised processes might support conservation professionals, participant observation has been used throughout this research.

The following areas would need to be considered when using participant observation, including the information that was required:

- Develop experience in conducting participant observation and identify where this might be most appropriate for collecting research data
- Consider access opportunities and limitations
- Understand how the data can be analysed and findings can be reported
- Observe digital and formalised processes considered to offer benefits for asset management and how people engage with these
- Observe people and organisations delivering asset management in heritage and non-heritage contexts to understand existing processes and challenges faced
- Consider the ANT method – follow the action and trace network elements
- Identify material / technological as well as social / organisational elements or actors and the associations between them

To gain experience in participant observation, particularly in a heritage environment and working with a range of stakeholders, a 'mini ethnography' was undertaken – 'Winter at Witley Court'. Voluntary work in the gardens team at the English Heritage site, Witley Court in Worcestershire from 6th December 2016 to 14th December 2016 provided an opportunity to develop skills in participant observation, studying, and writing about the people of the Winter heritage garden team (Ingold, 2014). The process of selecting the site provided further experience in the practical issues of doing ethnography. Gaining access, particularly to organisational settings, and finding a suitable role can be a challenge (Silverman, 2013). Witley Court was selected as it allowed access to a range of stakeholders working in a heritage context. As the team already included volunteers it was not difficult for the team to accommodate a further volunteer. The team included the Head Gardener, three further employed gardeners and 4 volunteer gardeners. During the placement, the researcher worked directly with the garden team, meeting daily at 08:00 in the site cabin, discussing the day's tasks and working in groups throughout the day completing activities such as collecting and chipping logs, cutting back dog roses and clearing privet from the car park. Observations were gathered in field notes.

Verbal informed consent was provided by all participants and this was recorded in the field notes. It was noted that this was a difficult part of participant observation. Starting the conversation to request verbal consent, explaining the research and the purpose of the participant observation felt awkward, and in most cases the other participants, while happy to give consent, still had no idea why the researcher was there. One participant, while clearing one of the car park areas, said '*I like these loppers, they're good. You can put that in your research!'.*

It was further identified how it can be difficult to pick out relevant information from conversations or steer conversations in a particular direction to try and answer planned questions, and to ensure that field notes accurately capture what has been discussed. It was also noted that it felt difficult to know what information, observations or conversations to record. Clearly, not every single conversation or observation could be recorded and so, identifying those that might be pertinent to whatever research is being undertaken is a skill in itself.

Figure 4.1 Witley Court (www.english-heritage.org.uk)

The study at Witley Court was a useful introduction to participant observation and helped to identify the type of observations that would be required to gather data relating specifically to the research question. It provided an opportunity to test a 'follow the action' method. Further, the experience helped to decide when participant observation or an alternative method might be more appropriate. A PowerPoint presentation was produced as an output of the study which summarised the following points that would be useful in any future participant observation and the ongoing research:

- Consider initial questions as conversation triggers to gain required research data
- Accept that you do not know what you are going to find out at the outset
- Employees may be reluctant to chat openly for fear of saying 'the wrong thing'
- Emerging themes may be identified through the research for later analysis

Noting that it is important to accept that you do not know what you will find out at the outset of a project of participant observation further demonstrates the potential of the ANT method. Approaching the fieldwork without any 'a priori' assumptions allows network elements to be traced and action to be followed without boundaries.

Between May and June 2017, with a further three 2 week periods across 2018, a research placement with Historic England in the Geospatial Imaging Team in the York office was completed. This team is responsible for research into geospatial imaging for the historic environment, providing geospatial imaging services to Historic England departments, and as a shared service to departments within the English Heritage Trust. Access was provided as part of the Collaborative Doctoral Award with Historic England and the team saw the researcher as a sort of 'intern' who was there to learn about the work they undertake and gain experience in undertaking geospatial surveys as part of their research. During this time participant observation was conducted, and field notes made relating to the activities undertaken by the departments that she was exposed to. The range of activities included:

- Geospatial Team Meetings – review of projects
- Assisting and observing the team while carrying out geospatial surveys
- Observing the team and learning how to process survey data and produce rendered point clouds or CAD drawings
- Observing the team providing training in the use of laser scanners and photogrammetry
- Attending the BIM 4 Heritage Committee meetings

With prior knowledge of both English Heritage and Historic England participant observation was found to be difficult. While the method should be considered an opportunity for the outsider to 'look in' on the group of people, organisation or process, the researcher's past experience, assumptions and ideologies impact what is observed, what is recorded and how this is analysed (Silverman, 2013). Identifying which information and observations to record was found to be problematic. It is considered that the reason for this might be that both placements had a principal aim to develop skills in participant observation rather than collecting data for analysis that directly related to the research questions. The researcher found that detaching herself from the research question and her own prior knowledge of the organisations while focusing on developing the participant observation skill was extremely difficult.

The Witley Court project provided purely experience in participant observation with very little data used for analysis. However, field notes taken during the Historic England placement were subsequently analysed to identify heritage stakeholders and how they collaborate and engage with existing heritage asset management processes, including documentation, information and technology. All stakeholder engagements were recorded along with the general theme of each engagement. Identified network elements were also recorded.

4.4 Active Participation

This section has been provided to distinguish between the participant observation conducted at Witley Court and Historic England and the active participation conducted at the UK Antarctic Heritage Trust and Organisation A. While participant observation has been acknowledged as the researcher 'looking in', being involved in processes, shadowing, learning, observing and taking notes for further analysis, active participation in this research involves the researcher being employed by an organisation and being actively involved and responsible for making decisions about the processes being studied.

Between July 2017 and July 2018, in the role of Heritage Programme Manager for the UK Antarctic Heritage Trust, active participation was conducted. This was a strategic management role in which the researcher was responsible for developing and implementing a programme of survey and subsequent conservation repair and maintenance projects across all British historic huts on the Antarctic Peninsula in the care of the UK Antarctic Heritage Trust. The role was undertaken as a self-employed consultant, working from home and visiting the Cambridge office on a weekly basis to meet with members of the team and discuss and agree various tasks. The role also included direct Project Management of emergency repair and condition survey at Base E, Stonington Island between December 2017 and April 2018 during which time the researcher travelled to Antarctica with the Conservation team and worked on site on Stonington Island. The team lived in tents on the ice for 3 months and worked 6 days a week carrying out surveys, conservation repairs and maintenance. As agreed with UKAHT, academic research was conducted in parallel to the daily activities of CRM planning in the UK, and onsite surveying and recording during the time spent in Antarctica. Colleagues were aware that the Heritage Programme Manager was also conducting PhD research but in general did not ask any questions about the research or what it involved.

Figure 4.2 Conservation Teams Tents, Stonington Island, Antarctica (Source: Joanna Hull)

To give further context, a description of Stonington Island and the historic sites and monuments are provided. Stonington Island is a small, rocky island located off the west coast of the Antarctic Peninsula in Marguerite Bay. The island can be circumnavigated easily at just 0.4 mile long and 0.2 mile wide. Until recently, the island was connected to the Antarctic mainland by an ice ramp, the terminus of the Northeast Glacier, which made it an ideal expedition base. The location offered sledging routes and opportunity for extensive ice travel required for research and surveying. Providing a base for 3 expeditions, Stonington Island is rich in Antarctic research history.

East Base was established and occupied by the US Antarctic Service Expedition between March 1940 and March 1941. The base was also reoccupied by the Ronne Antarctic Expedition between March 1947 and February 1948. East Base comprises a number of buildings. The shed and machine shop are now collapsed with just the timber floor of the machine shop evident. The science building is derelict but is generally intact and contains a fair number of artefacts. The bunkhouse is derelict and only partially accessible. The Ronne Hut is generally intact but now derelict. There are no artefacts remaining. The series of structures were once connected by tented walkways as illustrated by the dotted lines on Figure 4.3.

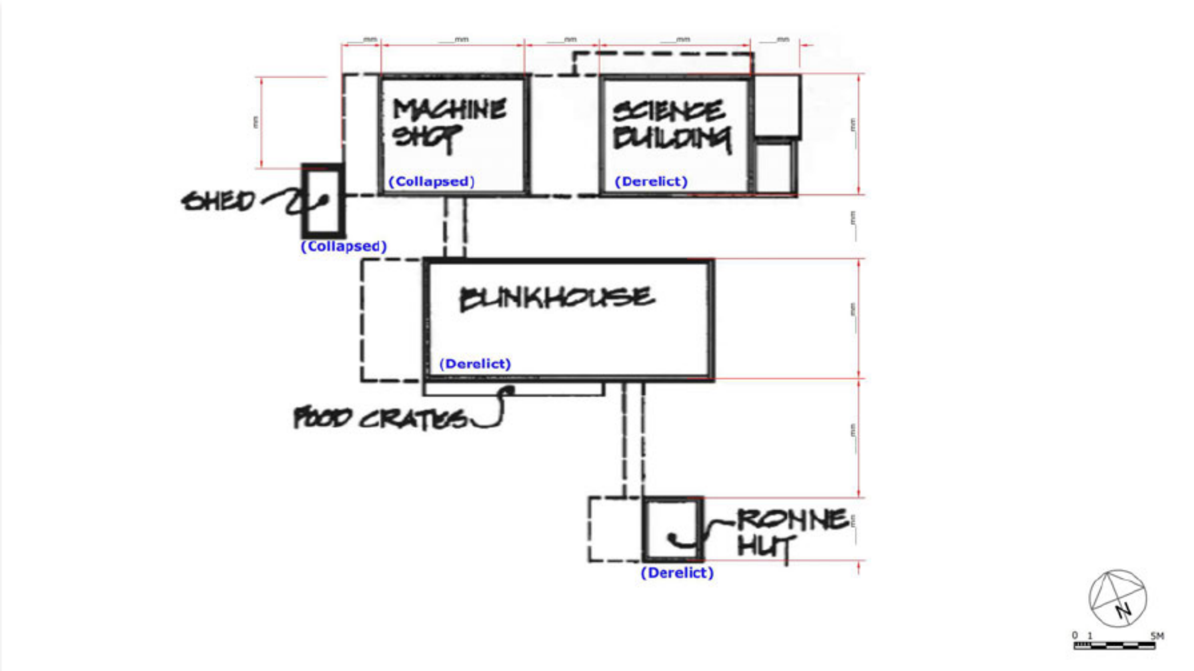


Figure 4.3 Sketch of the East Base complex, Stonington Island, Antarctica (Source: UKAHT)

Figure 4.4 Photograph of East Base, Stonington Island, Antarctica (Source: Joanna Hull)

Tracked vehicles brought to the Island for the American expedition are still visible when the snow melts, along with a number of timber crates and containers around the perimeter of the buildings.

Figure 4.5 Photograph of tracked vehicle in the snow, Stonington Island, Antarctica (Source: Joanna Hull)

While East Base is American and conservation repair and maintenance does not fall to the UK Antarctic Heritage Trust, the Trust supports America and have undertaken emergency conservation repairs where possible to ensure the future of these historic structures.

In February 1946 Base E was constructed by the British Government's Falkland Islands Dependencies Survey (FIDS). The timber, single storey hut was named 'Trepassey House' and included a greenhouse. The base closed in 1950 and reopened for a further year between 1958 and 1959 but the difficult sea conditions and access to Stonington Island forced its closure. The only evidence of Trepassey House today are several rocks and timbers that indicate the former footprint of the building after being burnt down in stages between 1973 and 1974.

The location and strategic importance of Stonington Island however prevailed, and a new Base E was constructed in 1961. The new construction was the first two storey (double decker) building in Antarctica and comprised both timber and steel frames. The hut was extended with additional single storeys in 1965 and 1972. Base E was closed permanently in 1975.

Figure 4.6 Photo of Base E, Stonington Island, Antarctica (Source: Joanna Hull)

The Base E complex includes a number of further structures which include:

- The Generator Shed
- Pup Pens
- Radio Masts
- Anemometer
- Water Tank
- Former Hangar
- Emergency Store
- Flagstaff
- Memorial

Figure 4.7 Photo of the Former Hangar, Stonington Island, Antarctica (Source: Joanna Hull)

All of the structures are significant as part of the overall Base E complex, and were all surveyed during the field season. Base E, the generator shed, emergency store and pup pens are the only structures that are complete in the sense of having walls and a roof etc. Conservation repair and maintenance was limited to these structures.

With Base E being a centre for mapping, it demonstrates a quintessential FIDS base that depended largely on dog sledge for travel. The pup pens are therefore of particular significance.

Figure 4.8 Photo of the Memorial, Stonington Island, Antarctica (Source: Joanna Hull)

Figure 4.9 Pup Pens, Stonington Island, Antarctica (Source: Joanna Hull)

Further evidence of dogs in Antarctica and their historical artefacts remain within Base E. Room 3 within Base E still includes hooks used for holding dog leads and equipment with the walls bearing the names of the various dog teams. Dog teams were like football teams, occasionally team members were switched in favour of new blood but the general principle was 'once a team member, always a team member' (Walton & Atkinson, 1996). There were 45 teams formed for the British Antarctic Survey and many spent time on Stonington Island.

Figure 4.10 Dog Team Hooks, Base E, Stonington Island (Source: Joanna Hull)

The initial task when joining the Trust was to understand the way their heritage data was managed and how this was used for the planning of conservation repair and maintenance (CRM) activity. Processes were initially adjusted working in collaboration with the various stakeholders, such as the Conservation Team and project architects, so that a full set of documents and processes for collecting and managing historic building data was in place for the onsite period on Stonington Island. During this time a variety of data was collected, all recorded as field notes in notebooks, recognising that there was a need to understand the relative influences of both the personnel and the technologies being used in order to further develop processes for the overall heritage management programme. In addition to the quantitative data that was generated through the work activities, using lessons learnt from the participant observation cases described previously the researcher maintained a flexible approach to documenting significant qualitative data. For such data an ethnographic approach beginning without any 'a priori' assumptions was adopted, the intention was to 'follow the action' (Latour, 2005) to see what information or themes emerged. While this was easier than previous cases since the researcher had not previously worked for UKAHT, the same personal interests, previous experience and preconceptions are considered to have impacted what data was recorded and how this was analysed. Further, as the manager of the team, it was difficult to not make notes that critiqued the existing processes or existing staff in order to make changes. This is a clear management role but is not following the action. With a clear objective of obtaining data that could by analysed to demonstrate existing heritage asset management processes and how digital, formal processes might support the activity, this could have limited the observations that were made. Effort was made to maintain the ‘follow the action’ method and successfully record data about the network of human and non human actors that has been subsequently processed. Data was recorded in a series of diaries that were made during the project. Data included:

- Observations of team members, their roles, how they worked, their engagement with processes etc
- Observations of wider stakeholder groups such as cruise ship visitors
- Observations of non human actors – technology, birds, jerry cans etc and their impact on the work undertaken and the various processes
- Details of existing processes and observations relating to the pros and cons of these

During data analysis, field notes and diaries were reviewed and a highlighter was used to pick out recurring issues or themes, particularly around existing processes. Key network elements were identified to allow further analysis, included key stakeholders and data relating to skill, experience and role.

Despite a positive start to this role, the researcher was surprised by some of the challenges presented to her as both the heritage programme manager and researcher. There were personal issues that led to some resentment of the role – she had replaced her colleague’s Wife in the role of programme manager. Furthermore, she was initially the only female on the team. UKAHT had also employed the services of the New Zealand Antarctic Heritage Trust’s Programme Manager to support the conservation team which led to some difficulties in establishing correct lines of communication and the introduction of new processes. Finally, one of the Conservation Carpenters had applied for the programme manager role and been unsuccessful. These tensions caused a difficult working environment which in turn led to some negativity around any research activity conducted. The recording of observations in field notes was seen as ‘spying’ rather than a positive contribution to both the development of the Trust’s heritage asset management programme and contribution to knowledge in the heritage field. A number of sarcastic comments were made making the situation very uncomfortable. Furthermore, other members of the team had not considered the amount of time that would spend on writing up research notes and gathering notes about the development and implementation of processes as part of the programme manager role. Roles had not been clearly defined and communicated prior to the time spent on site in Antarctica which was a mistake.

In regard to the socio-technical approach and ANT method, both participant observation and active participation through ethnographic fieldwork and, the recording of diaries for later analysis, was an effective way to record action or trace networks. The Antarctic fieldwork provided an ‘unknown’ experience which allowed a more effective discovery of action and network elements than the more well known situation of other case studies. The case reminds the author of a ‘snowy’ version of the historic John Law paper on the case of Portuguese maritime expansion (Law, 1987). The *heterogeneous engineering* of snow, batteries, jerry cans, solar panels, paper templates and so on to create a stable, or relatively stable network of components shows many similarities.

4.5 Interviews

During the placement with Historic England, interviews were arranged with stakeholders and contacts provided by the Geospatial Imaging Team. Due to the nature of these meetings, arranged as informal ‘catch up’s’ between the Geospatial Imaging Team manager and the various participants, interviews were informal and questions were based on the type of work the stakeholder was undertaking, the technology they were using and observations they had made. Notes from informal interviews were recorded in notebooks and subsequently analysed to pick out typical practices of the various organisations and key themes identified during discussions. A record of the informal interviews conducted during the placement were compiled in a spreadsheet, Table 4.2 Record of informal interviews (overleaf), along with a summary of the discussion which notes key areas of work, and finally the key themes or findings.

Table 4.2 Record of informal interviews

Research Interviews				
Date	**Organisation**	**Contact Name**	**Area of work / discussion / research**	**Key findings / themes**
03/05/2017	North York Moors National Park	Tom Mutton - Programme Manager	This Exploited Land of Iron Project - digital recording of industrial heritage sites prior to conservation works. Historic England were providing photogrammetry training to staff and volunteers which will assist in the data capture process.	Limited digital skills Volunteer input Photogrammetry and rendered point clouds for visualisation and engagement.
12/05/2017	Greenhatch Group	Andrew Dodson / David Strange-Walker	Company providing surveying, laser scanning and 3D modelling services.	Only provide 'BIM Ready' models Lack of information on how Clients use models Essentially providing 3D CAD for visualisation.
17/05/2017	Hexagon - Conference	N/A	Demonstration of various laser scanners including specifically the new - Leica BLK360.	Technology is becoming more accessible.
18/05/2017	Kennedy O'Callaghan Architects	Kennedy O'Callaghan	Project architects for UKAHT. Interested in BIM. Using 3D CAD for project planning.	Still at 3D CAD stage rather than BIM. Use SketchUp rather than REVIT.
26/05/2017	AHR - Architects and Surveyors	Lee McDougall	Undertaking BIM work and working with Estates that carry out Hard FM/O&M.	Most BIM take up is from new build. With O&M / existing portfolios, there is no appetite for BIM.
Unrecorded	English Heritage	Carmel O'Grady - Documentation and Process Review Advisor	Came to geospatial team for help and advice with measured drawings to use for collections/display - space planning and logistics etc. There is not a set of base data - measured drawings within EH. All different departments using their own plans, in different formats and mostly not measured.	Information management Lack of collaboration
08/06/2017	English Heritage	Carlos Lemos - Graphics Manager / Guide Books	Interested in geospatial team provided 3D data capture / point cloud from laser scanning (and photogrammetry if required) in order to use the point cloud to create plans and models for use in Guide Books etc. Carl is looking at putting the point cloud into SketchUp to do his models using the UnDet plug in.	Information management Lack of collaboration
21/06/2017	VAM-iS / Spheron	Barry Bassnett	New technology that captures 3D data.	Technology is becoming more accessible.
07/07/2017	Ramboll	Carl Brookes	Carried out BIM case studies/research for Historic England on Ironbridge and Harmondsworth Barn.	BIM research for Heritage contexts Used for visualisation and monitoring

The interviews provided a wide range of data due to the varied stakeholders/organisations involved. These were not specifically targeted at gathering data in relation to specific questions or objectives, instead aimed at gaining knowledge and understanding to support the literature review.

Interviewing as a research methodology however can be particularly useful in obtaining answers to specific questions. Where the researcher is not able to undertake long term observation or where access might be limited, using interviews to gather data on things such as organisational processes, systems, user skill and experience for example can be a quick and effective method 'allowing indepth analysis from a relatively small sample size' (Young *et al.,* 2018). Furthermore, interviewing places the focus of research on the views of users or participants (Young *et al.*, 2018) which is extremely useful in understanding challenges faced in particular situations, such as heritage asset management, or how and why formal processes may or may not be adopted by users. Interviewing is a common methodology used in research that has been considered in the literature review (Becerik-Gerber *et al.*, 2012; Cavka *et al.*, 2017; Galiano-Garrigós and Andújar-Montoya, 2018; McGibbon *et al.*, 2018).

With a need to gather data and an understanding on existing heritage asset management processes, and with digital, formalised processes as a primary focus, the researcher identified the work of Historic Environment Scotland through literature review. Access to this organisation was limited, however interviews provided an opportunity to ask specific questions and trace the systems and processes used. On 31/05/2018 a formal interview via telephone was held with the Head of Conservation at Historic Environment Scotland. Due to the collaborative work undertaken between Historic Environment Scotland and the British Geological Survey (BGS), a further interview with BGS was conducted on 13/06/2018. To ensure as many major UK heritage organisations were covered as possible, a further interview with the Head of Digital Information Management at the National Trust took place on 06/07/2018. These interviews were semiformal with a small number of set questions about existing heritage asset management and information management processes. Notes from the interviews were made in notebooks. The primary goal of the interviews was to:

- Gain an understanding of existing heritage asset management processes

In a similar fashion to all other data gathered in notebooks as a result of fieldwork, observation or interview, all notes were later analysed by rereading through all the notes, highlighting common themes, and picking out things such as heritage asset management processes, information requirements for heritage asset management, key stakeholders and network elements. Although three interviews is a relatively small sample, data gathered from the full range of interviews was combined with data from participant observation, active participation and secondary data leading to the mixed methods approach. In terms of gaining an understanding of existing heritage asset management processes it is acknowledged that the number of UK organisations with such processes in place is limited to the major heritage organisations and so the selection of interviews is based on this fact.

An interview with a conservation data manager at Historic Environment Scotland took place on 01/08/2018 and finally an interview with Lendlease BIM Manager was conducted on 22/08/2018. Consent forms were completed prior to all interviews and each interview was recorded. These were subsequently transcribed into written notes.

The noted interviews, and the prepared questions (Appendix 1), had two main objectives:

- Gain an understanding of how conservation professionals define BIM or Heritage BIM
- Understand views on how BIM technology and processes could improve / facilitate digital data management for conservation repair and maintenance activities

Access to professionals with an understanding of both BIM and Heritage for formal interview was limited and so the results of these interviews has a positive bias towards the potential of BIM to support conservation repair and maintenance activities. In such a case a questionnaire to a wider range of stakeholders may have provided a broader range of data for analysis.

Throughout February, March and April 2019 the researcher met with four English Heritage staff each of whom worked in the Estates department. Semiformal interviews were conducted with a view to gaining a deeper understanding of how heritage asset management is delivered by one specific organisation. Questions and discussions were aimed at gaining an understanding of the different roles undertaken, the processes followed in the heritage asset management process, and how heritage data is collected, managed, and used for the planning of CRM. The primary aim however was to gain a detailed understanding of the existing asset management database used by English Heritage to support their heritage asset management activities and the user experience of this. A specific range of questions was posed to each participant, but notes were also made about the conversation, the direction it took and the information that it revealed. Interview notes were written in a notebook. These notes were subsequently typed up and grouped into particular themes as follows:

- System functions
- Documents used
- Information used for CRM
- Condition survey and data capture
- General comments

The noted interviews are recorded in Table 4.2 below.

Table 4.3 Record of formal interviews - English Heritage Trust

Survey Data Manager	27/02/2019
Building Conservation Manager	28/02/2019
Head of Survey and Asset Management	28/02/2019
Territory Project Manager	13/03/2019

Interviews provided a wide range of data that has been analysed and used throughout the research. While interviews were arranged specifically to meet particular research objectives, selecting appropriate interviewees from identified heritage organisations, the limitations of this approach are acknowledged. Sample sizes are small, and while informal interview was proposed to allow information to be revealed, it is acknowledged that the collected data would need to be analysed along with data from other methods.

While it was hoped the informal approach would reveal new or surprising information for analysis, she found that due to her existing knowledge, particularly of English Heritage, data collected and grouped into 5 themes was as expected.

4.6 Document Analysis

Through interviews held with staff at the English Heritage Trust, where the aim was to understand existing heritage asset management processes, 'Documents used' was highlighted as a key theme emerging from each of the conversations. During such discussions, the researcher was shown documents used by the team in the CRM process. Some of these are fixed documents such as reports or policy documents that are used as a source of information, while others are documents that are to be completed by staff during the CRM process, such as consent application forms or scripting spreadsheets for recording survey data so it can be loaded into the asset management database. Following interview with the Head of Survey and Asset Management the researcher was further provided a number of documents that have been developed to support the Trust's asset management plan. In this case, the content of documents was studied to gain an understanding of asset management strategy, formalised processes and information requirements for CRM planning.

Further secondary data was gathered and analysed from a number of published documents while trying to identify critical information requirements for CRM planning. The aim was to consider the type of information available within different documents, establish data categories and understand how this information would be used in the CRM process. Guidance published by heritage organisations was selected as the primary source of information owing to such organisations being the leading bodies when it comes to CRM. An extensive search of freely available, published guidance was conducted using internet searches. A specific search for *critical information requirements for heritage asset management* or *critical information requirements for conservation repair and maintenance* offered few results and so a number of criteria were defined in order to select relevant data from the wider literature search;

- Published by UK registered charity responsible for the management of national heritage
  Or
- Published by UK government advisor on the historic environment

- Guidance/Document aimed at those responsible for the management of national collections, heritage estates or heritage assets within local authorities rather than individual property owners

- Document title refers to heritage asset management, heritage assets or heritage management
  Or
- Document would be used in the process of heritage asset management or CRM planning

6 key documents, published by 4 different heritage organisations, were identified:

1. Heritage Assets Data Template as developed by Historic England
2. English Heritage Asset Management Plan 2011-2015
3. English Heritage Sustainable Conservation Strategy and Asset Management Plan 2019-2023
4. Historic Environment Scotland Asset Management Plan for the Properties in Care of Scottish Ministers 2018
5. English Heritage K2 Basic User Guide
6. CADW - Managing Scheduled Monuments in Wales

The content of each document was studied and through analysis it was identified that all documents fell into two broad categories. Moreover, data analysis allowed for critical information requirements for CRM planning to be identified which were subsequently recorded in a spreadsheet under seven different categories.

In both the active participation roles of Heritage Programme Manager for the UKAHT and within Organisation A, the first task was to understand the organisation’s existing processes for asset management/CRM planning. Initially this involved a review of existing documents and their content, but more critically a need to understand how the content was being used, how the documents had developed, how the documents themselves were being used, and the ongoing development of the documents.

Prior (2011) identified four routes to the analysis of documents which include:

- The study of content
- The social construction of documents and records
- Documents in 'the field'
- Documents in action and documents in networks

As noted above, the study of content is useful for collecting certain data such as – specific information requirements and defined processes however, document analysis through fieldwork, involving more than just analysis of document text, is particularly useful for gathering data on how documents are being used. Taking images of documents, observing how documents are used by people, how they are used in different formats, and asking individuals about documents (Silverman, 2021) is another method that follows the action, often 'triggering chains of interaction far beyond the original piece of paper' (Silverman, p168, 2021) and supporting a socio-technical networks oriented approach to research. Taking the ANT approach into consideration, documents could be considered actors themselves. While people use documents, documents themselves create action.

While a range of documents at both UKAHT and Organisation A were studied, as discussed in later chapters, one document used by UKAHT was studied in detail:

- recommendations for future work template

Documents were studied in terms of identifying critical information requirements for CRM planning, but also to consider how people use certain documents, and how they engage with digital or formalised processes.

As demonstrated above, during this research several routes of document analysis are used. Of the four routes of analysis proposed by (Prior, 2011) the researcher has selected to categorise all documents used into either the study of content, or the study of documents in action and networks. These are summarised in Table 4.3.

Table 4.4 Record of document analysis method applied to various documents

The study of content	Documents in action and documents in networks
AMP 2011-2015	Recommendations for future work template
SCAMP Final March 2019	Record of completed works template
K2 Basic User Guide	Asset data capture spreadsheet
EHS 0003/3:2013 K2 Naming and Numbering Standard	UKAHT HSM Gazetteers
Annex 5 Scripting Spreadsheet	UKAHT Conservation Management Plans
Application for Tier 2 Consent – Supporting Document	Building Reports
Historic England Heritage Assets Data Template	Building Plans
Historic Environment Scotland Asset Management Plan 2018	UKAHT Window and Door Schedule
CADW Managing Scheduled Monuments in Wales	UKAHT Sampling Worksheet_Master

Document analysis, through both the study of content and the study of documents in action was successful in providing data relating the following research objectives:

- How does conservation asset management differ from conventional asset management?
- How do people engage with formal process and guidance and, why do they not always follow it?
- What features would Heritage BIM need to have to support conservation professionals?

This method of data collection was found to be most appropriate, particularly from a 'follow the action' perspective as there was a focus on which action to follow. The UKAHT case study allowed documents to be easily identified, a study of their content and structure, observe how people used the documents both in digital and analogue format, and trace a network of actions surrounding the use of the documents.

4.7 Methodology summary by case study

This section reviews the methods noted above and how they have been applied within each case study. Case studies were developed in order to answer the four key research objectives which are repeated here as a reminder:

- How does conservation asset management differ from conventional asset management?
- How do people engage with formal process and guidance and, why do they not always follow it?
- What features would Heritage BIM need to have to support conservation professionals?
- What are the specific challenges that conservation professionals face when engaging with BIM?

As described in section 4.1, a mixed methods approach offers a range of data that has been used and analysed dependent on the particular case study research objectives. Using the 'follow the action' approach, questions that emerged from each case study are recorded and used to develop subsequent case studies.

In Chapter 5 asset management in heritage and non-heritage contexts is compared by studying how each of the key organisations noted in section 4.2 plans and delivers their asset management repair and maintenance activities. Four research questions were established and the data required to answer each question was identified. This is detailed further within Chapter 5. Active participation was undertaken as an employee of both UKAHT and Organisation A to study asset management processes and all data was recorded as field notes. Although the researcher had prior knowledge of the asset management processes of English Heritage, interviews were used to gain further and up to date knowledge. Interviews were typed up and topics were grouped thematically for subsequent review and analysis. Both active participation and interviews highlighted the importance of documentation in the asset management process and so document analysis was used for all three organisations. Both the study of content, and the study of documents in action were used to develop a complete picture of asset management processes in heritage and non-heritage contexts.

As a result of findings from the case study described in Chapter 5, Chapter 6 builds upon the objective to compare asset management in heritage and non-heritage contexts and focuses on the need to identify critical information requirements for effective heritage asset management, referred to as conservation repair and maintenance (CRM) planning. The case study uses document analysis to identify the critical information requirements for CRM planning. Document analysis in this case study is primarily limited to the study of content. The case study uses two layers of data collection; first secondary data was gathered and analysed from a number of published documents. Data was analysed and categorised in order to produce a initial set of critical information requirements for CRM planning that are subsequently proposed as a framework of conservation data parameters that may be used for heritage asset management. Second, documents identified as 'relevant data sources' by UKAHT in their heritage management programme were studied in detail to answer two questions:

- Do heritage organisations have this information readily available?
- Are they using this information and is it successful?

In response to reported issues surrounding the implementation and adoption of new technologies and processes, and a failing in the development and implementation of structured and standardised approaches to heritage maintenance management, the empirical vignettes described in Chapter 7 aim to provide data for analysis to understand how people engage with formal process and guidance and why they do not always follow it. Further, the data allows analysis of the issues identified when implementing heritage asset management. An overlap between social organisations at different scales and their range of stakeholders, the implementation of technological innovations, practical issues and diverse user requirements have been highlighted in the literature, offering justification for the adoption of a socio-technical networks oriented-approach to this research.

Using participant observation, active participation and document analysis, the principal case studied is the new data management process established by UKAHT during their Stonington Island, Base E conservation project which formed part of their wider Heritage Management Programme. While actively involved in the development of the new data management process, observations were made about both human and non-human actors surrounding the new process. Observations were recorded as field notes for future analysis. Second, interview data from the study conducted at English Heritage was further analysed to see what additional information presented itself with regards to how people engage with formal processes and guidance.

Chapter 8 considers how digital, formalised processes, such as BIM could support conservation professionals, and specifically reviews the features that Heritage BIM would require. The specific challenges heritage professionals face when engaging with BIM is also considered. The overarching objective is to present a digital, formal process to support conservation professionals with information management for CRM. Data gathered through the mixed methods approach was reanalysed from a different perspective. Instead of considering the similarities and differences of asset management in heritage and non-heritage contexts, here the data is analysed to consider information management systems and functions, management processes and roles and responsibilities between the organisations. Asset management system functions more specifically are compared to those within in a BIM system to identify commonality. Through this analysis it is demonstrated that BIM systems offer the potential to support conservation professionals with heritage asset management and so, a proposed method – The Heritage Information Management (H-IM) Workflow, is described.

Chapter 8 is intentionally different to other chapters. While theoretical research, including critical literature review, data gathering and analysis, BIM lenses and socio-technical network approaches, offer an academic contribution of knowledge the proposed Heritage Information Management (H-IM) Workflow is offered as a contribution to practitioner guidance, for use in industry, as a result of the conducted research. The chapter's style, particularly section 8.6 which is based on industry guidance published as a result of the research, is less anthropological and more formal.

4.8 Chapter Summary

In this chapter, the research approach and methods used are described in detail, along with a summary of the methods used in each chapter. The methods employed have been commonly used in research that explores the implementation and adoption of new technology and process, such as BIM, and come from well established research practices based on a tradition of socio-technical research. This involved a mixed methods approach, and a combination of datasets which allowed the researcher to become immersed in the day to day life and cultural perspectives of a group of CRM practitioners, undertake interviews with national professionals that provided a back office, desk based view of the CRM process and their use of specific IT systems and documentation.

The researcher has noted the effectiveness of various methods and her experience with these. In her practice of ethnographic research and the method of participant observation at Witley Court it was noted that the method can feel quite awkward in practice, and difficult to determine which data to record and why. Similar issues were noted while carrying out active participation. ANT studies 'can be prone to getting lost in detail' (Cresswell *et al.,* p8, 2010) and researchers need to remain focused on the key research aims. This was an issue that the researcher experienced herself, particularly with the rich description of particular work practices or processes. A reminder of chapter aims and objectives is therefore provided at the beginning of each chapter and where necessary, repeated in chapter subsections to remind the reader of the aims and the purpose of the presented data.

A further noted limitation to both participant observation and active participation is that the researcher's own personal interests, and knowledge of the key organisations and their processes may impact the data recorded, the action followed or the associations that are traced, potentially resulting in bias or certain associations being missed. It is considered that this limitation was a lesser issue with the UKAHT case study as the organisation was both unknown prior to being recruited into the role of Heritage Programme Manager, and offered access to a more typical, small, heritage trust, of which the researcher had less previous knowledge and experience. However, limitations in observing and recording all action, and selecting which to follow and what associations are subsequently traced remain.

The interviewing method offered the chance to collect a large range of data for analysis despite the sources being limited in number. Interviews also allowed data to be gathered more specifically, in relation to research objectives. It was however noted that interview data would need to be analysed alongside other research data. In 'Reassembling the Social: An Introduction to Actor Network Theory', Latour (2005) discusses how the material and social allow collective action but, that research must take into consideration the difference between what actors say they do, and what they actually do. Ethnomethodology is therefore crucial in this process and the combination of methods such as interview, participant observation and active participation allows the researcher to consider these differences.

Despite the acknowledged limitations, the 'follow the action' approach of ANT allowed observation and the making of notes without any 'a priori' assumptions throughout all research methods employed. It was found that this was most appropriate in the document analysis method as the documents themselves provided a central focus around which to trace actions. Moreover, the resultant field notes have been extremely useful for analysis using the ANT concept of 'translation'. This concept of translation offered by the ANT method is an opportunity to use an academic vocabulary for the analysis of data and describing *how* things occur however, on the other hand ANT has been criticised as 'challenging' when attempting to explain *why* things occur (Cresswell *et al.,* 2010). Furthermore, it offers a 'limited capability in developing empirically verifiable evidence' (Cresswell *et al.*, p6, 2010). Such limitations are acknowledged but the benefits presented are considered to still offer significant contribution to the research.

To understand the development of a technological artefact one must study 'what the collective existence has become in their hands' (Latour, p12, 2005). Further, an ANT approach suggests that this understanding cannot begin unless the participants in action, human and non-human, have not been thoroughly examined. The approaches used in this research, the data collected and the analysis undertaken has identified and examined these participants to provide a robust study.

Human-Machine Reconfigurations (Suchman, 2006) illustrates ideas that associate with the ANT concept of translation and expands the thinking to suggest:

- *'An action's course cannot be predicted from knowledge of the actor's intent'*

- *'The course cannot be inferred from observation of the outcome'*

(Suchman, 2006)

Suchman's discussion looks at the way humans interact with technology and the ways that Designers/Technologists/Scientists approach the development of technology in order to deal with human-computer interaction. This is an important area to consider when studying how new digital, formalised processes such as BIM may support conservation professionals and how individuals may interact with such processes and justifies the research approach that follows in the next 3 chapters.

5. Comparing asset management in conventional and heritage contexts

This chapter is the first of four data collection chapters designed to answer the secondary research questions. Within the chapter the data collected is presented, along with subsequent analysis and findings. A study of 3 organisations and their asset management process is presented to consider how asset management differs in conventional and heritage contexts, and what impact this has on data management.

5.1 Introduction

‘Buildings are expensive assets to acquire, manage and operate’ (O’Brien and Rees, 2016), but are valuable to individuals, organisations and the public. The concept of value however may be considered from a number of different perspectives. As homes buildings provide accommodation, warmth, safety and a place to create memories. For companies and organisations buildings are operational, a place to undertake business and economic, social or community activity. Buildings may hold meaning or significance, ecclesiastical buildings for example, or historic, unique or local landmarks. Clearly, buildings hold a range of values including commercial and social value and this value may fluctuate across a building’s lifecycle.

In the case of heritage assets, in particular those that are scheduled or benefit from statutory protection as a historic site or monument, the issue of value requires further consideration. Value of these assets comes in part from their overall significance in relation to historic, evidential, aesthetic, and communal values, and it is these values, or conservation principles, that are used to determine how the UK’s built historic environment is managed and conserved (Jones, 2013). Such significance, or intangible value, impacts how heritage assets are used and, how they are repaired and maintained. For this reason, the concept of value over the life of a heritage asset is different than non-heritage assets, where there is a clear lifecycle from construction or acquisition to use and disposal or redevelopment. This cycle is based purely on ‘need’ and the asset’s tangible value.

Where heritage assets are managed and operated by Trusts for example, for public enjoyment, there are clearly business and organisational goals that need to be met. If monuments are not presented well with interpretation and visitor facilities, organisations will not raise the vital funds they require to operate and to continue to maintain the assets. However, in this process it is crucial that the significance of the asset is not damaged. Statutory protection of heritage assets, and principles of conservation philosophy provide the security to ensure significance is safeguarded.

While the value of assets can be considered in relation to their ability to meet business or organisational goals, it is clear that this is not the only consideration when managing heritage assets and so, in response to the research question that seeks to understand the challenges of heritage asset management, the wider subject of asset management and the similarities and differences across heritage and non-heritage contexts are discussed in this chapter.

5.1.2 Chapter aims and objectives

The broad topic of asset management is discussed in Chapter 2, where an integrated approach to the management of information allowing organisations to apply analytical approaches towards the management of assets and to maximise value (Giglio *et. al.*, 2018; Lu *et al.*, 2020) is discussed. Built assets, building components and materials have a limited lifespan. Regular maintenance is required to achieve expected lifespans and when lifespans are reached, assets will need to be replaced. New build, or non-heritage, assets go through a building lifecycle from acquisition, operation and maintenance, to disposal or reuse. This allows operation and maintenance costs to be planned across the building's life. Lifecycle asset management will achieve cost optimization through a holistic approach that considers preventative maintenance, the timely replacement of assets, and good quality design and construction. When an asset no longer provides the required value, businesses may demolish or dispose of an asset to make way for new assets of higher value. Alternatively, they may entirely renovate or remodel an asset to increase its value.

Once statutory protection is in place, it is rare that the significance of a heritage asset will change and so, value does not necessarily decrease in the same way it might in a non-heritage context. We act as custodians of heritage assets in order to protect them and pass them on to future generations. Management of heritage assets is therefore based on the conservation principles of minimal intervention and ongoing conservation repair and maintenance (CRM) for preservation rather than asset replacement and ultimate disposal or reuse.

Whether a heritage or non-heritage context, asset management facilitates the process of managing value through a systematic and analytical approach. Following a thorough literature review it was demonstrated that frameworks for asset management in a heritage context are lacking (Dann *et.al.*, 2007). Noted above, asset management relies on the management and analysis of information yet, it is demonstrated that fragmentation of building information is a typical problem across the whole AEC industry, including the heritage sector. Multi-disciplinary teams and stakeholders, and issues in collaboration are considered to cause severe problems with data acquisition and management (Parato *et al.*, 2011) and thus a whole section of each literature review is given to a review of information management for O&M and asset management.

The research question seeks to understand the reason for identified issues by asking what the challenges of heritage asset management are. Despite some implementation of asset management best practice in a non-heritage context, nuances of value and the impact of this raises 4 distinct questions that will be addressed in this chapter.

1. Is asset management different in heritage and non-heritage settings?
2. Do different heritage organisations carry out asset management in the same way?
3. What challenges do heritage organisations face when implementing asset management programmes?
4. What information is used for asset management, and how is it used, in heritage and non-heritage settings?

To consider these questions it was established that certain data would need to be gathered. These are summarised in Table 5.1:

Table 5.1 Data required to answer research questions

Data to be gathered	Questions it will support
Type of built assets being managed	1
Organisation structure, roles and responsibilities	1
Funding and resource	1, 2
CRM, Asset Replacement or Maintenance Programme examples	1, 2, 3
Existing processes or frameworks	1, 2, 3
What heritage information is used?	2, 3
Who uses the heritage information?	2, 3, 4
How is the heritage information used?	1, 2, 3, 4
How is the heritage information managed?	1, 2, 3, 4
Challenges faced	3

The chapter studies three key organisations, two heritage and one non-heritage, responsible for the management of assets. The organisations were selected on the basis that they meet the following criteria and therefore offer typical examples from which lessons can be learnt and analysis and proposals can then be applied to the wider field:

- An organisation responsible for the management of a collection of built assets in a heritage or non-heritage context and thus, undertaking asset management
- Has a specific team responsible for asset management or conservation, repair and maintenance activity
- Accessible to the researcher to carry out participant observation or active participation
- Provides an opportunity to observe digital, formalised processes
- Provides an opportunity to observe digital technology used by heritage professionals
- Typical examples from which lessons can be learnt and analysis and proposals can then be applied to the wider field

While the 3 key organisations were introduced in Chapter 4, this chapter focuses on gathering data to allow an understanding of the differences between the organisations and how they manage their assets as the key point of comparison.

Much of the UK's historic environment is managed or supported by heritage or building preservation trusts that are registered charities. While some are bigger than others, managing whole collections of buildings, others may support individual buildings or historic buildings that have fallen into disrepair in specific regions or counties. It is not uncommon for Trust's to be run by enthusiastic groups of volunteers (Humphrey-Taylor *et.al.*, 2020) – such as The Heritage Trust ®, Derbyshire who form partnerships with local communities, businesses, and volunteer groups to regenerate historic buildings that have fallen into disrepair or, The Hartpury Heritage

Trust who purchased and restored The Old Chapel Hall, Hartpury to save the heritage asset and regenerate it for use by the local community. Heritage Trusts that are registered charities benefit from the opportunity to acquire funding from the Heritage Lottery Fund, the Architectural Heritage Fund and other funding providers. In addition to individual heritage trusts membership organisations (such as the Heritage Trust Network), predominantly run by volunteers, bring together heritage trusts to offer peer to peer support, knowledge sharing and skills development.

For the purpose of this research, Trusts responsible for collections or estates are chosen as this will result in a requirement to undertake a programme of asset management. Although Trusts restoring individual buildings for regeneration and community use are ignored as case studies, they share typical characteristics with the larger organisations such as, varied stakeholders, funding and resource (Hirsenberger *et al.*, 2019) issues, and neglected and fragmented information, and so may also benefit from the research.

5.1.3 Chapter structure

Each organisation was introduced in Chapter 4 by describing the type and range of assets managed, the broad organisational structure and the access and methods used to study the organisation. Here a summary is provided to illustrate the similarities or differences between the 3 organisations and how they represent typical examples:

UKAHT

- Access: Between 2017 and 2018 the researcher worked as Heritage Programme Manager for the UK Antarctic Heritage Trust.
- Responsible for a collection of statutorily protected heritage assets
- Organisational aim – to preserve evidence and remains of British Antarctic scientific exploration and research for global audiences and future generations
- Registered charity
- Board of Trustees

English Heritage:

- Access: The researcher had worked as a Territory Project Manager for English Heritage between 2014 and 2017 and was granted time to undertake participant observation and carry out informal interview during 2018/2019.
- Responsible for an Estate of protected assets
- Organisational aim - Bring history to life and preserve for future generations
- Registered charity
- Board of Trustees

Organisation A

- Access: The researcher was given access to this organisation between 2018 and 2020
- Responsible for an Estate comprising new build, aged building stock and listed buildings
- Organisational aim – A private organisation providing public sector services. To be a profitable and sustainable organisation providing excellent public services.
- FTSE 250 company
- CEO

Of note are the different organisational aims. A key difference of asset management in heritage and non-heritage contexts, as noted in the introduction, is that in a heritage context, assets are typically preserved for the benefit of future generations (Humphrey-Taylor *et.al.*, 2020). In contrast, in a non-heritage environment, assets should be maintained or replaced in order to provide a service and maintain a profitable business.

This chapter is structured to provide a deeper understanding of each of the organisations, with an emphasis on asset management processes and information, therefore answering the specific chapter/research objectives. The description of each organisation is structured in line with both the research objectives and key themes identified through literature review as potential challenges for asset management. Each organisation is discussed using the following subheadings:

- Type and range of assets managed
- Organisational Structure and Resource
- CRM and/or Asset Management Process
- Data Fragmentation & Challenges

Beginning with a review of the types and range of assets managed by each organisation, these sections differ slightly due to the differences of the organisations and the differing access available. In one example (UKAHT), all major assets within the portfolio are described. With the two larger organisations, a selection of the assets are described. By including ‘the good, the bad and the ugly’, a picture is presented of the range of assets managed within those portfolios as a representative selection for analysis. Planned conservation projects in Antarctica are a new approach to UKAHT, instead previous work being based on period maintenance and emergency repair. The description of the assets is therefore purely on the type, range and location. English Heritage and Organisation A are however focused on existing asset management programmes and therefore planned repair and maintenance projects. The asset descriptions therefore also include detail of recently completed projects.

A more detailed observation of each organisational structure is next provided, along with a description of funding and resource. This data is gathered to allow further analysis and comparisons to be drawn. Structure, strategy and finance are identified as factors impacting the effectiveness of heritage maintenance practice (Dann and Wood, 2004) and so comparisons between these factors in both contexts is useful data. Access to this type of information varied considerably between each organisation. With UKAHT, where active participation was undertaken, a much richer description of funding and resource is provided. It is important to note that this data for the smaller charity is perhaps more pertinent, as it is within such organisations where funding and resource is more limited that there is a greater impact on asset management activities. It is acknowledged that funding and resource is different and has a different impact in the various contexts and so the level of data presented for each organisation differs accordingly. The level of finance related information available from Organisation A is much more limited, and so explanation of how the budget itself is managed is provided.

Next the CRM or asset management processes of each organisation is considered. In line with the data requirements identified in section 4.1.2 this section will review the existing processes or frameworks, the type of information used by various parties, and how this is managed. Again, different research methods and access impact the level and type of data gathered resulting in some variances. Further, the different organisational structures, and way CRM is delivered results in quite different data. For example, UKAHT are a small trust that not only plan asset management but use directly employed teams to carry out the conservation and maintenance works. For this reason, data includes detail on how maintenance tasks have been identified and how they are undertaken. In contrast, English Heritage and Organisation A have more focus on the development of the maintenance strategies, an overall asset management strategy used to plan CRM activity. This is then given to individual project managers to plan and deliver using external resource to carry out the actual CRM. For this reason, the data around the existing asset management plan or framework is more detailed.

The concept of value plays a pivotal role in both CRM process (Dann and Cantell, 2008; Worthing and Bond, 2008) and within the more general asset management field (Giglio *et al.,* 2018). It is therefore important to understand how value is assessed within the various organisations and what impact this has on asset management activity. This is discussed in relation to the CRM practice or the asset management strategy depending on the organisation. Where this may be related to significance or risk within the heritage organisations, value is based more around providing an operational service in Organisation A, and so asset replacement programmes are developed around operational requirements.

Finally, data gathered from each organisation is considered in relation to data fragmentation and challenges. Information management was considered a key challenge for operation and maintenance in both heritage and non-heritage contexts in the literature e.g. (Dann and Wood, 2004; Ciribini *et al*., 2015; Bruno & Fatiguso, 2018) and so an understanding of information management for asset management in each of the cases is studies.

5.2 The UK Antarctic Heritage Trust

5.2.1 Antarctic Historic Sites and Monuments

UKAHT is responsible for six historic sites and monuments located across the Antarctic peninsula. Historic sites and monuments (HSM) were first listed under the Antarctic Treaty in 1972. Criteria for the designation of HSM's include:

- a particular historic event occurred at that location
- it is associated with a significant person in Antarctic history
- it is associated with a significant feat of "endurance or achievement"
- it is representative of a wider activity "important in the development and knowledge of Antarctica"
- the building itself is of intrinsic technical, historical, cultural or architectural significance

- it has educational potential about "significant human activities" in Antarctica
- it has "symbolic or commemorative value for people of many nations

With only six sites in their portfolio, all will be described here. The location of these sites, access issues and use impact the heritage management programme and so it is important to understand the full portfolio. Visits to the Antarctic historic sites is ‘free’ for anybody fortunate enough to be visiting Antarctica by sailboat or by cruise ship with one of the Antarctic tour operators. The six HSM’s include:

Figure 5.1 Port Lockroy HSM 61 - Base A, Goudier Island (www.ukaht.org)

Base A was the first permanent British base in Antarctica, serving as a base for Operation Tabarin from 1944 and for scientific research including, the first measurements of the ionosphere and, the first recording of an atmospheric whistler until it closed in 1962. Operation Tabarin was the code name for the Government’s secret mission to establish a permanent presence in Antarctica. These important historical events contribute to the significance of Port Lockroy and thus resulted in its designation as an HSM in 1994. In 1996, Port Lockroy was restored as a ‘living museum’. The ‘museum’ is opened every Austral Summer between November and March to welcome nearly 18,000 shipborne visitors.

Figure 5.2 Wordie House HSM 62 - Base F, Argentine Islands (www.ukaht.org)

Base F was established in January 1947 on the north of the peninsula. It is a small hut which stands on the foundations of an earlier 1930’s British Graham Land Expedition building that was destroyed in 1946, possibly by a Tsunami. The building was replaced by a more modern facility (Faraday Research Station) in 1954 on neighbouring Galindez Island which was sold in 1996 to the Ukraine.

Figure 5.3 Horseshoe Island HSM 63 - Base Y, Marguerite Bay (www.ukaht.org)

Base Y was established as a scientific research base in 1955 but closed just 5 years later in 1960. During this short time large scale geological and topographical surveys covering hundreds of miles were carried out using dogs and sleds, with men returning to the base months later to complete their research.

Figure 5.4 Stonington Island HSM 64 - Base E, Marguerite Bay (Source: Joanna Hull)

Base E was first established as a base for exploration and research in 1946 and closed permanently in 1975. The British hut currently standing at Stonington is a steel framed hut and the first two storey building to be erected by the British Antarctic Survey. It marked the beginning of modern construction techniques. As well as the main building, the station also comprises 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.

Figure 5.5 Detaille Island HSM 83 - Base W, Lallemand Fjord, Loubet Cost (www.ukaht.org)

Base W was established in 1956 and was primarily used as a base for mapping, geology and meteorology. It closed unexpectedly in 1959 due to severe pack ice. Today the base is still difficult to access. South of the Antarctic Circle the ice conditions limit the number of vessels able to reach the base. The hut is mostly unaltered, offering a glimpse into 1950's Antarctic life. While emergency repair and routine maintenance is infrequent at Base W, work was undertaken by UKAHT in 2010/2011 and 2012/2013 to ensure the building was structurally sound and weathertight.

Figure 5.6 Damoy Hut HSM 84 - Dorian Bay (www.ukaht.org)

Damoy Hut stands in Dorian Bay on Wiencke Island. It is the most modern of Britain's Historic Sites and Monuments in Antarctica. The hut was, for a number of years, a British summer air facility and transit station for scientists travelling south to scientific stations.

The six huts are spread out across the Antarctic Peninsula on small islands. Stonington Island is the furthest South.

Figure 5.7 Location of Antarctic HSMs on Antarctic Peninsula (Source: UKAHT)

5.2.2 UKAHT organisational structure and resource

The Trust is small, overseen by a Board of Trustees, and in July 2017 permanent team members included the CEO, an Antarctic Operations Manager, Antarctic Operations Assistant, Administration Manager, Administration Assistant and Communications Officer. Specialist and support services were provided by an ICT & Communications Specialist and a Supporting Officer in the Falkland Islands. Consultancy services were provided by an Architectural Practice and a Heritage Programme Manager/Building Surveyor (the role undertaken by the researcher). A conservation team comprising conservation carpenters, an artefact conservator and camp manager are employed on an annual basis to undertake survey and conservation repair and maintenance (CRM) work in Antarctica. Although not voluntary roles, contracts are not permanent and remuneration is low. The team ranges from experienced enthusiasts to qualified conservation professionals. The Trust has a Memorandum of Understanding with the New Zealand Antarctic Heritage Trust who provide support and assistance in relation to the heritage management programme and, they partner with the British Antarctic Survey (BAS) who provide specialist assistance such as mapping and geospatial imaging.

Figure 5.8 2017-2018 UKAHT Conservation Team (Source: Joanna Hull)

An annual team is formed each year to manage the museum, shop and Post Office at Base A – Port Lockroy, along with carrying out a series of annual maintenance tasks. Each spring people are invited from around the world to apply to work a season at the 'penguin post office' on a 6 month contract. Chosen applicants will go through a selection process, team bonding and training. The role gets much media attention and there are large numbers of applications. There are no specific requirements of applicants – conservation qualifications and heritage training are not essential. Applicants are often enthusiasts with a passion for Antarctica or those wishing to embark upon a once in a lifetime challenge and unique opportunity.

Figure 5.9 UKAHT Port Lockroy Team (www.ukaht.org)

Financial resources for heritage range from public grants to donations, charitable funding, and income generation by heritage organisations and trusts (Dimitriyadis *et.al.*, 2012). UKAHT is entirely self-funding, generating income from retail activity at Port Lockroy and in the UK, and from individual donations, legacies, grants from trusts and foundations and other supporters. All proceeds go towards the preservation of the heritage sites in the care of UKAHT. The trust is dependent on a number of factors to ensure continued income to support their conservation programme including a thriving and responsible tourism in Antarctica guided by the International Association for Antarctica Tour Operators (IAATO), and digital engagement. The success of their programme relies on securing funding from a diverse range of sources.

In their 2020 consolidated accounts UKAHT note that funding from retail, through Antarctic Heritage Ltd, continued to make a significant contribution to their income despite reduced numbers of tourists as a result of COVID 19. New products were introduced to their range, including Whiskey shot glasses and a new Antarctic map shower curtain. All new products sold out.

The Antarctic Post Office managed by UKAHT at Port Lockroy, and during 2017-2018 at Stonington Island, is integral to the Trust's operation and returns a grant in acknowledgment of the work. In 2019-2020 67,000 stamps and first day covers were sold.

Figure 5.10 The UKAHT Post Office in Base E, Stonington Island (Source: Joanna Hull)

A fundraising campaign in 2019-2020 for the Antarctica in Sight project was supported by the appointment of a specialist cultural fundraising consultancy. Accelerated efforts resulted in income generation of £140,000. In the year ending 30 April 2020 the Trust and its subsidiary, Antarctic Heritage Limited, had total consolidated income of £992,547 (2019: £971,051). A good proportion of the income was derived from the gift aid of the profits from the trading subsidiary Antarctic Heritage Ltd (AHL), totalling £72,654 in 2020, a 57% decrease on the previous year. This income was supplemented by the gift from the Government of the British Antarctic Territory (GBAT) of £40,672 which represents 50% of the proceeds of Post Office sales at Port Lockroy, which is made on behalf of GBAT. Of a total expenditure by the Trust of £539,053, some £476,482 was used for charitable purpose –public engagement and outreach, and heritage conservation. In particular, expenditure on public engagement was increased. The published accounts do not indicate the specific spend on heritage conservation.

Although the remote location of the Antarctic huts managed by UKAHT is fairly unique, the task of the Trust and the limited resource available for the management of historic sites (Strange and Whitney, 2003; Hirsenberger *et al.*, 2019) compared to those available in commercial sectors is not uncommon, making this case study quite typical.

5.2.3 Conserving British Antarctic Heritage – existing CRM/asset management processes

In section 5.2.1 the 6 key historic sites and monuments managed by the UK Antarctic Heritage Trust are described. A brief introduction to these notes their historical and evidential significance, and value as reminders of British presence in Antarctica and the Antarctic research undertaken. As a result of the statutory protection placed upon them, UKAHT are responsible for carrying out routine conservation repair and maintenance.

Part 6 of the UKAHT Operations Manual used by the Port Lockroy team each season is the Maintenance Manual. The manual states that at the beginning of each season, the team will be provided with a schedule of maintenance tasks that are listed in order of priority. High priority tasks should be completed first. A half day each week is allocated to carrying out maintenance tasks, followed by a rest day. The Port Lockroy team are primarily employed to manage the museum and Post Office and, to host ship visits. The individuals do not necessarily have maintenance or conservation skills or experience as discussed earlier, which is not uncommon for the heritage sector which relies often on enthusiasts and volunteers (Orr, 2006; Humphrey-Taylor *et. al.*, 2020) (Chapter 3). The manual therefore provides instructions on how to carry out each of the routine tasks which include:

- Bitumen painting of external walls and roofs
- Removal of flaking paint and repainting of window frames
- Window puttying (putty is apparently a favourite of Sheathbills who like to pick it out)
- Shovelling of snow and breaking up ice build up around the hut
- Ventilation – opening and closing of windows

Whilst routine maintenance is carried out annually at Port Lockroy, access to the other huts is not so frequent. To get to the Antarctic Peninsula, UKAHT rely on the support of the Royal Navy and the various cruise operators that travel to Antarctica. Sea ice further South means that access to bases such as Stonington Island and Horseshoe Island is even further limited. These huts had been previously managed with what can be best described as adhoc maintenance work. Whatever appeared to require maintenance during infrequent and short visits to the huts would be undertaken as best possible, with the materials available. Information gathered from existing data sources was used to plan as best possible prior to each visit.

Using the maintenance regime as a starting point, historic building reports, and the knowledge of one of the carpenters (an ex-BAS employee who has spent many a season in Antarctica), had helped to establish a programme of routine maintenance for the huts based on historic maintenance regimes and using traditional materials and techniques. The key routine maintenance tasks that were established are as follows:

- Refelting of roofs and walls
- Reglazing broken windowpanes
- Painting – window frames
- Repairing guy wires
- Carpentry repairs to timber huts – replacing lost, broken or damaged panels or shutters

Each year a conservation team would visit one or two of the huts to carry out routine maintenance tasks.

Figure 5.11 Routine maintenance including painting and roof repairs (www.ukaht.org)

A visit to Horseshoe Island over the 16/17 Austral Summer would be the first year that the Conservation Team would carry out the routine maintenance as well as working towards their 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. To date, information used in the planning of conservation repair and maintenance was either from a range of historic sources or, individual knowledge – aligning with the issues reported in the literature review (Pärn *et.al.*, 2017). The Trust required this information to be structured in a useable format. Developed by the consultant Architects, the Conservation Team were provided with a Task Schedule that outlined all the activities they were to complete during their time at Horseshoe Island. This task schedule formed the basis of the initial structured process following best practice. A sample task schedule is provided at Appendix 2.

Central to achieving a more informed and structured approach to the conservation of the Antarctic HSMs would be the development of a new heritage management programme. Revision 1.0 of the Heritage Management Programme (later the Antarctic Peninsula Heritage Conservation Programme) was developed during the latter part of 2017 and illustrates the phased approach of the programme. The Heritage Management Programme meets one of the Trust's 5 strategic aims; to safeguard and preserve British heritage in Antarctica. Phase 0 – Initial Planning tasks were underway but the Phase 1 tasks of survey and data capture were pertinent to the successful development of a new digital data management system to organise and store accurate building data and to meet the Trust's asset management requirements.

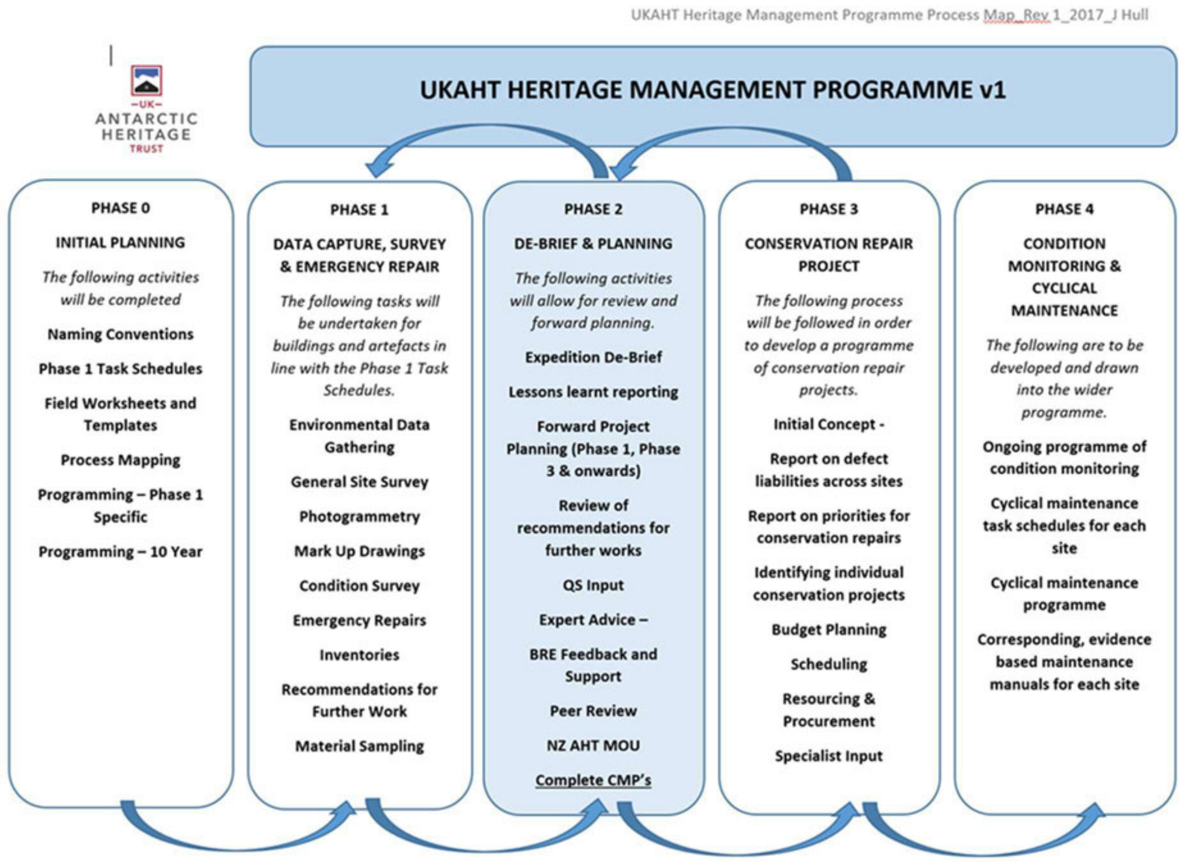


Figure 5.12 UKAHT Heritage Management Programme v1 Diagram (Source: UKAHT)

5.2.4 Data fragmentation and challenges

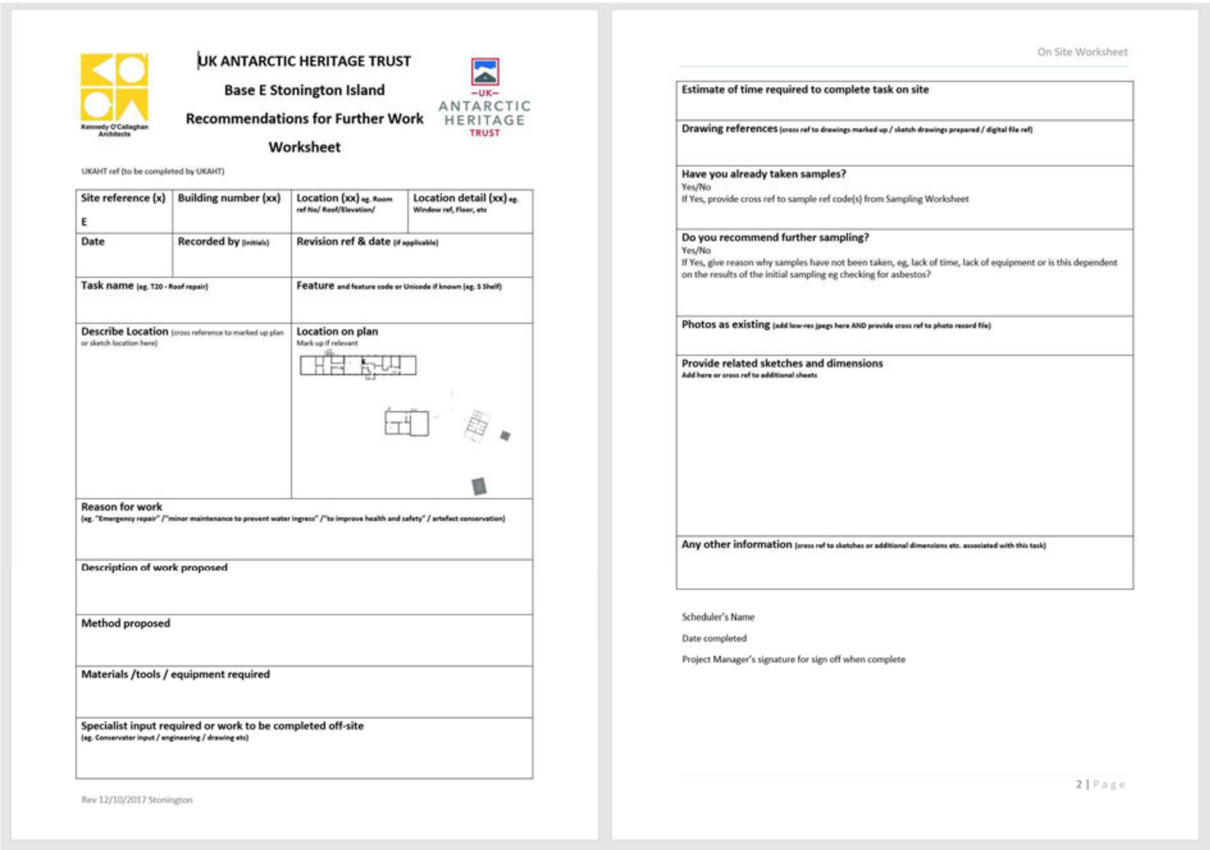
In July 2017, UKAHT's heritage information reflected the findings of existing literature. It was often document based, dispersed, in-accessible (often individual knowledge and not written information) and unstructured resulting a lot of duplication (Simeone *et al*., 2018; Jordan-Palomar *et al*., 2018). Often individuals relied on the knowledge of long standing team members to provide information or to suggest where information may be found. If the required information could not be found, such as photographs, survey reports etc, this information would need to be gathered during the future field visits.

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 works (Smith, 2005). Secondly, current condition survey data of the assets was also required.

Historically, building material, repair and condition information had been provided in end of season reports which to date were available through the British Antarctic Survey (BAS) archives or, were randomly stored in the ‘SharePoint’ electronic document management system (EDMS). As the Architects commented, scouring these documents to pull out information on the buildings and their condition in order to plan for repairs & maintenance was not efficient and not particularly precise. During the 16/17 field season, steps had been taken to structure the data collected on site with a number of template documents being 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 Architect’s suite of documents and future recommendations were recorded in the end of season general report, as had been done historically. This did not provide the required structure for analysing data for CRM.

During 16/17, in addition to documents and processes that would help collect and collate base data about the Antarctic huts, UKAHT had begun to consider the heritage information they required for the planning of future CRM projects in a more structured way and in the role of Heritage Programme Manager, the researcher helped to develop a further suite of template documents to capture this;

- recommendations for future work
- record of completed works
- asset data capture spreadsheet


UK ANTARCTIC HERITAGE TRUST
Base E Stonington Island
Recommendations for Further Work
Worksheet

UKAHT ref (to be completed by UKAHT)

Site reference (x) E	Building number (xx)	Location (xx) eg. Room ref No/ Roof/Elevation/	Location detail (xx) eg. Window ref, Floor, etc
Date	Recorded by (initials)	Revision ref & date (if applicable)	
Task name (eg. T20 - Roof repair)		Feature and feature code or Unicode if known (eg. 5 Shelf)	
Describe Location (cross reference to marked up plan or sketch location here)		Location on plan Mark up if relevant	
Reason for work (eg. "Emergency repair" /"minor maintenance to prevent water ingress" /"to improve health and safety" / artefact conservation)			
Description of work proposed			
Method proposed			
Materials /tools / equipment required			
Specialist input required or work to be completed off-site (eg. Conservator input / engineering / drawing etc)			

Rev 12/10/2017 Stonington

On Site Worksheet

Estimate of time required to complete task on site
Drawing references (cross ref to drawings marked up / sketch drawings prepared / digital file ref)
Have you already taken samples? Yes/No If Yes, provide cross ref to sample ref code(s) from Sampling Worksheet
Do you recommend further sampling? Yes/No If Yes, give reason why samples have not been taken, eg, lack of time, lack of equipment or is this dependent on the results of the initial sampling eg checking for asbestos?
Photos as existing (add low-res jpegs here AND provide cross ref to photo record file)
Provide related sketches and dimensions Add here or cross ref to additional sheets
Any other information (cross ref to sketches or additional dimensions etc. associated with this task)

Scheduler’s Name

Date completed

Project Manager’s signature for sign off when complete

2 | Page

Figure 5.13 UKAHT Recommendations for Further Work Worksheet (Source: UKAHT)

The ‘Recommendations for Further Work’ document provided a standardised approach to the collection of information about building defects and the required works. The document was designed to be user friendly and provide a clear approach for the conservation team to gather the required information which included:

- Description of work proposed
- Proposed method
- Tools and Materials required
- Specialist input required
- Estimated time
- Samples / Sample requirements
- Photo / Sketches

While this was a significant improvement in the approach to managing conservation repair and maintenance, it still required the conservation team to read individual documents when planning future projects. The 'Record of Completed Work' documents would need to be reviewed as time went on to understand which of the recommendations had been completed.

Finally, the researcher developed the asset data capture spreadsheet. The asset data capture spreadsheet was intended to 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 heritage asset management by the management team. This would be a 'live' document, updated as new information was received and to ensure the most current and accurate information was available in a single location.

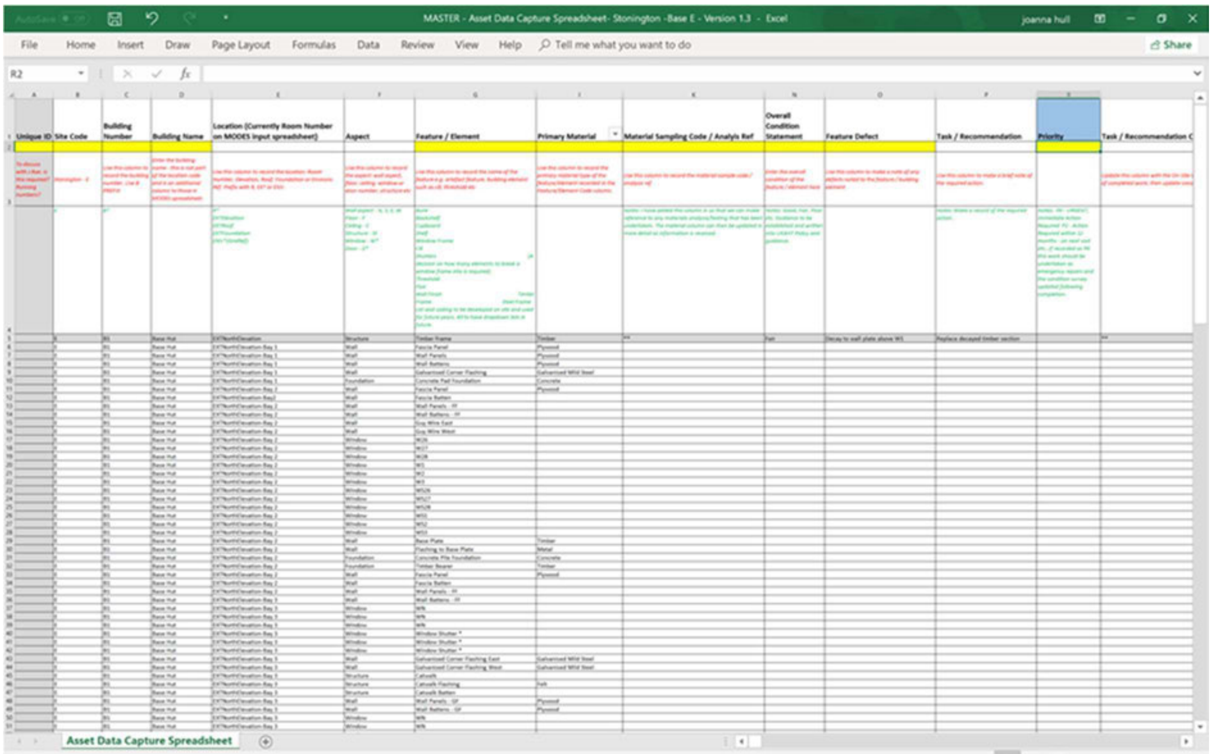


Figure 5.14 UKAHT Asset Data Capture Spreadsheet (Source: UKAHT)

It was noted that while information such as materials and methods for future repair and maintenance would be captured within the completed and future works documents, this data would still require some interpretation and analysis, and it would be spread across numerous documents. While the asset data capture spreadsheet was intended as a single location for asset data, it would require some duplication and the transfer of data from a number of different locations which does not improve efficiencies.

In line with their efforts to standardise and structure best practice process for their Heritage Management Programme, UKAHT had set up a SharePoint electronic document management system (EDMS) where they had started to try and create some sort of structure and digitise the information required for ongoing CRM. A folder was created in SharePoint for each HSM and to these, within subfolders, pieces of data considered to be relevant were added. In general, the categories of data included:

- Building Reports
- Building Plans
- Photographs
- New Field Season Records – (a variety of data; reports, spreadsheets, photographs)
- New Conservation Management Plans

Relevant data (Heras *et al.*, 2012) had been decided primarily on the type of information already available and based on the knowledge and experience of those involved in the project. Heritage information added to the SharePoint was either documents already held by various members of staff in different drives on the computer network or, document based archive files that were held by the British Antarctic Survey (BAS) archives team and had been digitised. Finally, data that had been captured during recent field seasons was added.

Whilst attempts had been made to produce a file structure within the SharePoint EDMS, not all existing files were named using naming conventions meaning there was still difficulty in finding information. Furthermore, a huge amount of data had been added in an unstructured manner, there were duplicate files and, there was no version control. While these data sources had been compiled into a single location information was buried within the depths of the reports. It took significant time reading through all the reports and picking out the useful pieces of information. When it came to the planning of conservation repair and maintenance for the upcoming field season, it was identified that despite the large amount of data there was still data missing.

An exception to this was the legacy data, such as historic reports, that came from the BAS archives. These had been named in a consistent manner making it easier to understand what the file was but, it was still impossible to know what information you would find within the report. The narrative nature meant having to read the whole document in order to pull out the relevant information. Whilst historic building reports and existing photographs had proved to be useful in producing some building plans and understanding some of the building defects and repairs that may be required, along with aiding the production of a programme for routine maintenance and repair, the work undertaken by the consultant Architects for the Horseshoe Island 16/17 field season, particularly in the preparation of the task schedules, had identified building information that had not been readily available. The list was generally based on information that the Architects required to complete a full set of building plans and, to complete the Conservation Management Plans that they were developing for each site. Starting with Horseshoe Island and followed by Stonington Island. This is common during the process of developing Conservation Management Plans from historic information and, on a single occasion might be acceptable. But, for ongoing CRM planning, this is not effective or efficient. The narrative and analogue nature of building information, whether in a heritage or non-heritage context is a commonly cited issue however e.g. (Gardner & Whitehead, 2003; Simeone et al. 2018) and so it was not unusual to find this situation.

It was also noted, and discussed with the team, that there was no single point of responsibility for data management. Documents could be added or removed by anybody that had access to SharePoint which caused issues throughout the year with missing/loss of data. Following the 17/18 field season to Stonington Island, a number of issues were encountered with data and file structures going missing in SharePoint. An e-mail thread starting on 13th July 2018, discussed the file structure and a large number of field season documents and data capture going missing. Looking through the chain of e-mails, it appears that a SharePoint update to a new version caused the loss of data, with not everything getting transferred successfully. A restore using the backup data was undertaken but this meant the structure was lost, there were duplication of folders and there was still data missing. A sync to a different computer and a comparison of the folders was undertaken but the IT specialist was unable to tell if all of the documents had been recovered. A copy of the file structure that had been developed and used on the hard drive (in the field) was issued and, subsequently duplicated into the UKAHT SharePoint (Appendix 3), along with the documents that had been loaded into each folder.

On 18th July 2018 the researcher wrote the following email:

'Hi Lauren / Jarred

I've just had a look and the file set up I created, and the documents I added do seem to be on there now. It is under - UKAHT Heritage (this is the only folder that I have access to) - Stonington & East Base (not Stonington & East Base(1)) - Stonington & East Base 17-18 - Field Season 17-18

Within this field season folder are all the folders I set up and the documents that I uploaded. It also appears that there are uploads from Michael (these are the ones that haven't really been named with any particular naming convention). I can also see that some photos Michael uploaded are on there and also photos that I had uploaded.

I hope this helps.

Kind regards

Joanna'

Figure 5.15 Email extract regarding missing data from the UKAHT SharePoint (Source: Joanna Hull)

5.2.5 Summary

In response to the research objectives of this chapter, the above introduction to the UK Antarctic Heritage Trust illustrates the range and type of assets managed by the organisation. Further it is described how the organisation is resourced in terms of both personnel and funding.

Development of a standard set of maintenance tasks, based on historic practice, is illustrated. This maintenance forms the basis of the Trust's heritage asset management however, further development of the Heritage Management Programme which includes activities such as survey and data capture, development of Conservation Management Plans and analysis of data for prioritisation and planning demonstrates a more sophisticated approach to heritage asset management is in progress. Issues of data fragmentation are noted along with inefficiencies caused by a lack of structure and identifies the need for data management systems to be developed. Key in the development of such systems is the identification of critical information requirements for CRM activity.

Template documents have been prepared by UKAHT to help structure data and improve information management and standardisation. The documents have been developed with the end purpose in mind. Information needs to be easily accessible so that it can be analysed for the planning of future conservation projects. While there are several different documents, for different uses (such as recording completed works or recommending future works), and the process still involves some duplication, the asset data capture document provides an overarching, single source of accurate building information. Furthermore, improvements to the structure of the EDMS – SharePoint have been made to create a single source of data.

5.3 The English Heritage Trust

5.3.1 The English Heritage Trust (English Heritage) – National Collection

The English Heritage national collection is large, comprising a vast range of heritage asset types. The collection includes over 400 sites, each including a number of different built assets. Heritage asset types range from prehistoric sites such as Stonehenge, to castles, abbeys and historic statues and bridges. A number of the sites and monuments cared for by English Heritage are also World Heritage sites. To illustrate the breadth of range and type of heritage asset managed by English Heritage, a selection of sites of different size, significance (UK scheduled monument or World heritage site) and type are described. In relation to type, there is a further consideration. English Heritage sites are either 'paying' visitor attractions – those that the public are required to pay a ticket entrance price for or, an annual membership, or are classed as 'free sites'. Free sites are generally smaller, prehistoric sites such as long barrows, bridges or statues/monuments.

Figure 5.16 Stonehenge (www.english-heritage.org.uk)

Stonehenge forms part of the UNESCO Stonehenge and Avebury World Heritage Site and is the Trust's flagship site, providing the most generated income from all sites within the Trust's care. The site, with its stone circle centrepiece, has a history spanning 4,500 years. In 2018/2019 English Heritage celebrated 100 years of caring for the monument, after the stones were gifted to the nation, with a series of events such as a curated exhibition and a crowdsourced photography project. In 2018/2019 Stonehenge saw its biggest ever number of visitors and the Trust has long term investment plans to improve visitor facilities and interpretation at the site.

Figure 5.17 Ironbridge (www.english-heritage.org.uk)

Iron Bridge is the World's first iron bridge, constructed in 1779 and marked a turning point in English Design and Engineering. Iron Bridge sits within the Ironbridge Gorge World Heritage site. Iron Bridge is a 'free site' that generates no income directly from visitors. In 2017 English Heritage embarked on a £3.6 million project to repair and replace cracked sections of the structure, repaint the iron bridge, and resurface the road that crosses the bridge. The project was the first ever crowd funding project run by English Heritage and achieved donations of £47,545.00 from 911 individuals, along with a single 1million Euro donation from a private foundation. The project was completed in 2018/2019.

Figure 5.18 Mortimer's Cross Water Mill (Source: Joanna Hull)

Mortimer's Cross Water Mill is a privately owned water mill, the care of which is the responsibility of the English Heritage Trust. Due to the ownership status, the site is generally not open to the public and so provides no income to the Trust. The ownership arrangement of this heritage is not typical to English Heritage but represents a certain category within the heritage sector. Such arrangements can cause difficulties in relation to access for CRM, particular where owners and trusts are not in agreement. Despite the lack of income generation from this site, English Heritage have spent not insignificant amounts of money on CRM projects. Annual maintenance is a portion of this spend but in 2016 a project including desilting of the Mill Race, stabilisation of the leat walls and repointing to the mill building was completed at a cost of circa £31k was completed.

Figure 5.19 Stokesay Castle (Source: Joanna Hull)

Stokesay Castle is a 13th Century fortified manor house with a 17th Century timber framed gatehouse overlooking the Shropshire Hills. Stokesay Castle was constructed by Laurence of Ludlow, a rich tradesman and one of the wealthiest men in England at the time, as he redefined himself as a wealthy country squire. The site incorporates a ticket office and shop which generates income. A pair of previously 'let' cottages within the car park grounds were redeveloped into tea rooms during 2016-2017 under a capital investment project. A large number of conservation projects have been undertaken at Stokesay Castle including render and plaster repairs and masonry repairs.

5.3.2 English Heritage organisational structure and resource

English Heritage is a large organisation comprising many departments such as the operational management of properties, curatorial and marketing services, business development, finance and estates. The estates department is responsible for all capital investment projects, conservation repair and maintenance, asset management planning and health & safety and so is now discussed in further detail.

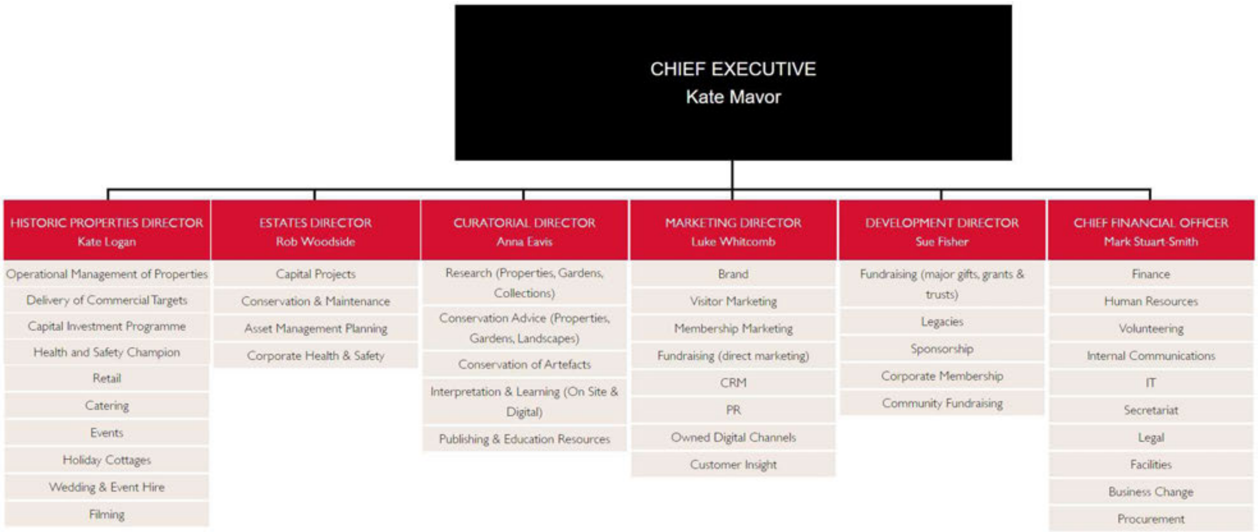


Figure 5.20 The English Heritage Trust Senior Management Structure (www.english-heritage.org.uk)

The Estates Director is supported by a senior management team that includes; Head of Estate Management (Conservation and Maintenance), Head of Survey and Asset Management (Asset Management Planning), Head of National Projects (Capital Projects) and Head of Health and Safety. The conservation and maintenance team comprise Senior Estate Managers, Territory Project Managers who deliver planned CRM, Building Conservation Managers who deliver planned and preventative maintenance (PPM) including cyclical and reactive maintenance, and Building Services Managers who manage the repair, maintenance and replacement of building services. The Survey and Asset Management team include Historic Building Surveyors and their team leader and, a team of survey coordinators.

Unlike smaller trusts (Savage, 2012), such as UKAHT, the English Heritage Trust Estates team comprises of skilled and qualified individuals with a wealth of experience in conservation management. While a review of advertised roles indicates that remuneration in the heritage sector is generally lower than the wider construction industry, the Estates department in particular is formed of paid professionals rather than volunteers or individuals on temporary contracts. Roles in the Estates department generally require a construction or heritage conservation related degree. It is remarked that a number of individuals who have completed the same Conservation of Historic Buildings Master’s degree have ultimately spent a period of time working in the English Heritage Trust’s Estates department.

Under the freedom of ‘The New Model’, the English Heritage Trust operate as an independent charity, outside the control of government. This financial model saw the Trust receive an £80 million grant from government on 31st March 2015. This New Model grant will be used to address urgent conservation defects (valued at £52 million) over an 8 year period, along with £18 million investment in commercial/capital investment projects such as new visitor facilities and exhibitions. £10 million will be spent on improving the presentation and interpretation of smaller sites and free sites. The £80 million grant is to be supplemented by tapering annual revenue subsidies until 2020/2021 (approx. £89 million) to support English Heritage’s transition to becoming financially self-sufficient.

As mentioned above, much income is generated from admission and membership fees. Further, English Heritage relies on trading income from shops and tea rooms, or holiday cottage rental and events. Notes above in relation to Iron Bridge, English Heritage also receives income from donations, along with fundraising and grants. New initiatives to generate income from Conservation in Action events and creative ways to collect donations will further support English Heritage in becoming financially independent. In 2016 English Heritage launched their Conservation Appeal. The appeal requests donations to support vital conservation work that is carried out across the national collection on information boards across the heritage sites. Further information is provided on the organisation's website and conservation in action videos are provided to inform and educate the interested public.

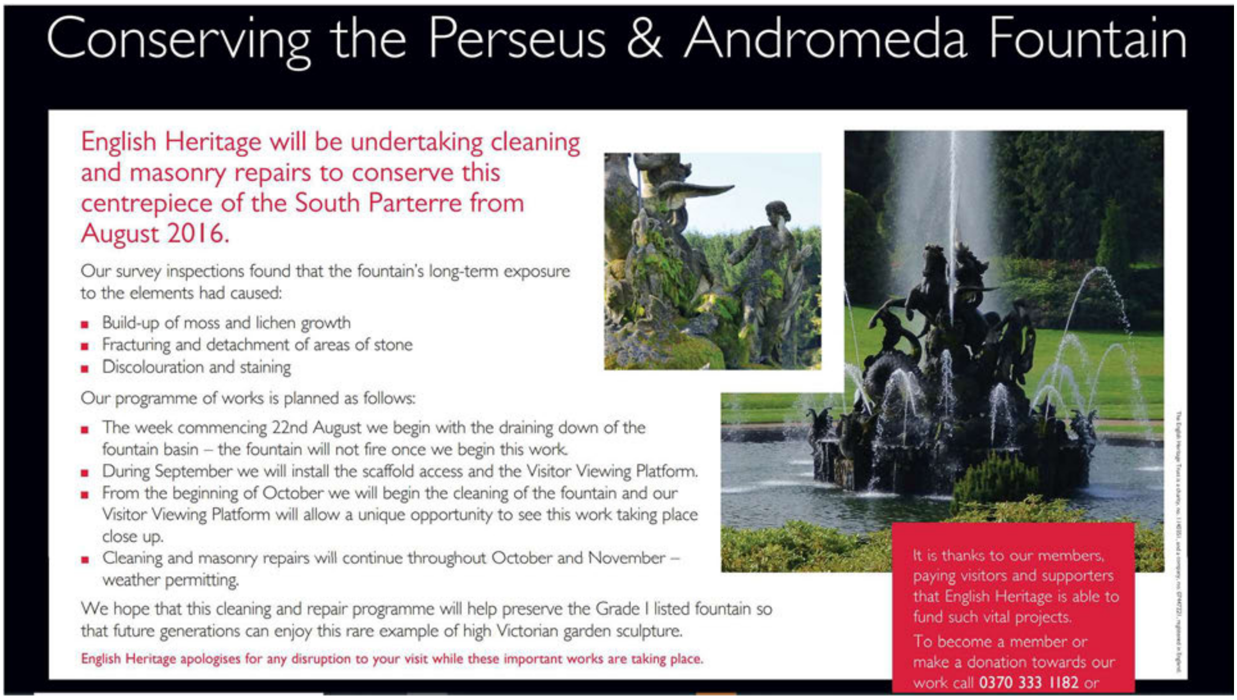


Figure 5.21 English Heritage Conservation in Action Notice - Conserving the Perseus and Andromeda Fountain (Source: English Heritage)

5.3.3 The English Heritage Asset Management Plan – existing CRM/asset management processes

Between 2006/2007 and 2009/2010 English Heritage produced condition surveys for all 423 properties in the National Heritage Collection. Surveys identified the nature and urgency of the work needed and these were costed to give a clear picture of the condition of the overall portfolio. The nature and urgency of work was categorised under 5 headings:

Category 0 – Urgent

Category 1 – Immediate (within 12 months)

Category 2 – Necessary within 2 years

Category 3 – Necessary within 4 years

Category 4 – Necessary within 8 years

Investment to address the top 3 categories of conservation defects was calculated at the formation of the new English Heritage Trust (2015) as £52million. It was estimated that conservation backlog would rise to £79million by 2015/2016 and £100million by 2022/2023 if this work was not addressed. It was noted that once the backlog of conservation defects was addressed, an annual conservation maintenance budget of £16million would be required to keep the historic estate in a steady state (Department for Culture and Sport, 2013).

English Heritage's first Asset Management Plan covered the period 2011-2015. Asset management planning in a non-heritage context is more common place, particularly in the private sector where financial implications and loss of profit result in more wide use of lifecycle asset management principles (Giglio *et. al.,* 2018) but this move by English Heritage is a welcome step, addressing issues of standardisation and best practice framework requirements (Dann *et. al.*, 2007). The plan provides a framework for conservation action and is 'intended to facilitate rational asset decision making based on identified needs and available funding. It is a practical tool which helps to define, implement and measure how English Heritage' makes investment decisions to protect and maintain heritage assets (English Heritage, 2015). The plan comprises four sections;

- Purpose of the plan
- The role of English Heritage, asset implications and broad principles
- Asset management issues and strategic direction
- Action plan

The broad principles in the plan shape management action and can be seen in the developed AMP process. Explicit responsibility & leadership for asset management is managed through the organisational structure and, systematic processes have been developed and embedded within the team to manage the way surveys are undertaken, data is captured and subsequently analysed for ongoing programming of CRM activities. An asset management database provides the central location for the management of comprehensive and current data to facilitate decision making.

Since the surveys that were completed in 2010 new defects have emerged. This is natural, buildings and building fabric continues to deteriorate over time. However, to address this and improve their understanding of the conservation work required, English Heritage have a developed a new sustainable conservation model that prioritises investment in sites based on their significance, vulnerability, and condition. English Heritage's second strategic plan covering the period 2019/2020 to 2022/2023 is supported by the Sustainable Conservation Strategy and Asset Management Plan (SCAMP). The Asset Management Plan will support English Heritage to manage the estate accordingly and includes the following workstreams:

- Conservation Maintenance Programme: used to fund works to address the conservation defects on heritage assets, specifically on land and buildings.
- Annual Maintenance Programme: planned cyclical and response maintenance.
- Minor Planned Maintenance Programme: small repair projects usually of less than £50,000 each.
- Major Planned Repair Programme: larger long term or one off conservation projects usually of more than £50,000 each.

The planning of CRM works at English Heritage is supported by K2, a Facilities and Asset Management computer software system developed by the Tribal Group. It was chosen by English Heritage to deliver their vision of a single, integrated system to help manage their assets, give them an understanding of the overall condition of the estate and detail the work required to maintain heritage assets to benchmark standards. The K2 system is based on a relational database within which each individual site has been built to component level using a 'tree' system. The software provides a number of modules including;

- Maintenance Module –

  component level condition survey data

  planned and preventative maintenance schedules (PPM)

  helpdesk system for reactive maintenance

  reactive maintenance call tracking

- Reporting Module –

  Cyclical Maintenance Reports

  Response Maintenance Reports

  Prioritisation Reports

During the time spent talking to various team members it was identified that there are a number of further modules in the system such as Finance, Stock Control and H&S that are not used. English Heritage use a separate finance system.

In a different approach to UKAHT, where planning is based on risk and preservation, English Heritage use a programme of ongoing cyclical condition surveys to obtain condition and defect records of all heritage assets and the financial liability of these. They are then recorded in the Asset Management System (K2). System reports provide English Heritage with the overall financial value of the deficit for each property and the estate as a whole. Conservation projects were prioritised based on reducing the financial value of the deficit. However over an 18 month period from March 2015 English Heritage realised that the scale of this deficit and reducing the financial value was not realistic. Furthermore, they justified that the financial value of the deficit did not need to be reduced in order to deliver good conservation outcomes. They realised that they had costed all defects in the Asset Management Database, adding to the financial value of the deficit, when not all defects necessarily needed addressing. For example, when the researcher worked as a Territory Project Manager for English Heritage she was asked to deliver a project of masonry repairs at Goodrich Castle. The value of these was £100k. Further to initial review of the defects listed in the Asset Management System and a subsequent site visit, it was established that many of these defects referred to low level masonry and vegetation growth within the moat structure. Work that was not considered a priority in terms of masonry repair. Finally, the cost estimates for defect repairs held in the Asset Management System were found not to match the reality.

English Heritage's new evidence based 'Sustainable Conservation' approach uses a matrix of significance, vulnerability and condition as a tool to prioritise conservation works and focus resource efficiently and could be considered more akin to the approach taken by UKAHT and in line with well embedded conservation philosophy and practice e.g. (Forster, 2010a, 2010b). A programme of projects is determined annually under each of the four workstreams mentioned above and will be delivered by the conservation team. This revised approach to English Heritage's asset management strategy, along with UKAHT's own approach to maintenance planning, is a very important factor. It illustrates that the different concepts of value in a heritage and non-heritage context must be considered and that these nuances impact the way heritage asset management is conducted. Expert judgement (Ruijgrok, 2006) and involvement in the development of heritage asset management strategies is vital.

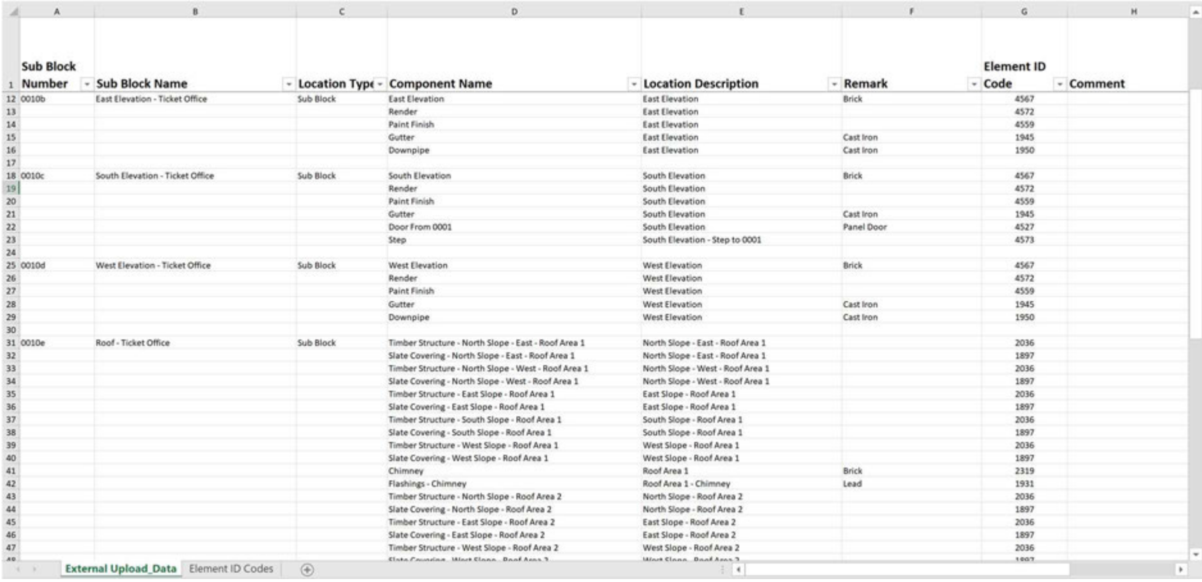
5.3.4 Data fragmentation and challenges - K2 asset management

Similarly to developments in data management at UKAHT, English Heritage have a large amount of document based and dispersed building information. Paper based documents that are unstructured and contain large amounts of data is noted to cause in-efficient analysis, planning and decision making (Becerik-Gerber *et al*., 2012; Kassem *et al.*, 2015). However, acknowledging this fact, English Heritage, as part of their asset management strategy, have purchased an asset management database which is aimed at ensuring information is accessible and structured, therefore reducing the failings reported in the literature (Simeone *et al*., 2018; Jordan-Palomar *et al.*, 2018). While UKAHT were still in the process of developing ways to structure their data for improved analysis, the English Heritage example described here demonstrates an acknowledgement that the way data is structured and presented will impact the effectiveness and efficiency of planning. Unlike an Electronic Document Management System as used by UKAHT, K2 is based on a relational database. K2 asset management database is the common system that holds heritage data about all of the Trust's assets. It is meant to be the place to go to find information that will inform CRM activity and holds data such as:

- Schedule of components/elements for each asset
- A condition record for each asset and associated defect liability (at component level) – including recommendations for work and associated costs
- Cyclical maintenance tasks – PPM schedules for each asset
- Documents

Introduction of the K2 system began with completing a 'virtual' build of each of the 423 sites. The physical hierarchy of historic properties, as defined by the Trust, determines the way surveys are carried out and thus, how heritage information is collated. 'Sites are sub divided into one or more assets; with each asset being determined by having a distinctive physical (location), historical or architectural aspect, which distinguishes it from other assets on the same site. Assets are then sub divided further into a number of elements, which are the individual building or structural components that make up the asset. Surveys to determine the condition and maintenance needs of sites are conducted at this element level and totalled to quantify needs at an asset or site level' (English Heritage, 2011).

During 2013 and 2014 a team of Site Surveying Assistants, supported by Historic Building Surveyors carried out elemental surveys of all of the sites, visiting site and recording every building element using the agreed naming and numbering standards, EHS 0003/3:2013 *K2 Naming and Numbering Standard*. Following site visit, the surveys were entered onto scripting spreadsheets ready for upload to the system and a 2D non-measured CAD plan of each site was completed, annotated with the K2 references.



	Sub Block Number	Sub Block Name	Location Type	Component Name	Location Description	Remark	Element ID Code	Comment
12	0010b	East Elevation - Ticket Office	Sub Block	East Elevation	East Elevation	Brick	4567	
13				Render	East Elevation		4572	
14				Paint Finish	East Elevation		4559	
15				Gutter	East Elevation	Cast Iron	1945	
16				Downpipe	East Elevation	Cast Iron	1950	
17								
18	0010c	South Elevation - Ticket Office	Sub Block	South Elevation	South Elevation	Brick	4567	
19				Render	South Elevation		4572	
20				Paint Finish	South Elevation		4559	
21				Gutter	South Elevation	Cast Iron	1945	
22				Door From 0001	South Elevation	Panel Door	4527	
23				Step	South Elevation - Step to 0001		4573	
24								
25	0010d	West Elevation - Ticket Office	Sub Block	West Elevation	West Elevation	Brick	4567	
26				Render	West Elevation		4572	
27				Paint Finish	West Elevation		4559	
28				Gutter	West Elevation	Cast Iron	1945	
29				Downpipe	West Elevation	Cast Iron	1950	
30								
31	0010e	Roof - Ticket Office	Sub Block	Timber Structure - North Slope - East - Roof Area 1	North Slope - East - Roof Area 1		2036	
32				Slate Covering - North Slope - East - Roof Area 1	North Slope - East - Roof Area 1		1897	
33				Timber Structure - North Slope - West - Roof Area 1	North Slope - West - Roof Area 1		2036	
34				Slate Covering - North Slope - West - Roof Area 1	North Slope - West - Roof Area 1		1897	
35				Timber Structure - East Slope - Roof Area 1	East Slope - Roof Area 1		2036	
36				Slate Covering - East Slope - Roof Area 1	East Slope - Roof Area 1		1897	
37				Timber Structure - South Slope - Roof Area 1	South Slope - Roof Area 1		2036	
38				Slate Covering - South Slope - Roof Area 1	South Slope - Roof Area 1		1897	
39				Timber Structure - West Slope - Roof Area 1	West Slope - Roof Area 1		2036	
40				Slate Covering - West Slope - Roof Area 1	West Slope - Roof Area 1		1897	
41				Chimney	Roof Area 1	Brick	2319	
42				Flashings - Chimney	Roof Area 1 - Chimney	Lead	1931	
43				Timber Structure - North Slope - Roof Area 2	North Slope - Roof Area 2		2036	
44				Slate Covering - North Slope - Roof Area 2	North Slope - Roof Area 2		1897	
45				Timber Structure - East Slope - Roof Area 2	East Slope - Roof Area 2		2036	
46				Slate Covering - East Slope - Roof Area 2	East Slope - Roof Area 2		1897	
47				Timber Structure - West Slope - Roof Area 2	West Slope - Roof Area 2		2036	

Figure 5.22 English Heritage Elemental Survey Scripting Spreadsheet (Source: English Heritage)

The data from the scripting spreadsheets has been entered into the system using the building editor, sub-block (elevation) editor, floor editor, room editor and finally, the component editor which gives the details of the individual building components. Against these building components, condition records could then be added.

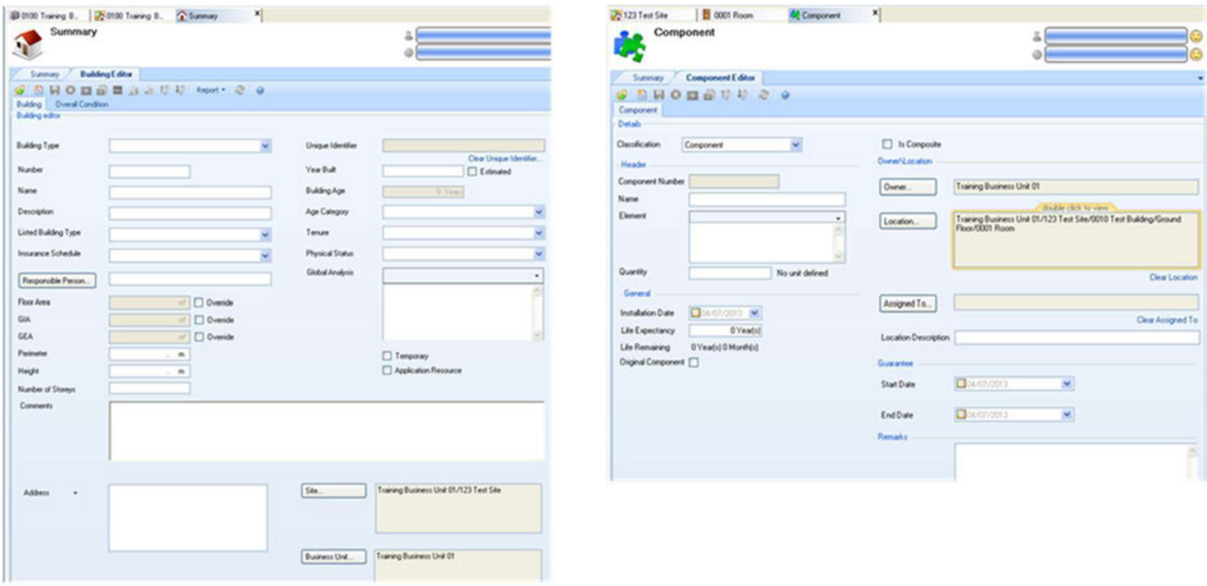


Figure 5.23 English Heritage sub-block editor - screenshot from K2 (Source: English Heritage Trust)

While English Heritage had undertaken condition surveys of all 423 sites within the portfolio during previous years, this data was held in Excel spreadsheets and was not integrated with other historic building information. The survey data, along with planned maintenance excel schedules needed to be transferred into K2. Tribal developed a validation and import utility that allowed data cleansing to be undertaken before the database was populated, thus ensuring only the accurate and validated data was imported.

The system is user friendly, with a documents tab for each site which is structured with the same set of folders within which relevant pieces of data are saved. It is this element of the database that is most closely aligned with the UKAHT EDMS (SharePoint). The document category list however is much longer than the one used by UKAHT, reflecting English Heritage's longer asset management journey and system development. The list is as follows:

- Asbestos Management Plan
- Briefing Documents
- Condition Surveys
- Conservation Statements/Plans (including gazetteer)
- Dilapidation Surveys
- Landscape Management Statements/Plans
- Lightning Protection
- PAT Testing
- Physical Access Audit
- Statement of Significance
- Wildlife Statement
- Images
- Plans

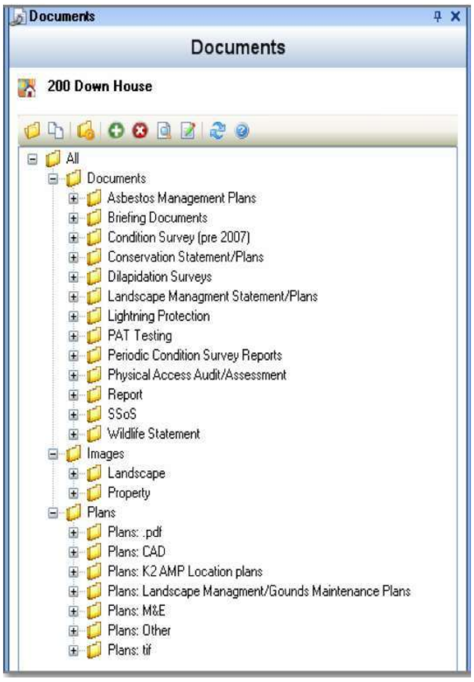


Figure 5.24 K2 Documents Function - Screenshot (Source: English Heritage)

The information in K2 can be accessed by any member of staff but is managed by the Survey and Asset Management team. Like UKAHT, in 2012 and 2013 legacy data from within the Estates team, held elsewhere in various locations on computer systems and from the English Heritage archive was compiled and added to the system by the survey data administrators.

The team work closely with the Historic Building Surveyors who provide data following condition survey, and procure and import specialist survey data. During the time spent with English Heritage, it was found that nobody could explain how these data categories had been developed, what the intended use of each type of document was (although some of these might be common sense – for example a statement of significance is used to understand the significance of an asset overall and for individual elements of the asset more specifically), or who might use each type of document. There was no written procedure on how documents were used or managed within the asset management system.

Through the researcher's own experience, informal discussion, and the receipt of a suite of survey guidance notes, a picture of how heritage building information is used and managed within English Heritage could be seen. When Building Conservation Managers or Territory Project Managers are allocated projects a list of the recorded defects for the building is downloaded from K2. This list is used to inform and develop a scope of works which is then tendered and subsequently delivered. To obtain a full list of all the defects, the remedial task and their estimated costs including any access and protection costs a C-Set Report can be run from K2 for the Sub-blocks (Elevations), Rooms (Interior) and Zones for the Property.

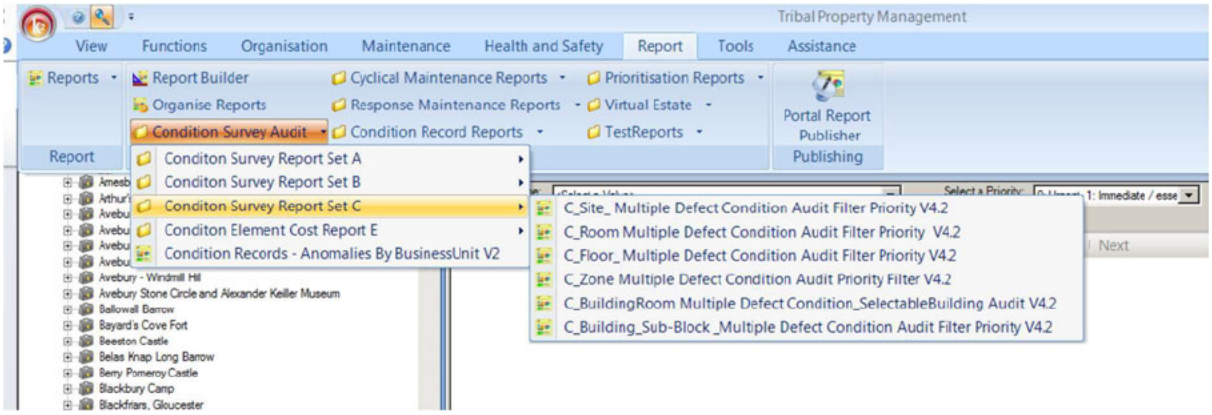


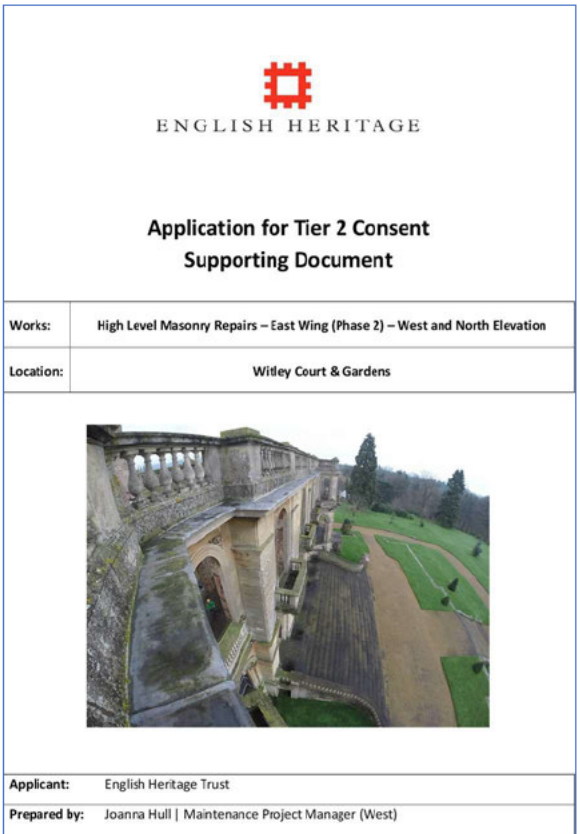
Figure 5.25 K2 C-Set Report - Screenshot (Source: English Heritage)

The condition survey report is used to develop a scope of works and specification but during this process supporting documents such as historic reports, plans, photographs, statement of significance and the conservation management plan may be referred to. Many of these documents will also be required to produce a consent application which must be approved before works can commence.

Consent applications required the following information to be provided:

- Location Plan
- Statement of Significance
- Existing Condition
- Proposal
- Repair Specification
- Conservation Philosophy

Based on the K2 structure, this information should all be available within the system.


ENGLISH HERITAGE

Application for Tier 2 Consent
Supporting Document

Works:	High Level Masonry Repairs – East Wing (Phase 2) – West and North Elevation
Location:	Witley Court & Gardens

Applicant:	English Heritage Trust
Prepared by:	Joanna Hull | Maintenance Project Manager (West)

Figure 5.26 Front Cover of the Application for Tier 2 Consent Supporting Document (Source: English Heritage)

In relation to this project delivery process, the researcher could not find any evidence to confirm that a heritage information management process existed formally. Furthermore, building information at project completion was rarely uploaded to K2. It was established that different

Project Managers provided different information at project completion and there appeared to be no standard process for this.

5.3.5 Summary

Introduction to the English Heritage Trust displays the similarities and differences between the two heritage organisations. Compared to UKAHT, English Heritage is a much larger organisation that although of charitable status, has received significant Government funding at the outset. Furthermore, income generation through tourism and membership is much easier for English Heritage due to the location, ease of access, and large number of sites within the collection, including several World Heritage Sites. In addition to this, the Estates department within English Heritage comprises a large number of construction and conservation professionals on permanent, full time contracts compared to the mixed team of enthusiasts, carpenters and construction and heritage professionals in the UKAHT team.

The English Heritage Trust have a very sophisticated Asset Management Plan that is in its second iteration, including a new Sustainable Conservation and Asset Management approach. At the outset, the AMP was supported by a digital system that had been developed in line with the plan and includes a large amount of structured data that is used for the planning and prioritisation of conservation works. Critical information requirements for CRM planning are defined by the AMP itself – such as significance, vulnerability and condition, along with existing and statutory processes such as requirements for the scheduled monument consent process. Data and documents have been compiled and although it is clear why some are these are included, and their intended use, there is no written procedure for the data management or anything to explain how the requirements have been defined.

5.4 Organisation A, a non-heritage public service provider

5.4.1 Organisation A – the Estate

For anonymity, the Organisation A estate cannot be specifically named however, a selection of images is presented to demonstrate the type and range of assets managed by the organisation. Organisation A is a non-heritage public service provider and all of the assets in their care are functional, or operational buildings rather than heritage assets or visitor attractions. The site does include a number of listed buildings but, the way these are used is very different to the heritage assets managed by UKAHT or English Heritage. They may be occupied, typically as office space and so, although in line with the listed building consent procedure, maintenance is based on operational requirements rather than heritage preservation. Organisation A receive a contract fee for undertaking hard and soft facilities management services. This fee includes a certain figure for asset management, maintenance and asset replacement. Due to the nature of the business and the researcher's access, details on these figures is not available. However, the point is to note the difference in funding for asset management in heritage and non-heritage contexts. Where English Heritage and UKAHT may set annual budgets for CRM, they must ensure that funding to support this is maintained. In comparison, Organisation A have received a fixed sum for their entire contract and so must work within the boundaries of the defined budgets. In 2019 the range of projects delivered by Organisation A under the lifecycle asset replacement/management programme ranged considerably in scope and value. Large scale projects to repair external fabric to buildings were undertaken including reroofing projects, along with projects to replace heating and air conditioning systems and to upgrade emergency lighting.

Figure 5.27 Masonry repair project to Asset A on Organisation A's estate (Source: Joanna Hull)

Asset A is a Grade II listed building at the centre of the estate managed by Organisation A. Its function has varied over time but presently houses office, catering and conference space. Under their asset management obligations, Organisation A have carried out a programme of maintenance works to the external fabric of the building including; repairs to the traditional roof covering, window repairs, masonry repair and repointing. Work was undertaken in a number of phases. Between February and April 2016 emergency repair works to unstable gable stonework was completed following condition survey as part of the ongoing asset management process that identified this as urgent works. Between October 2018 and February 2019 further stonework repair and repointing along with roofing works and chimney repair were completed. Further phases of stonework repair and repointing were carried out in 2019 and 2020. Costs totalled over £1.5 million.

Figure 5.28 Asset B - Organisation A (Source: Joanna Hull)

Asset B is located at one of the entrances to the site and had been hit previously by a bus. The right hand gate pier had been repaired when shortly after the left hand gate pier was hit by another bus causing damage to the pier and meaning the gate had not been hung for some time. In August 2019 the works were scheduled for completion, making use of quieter times on site and allowing the entrance to be closed and diversions around site to be put in place. The gate pier was repaired along with the flanking wall. The gate was also rehung and the pair were redecorated. This project cost <£25,000 illustrating the range in scope of value of works that are undertaken as part of the asset management programme.

Figure 5.29 Asset C - Organisation A (Source: Joanna Hull)

Asset C is located in the centre of the estate, comprising dated office accommodation with w.c. facilities and a small kitchen. Under their lifecycle asset replacement/management programme Organisation A have carried out roof repairs and a programme of window and door replacement. The project has involved the removal of asbestos containing materials prior to the replacement works.

5.4.2 Organisational structure and resource

Organisation A at Contract X is managed by a senior management team comprising:

- Services Director
- Chief of Staff
- Contract Manager
- Head of ICT and Business Services
- Head of Logistics
- Head of Service Desk
- Head of Library Services
- Head of Estates

As can be seen from the range of roles above, many of Organisation A's services are in soft facilities management. The Estates team however is responsible for hard facilities management, maintenance of the estate, asset replacement and delivery of service variations and capital investment projects (Haugen and Klungseth, 2017). The Estates team is managed by the Head of Estates, supported by the Head of Operations and Head of Projects. Teams sit under each head of department as illustrated in the organisational chart below:

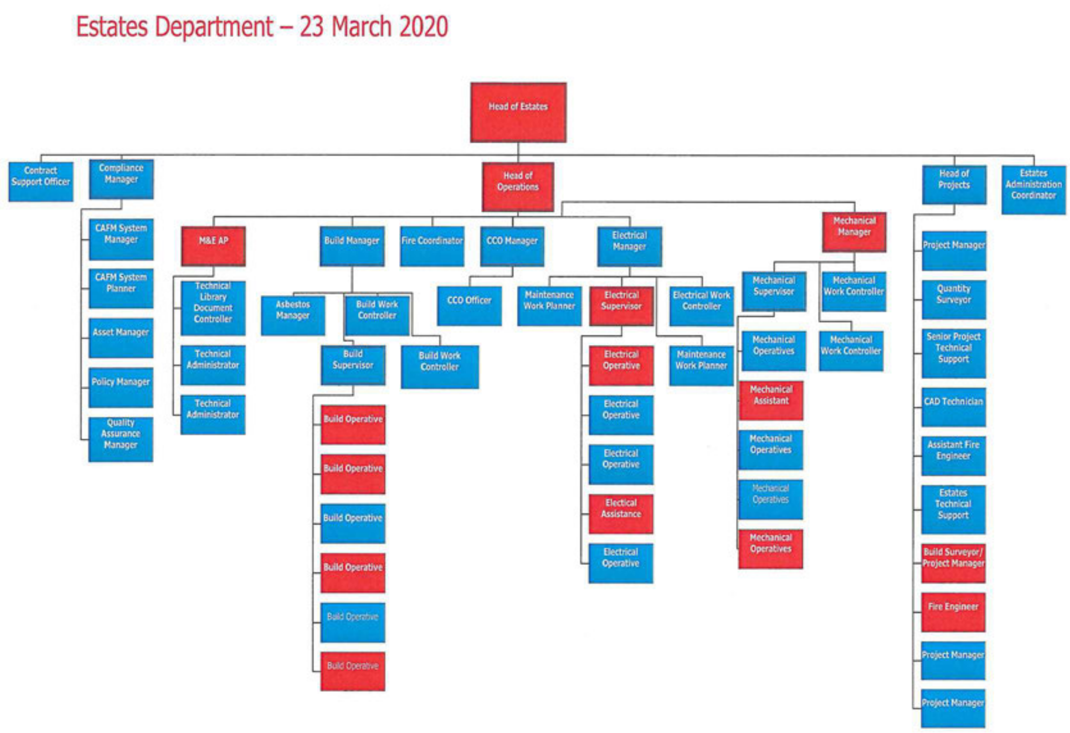


Figure 5.30 Organisation A Estates Department - Organisational Chart (Source: Organisation A)

Staff working in the Estates Department tend to have much experience of working in the construction or maintenance industry and within the various trades. For example each Trade

Manager has worked for many years in Electrical or Mechanical roles or, in the case of the Build Manager, in surveying or building maintenance positions. Most, through time and experience, have seen promotion into managerial roles without specific management experience or qualifications. All staff have received statutory/mandatory training such as:

- Asbestos Awareness
- Working at Height
- Manual Handling etc.

Project Managers have a range of experience, in general including Building Surveying or Mechanical Engineering degrees and some have industry membership such as MCIOB (Member of the Chartered Institute of Building), MIWFM (Member of the Institute of Workplace and Facilities Management), or MAPM (Member of the Association for Project Management).

With Organisation A being a private sector organisation, access to information relating to the contract fee and budgets for maintenance and asset replacement programmes is not as freely available as with the heritage trusts. However, as mentioned above, typical of many organisations delivering public sector services (Ikediashi and Okwuashi, 2015), there is an agreed, fixed fee for the services provided and the Organisation must manage its budget streams within this accordingly.

Typically, the Head of Estates will work within an annual budget for asset replacement, planned and preventative maintenance, and reactive maintenance. Financial spend will be managed across the year in line with such budgets. The master asset management database, and planning of the annual asset replacement/management programme is managed by the Estates Quantity Surveyor and overseen by the Head of Estates. The asset management process uses base data from initial LCC surveys to set annual budgets for asset replacement but before any of these works are delivered, annual validation surveys are completed to either approve works, defer works or bring other works forward. Essentially, the technical skill and knowledge of the team are used to decide if assets are in sound condition and can be deferred for replacement at a later stage, or if the replacement needs to take place sooner. The annual budget therefore changes from one year to another but overall, this is managed within the overall contract budget.

Once an annual programme of works has been established following review of LCC data, validation and scoping surveys, the AMP packages/projects are delivered by the project team, overseen by the Head of Projects.

5.4.3 Organisation A - Annual Schedule of Maintenance Works

Under their contract with the Customer, Organisation A are responsible for delivering the annual schedule of maintenance works (SoMW) which incorporates routine maintenance, asset renewal and a forward maintenance plan. The plan was developed in detail for the period 2005-2010 when the contract first came into force with a summary of tasks provided for the remaining duration of the contract 2011-2028. Typical of private sector contracts involving the management of large scale assets (Giglio *et. al.,* 2018) the performance of Organisation A is monitored and measured by the Customer for the purposes of calculating Performance and Availability Deductions however, Organisation A are responsible for identifying deficiencies and failure, monitoring their performance in accordance with the provisions of the contract, and reporting this monthly to the Customer in the Service Performance and Asset Availability Report (SPAAR). Since Organisation A face deductions to their monthly contract fee in the event of deficiencies, failures and unavailability of capital assets, such performance measurements are key in the planning of asset renewal and maintenance planning.

Contractually the Customer is entitled to request the use of any Asset from the Contractor for any relevant business or social function use, at any time. Organisation A must identify where the asset does not meet the availability criteria as tabled within Schedule Q of the contract and notify the Customer accordingly to allow deductions to be calculated.

In their Asset Management process document, Organisation A state that they will maintain a comprehensive register of all notified contract Assets and maximise their design life expectancy through diligent and proactive planned and preventative maintenance (PPM). Furthermore, they will monitor significant Assets through professional condition surveys to ascertain life periodicity and where nearing end of life, will include these in the asset renewal programme. Cyclical planned and preventative maintenance (PPM) is managed by the Estates Operations team whilst the asset renewal and forward maintenance plan, otherwise referred to as the Asset Management Plan (AMP), is managed by the Estates Projects team. For the purposes of gathering relevant research data, it is necessary to limit the scope of study of Organisation A to the asset management plan without further study of the way PPM is managed.

In 2016, Organisation A procured services to undertake life cycle cost surveys of all assets (buildings and infrastructure) on the estate. Over 3 years, these were carried out in 4 tranches. The data gathered from the surveys was then used to create the Master AMP database, a complex Microsoft excel spreadsheet, and the annual renewal and forward maintenance plan is derived from data within this. In accordance with the project agreement relating to the provision of services, Organisation A issue their draft schedule of maintenance works (SoMW) to the Customer annually in respect of the asset repair or replacement programme for the following year. A further monthly meeting is held to facilitate an opportunity for the parties to discuss and agree the programme for the subsequent 12 months, consider comments made by the Customer and, for Organisation A to update the Customer of any changes to the programme. Changes to the programme may come about during the year as a result of failure of plant that then requires immediate replacement or following the validation process.

Prior to any of the proposed works being undertaken Organisation A carry out validation surveys for each identified asset or package of works to ensure the asset still exists and that it has not already been replaced by the Operations Team through reactive maintenance. A sense check is also carried out to confirm the maintenance or replacement is required. The Operations Team are also asked to provide recommendations for asset replacement based on their knowledge of assets across the site, increasing reactive call outs to failing plant and issues with obtaining discontinued parts for maintenance. The annual programme is then updated accordingly and finalised so that the works packages can be procured for delivery. Whilst this process is sufficient, it represents an element of duplication and inefficiency. Although Organisation A state they will maintain a comprehensive asset register, they actually have two.

The primary asset register is managed by the Operations team through a computer aided facilities management system (CAFM). As assets are removed, replaced or added through work and projects delivered by the Estates department, the asset register in CAFM is updated accordingly following the department's documented asset change process. On the other hand, the condition and LCC survey data is managed through the Master AMP database. This is not the primary asset register used by the department and as such, is not maintained as an asset register which results in the need to carry out validation surveys (Cohen and Cram, 2004).

Whilst a number of asset management principles have been established, such as;

- run to fail
- defer
- bring forward

these are yet to be formalised in an overarching Asset Management policy or strategy document as like that studied at English Heritage. During the researcher's time at Organisation A, this strategy was in review and development.

5.4.4 Data fragmentation and challenges

Within the Estates department building information and records are saved in a variety of formats and locations, echoing reported fragmentation issues and difficulties faced by construction sector professionals to manage building information required for operations and maintenance activity e.g. (Becerik-Gerber *et al.*, 2012; Pärn *et al.,* 2017). When the researcher joined Organisation A in November 2018 the Estates department had gone through recent changes. The target operating model (TOM) had resulted in some restructuring of the department. A number of people had left the organisation and the senior management team comprising the Head of Estates, Head of Operations and Head of Projects were all new. An Estates department electronic document management system (SharePoint) had been developed and the department were in a transition period between the use of SharePoint and a network drive ('R' Drive) which had previously been the central file store. In addition, the asset register and PPM and reactive maintenance tasks were managed in a computer aided facilities management system (CAFM). These align with those reported in the literature as common systems used within the industry. The Estates SharePoint had been developed using a structure that broadly mirrored that in R Drive, with common folders such as:

- Projects – SV, ARC, CRF (These are specific types of service variations/projects named by the organisation)
- Fire
- AMP
- Surveys
- Drawings
- Maintenance Certificates

During the researcher's time with Organisation A it was not possible however to ascertain exactly how this structure had been developed but, it was not structured in the same way that UKAHT and English Heritage systems were, using buildings as the main framework. This meant that instead of building information being filed per building, it was filed by category. It was noted that there were a huge amount of documents in quite an unstructured format. For the purposes of this research, through both active participation and participant observation, the researcher was able to identify the range of documents used by those involved specifically in the asset management process and document their location to demonstrate the level of fragmentation. These are summarised in Table 5.2.

Table 5.2 Type and location of documentation held by Organisation A for Asset Management

Document	Type / Format	Location	Folder
Master AMP database	Excel / Digital	Held by third party (external)	Unknown
Schedule of Maintenance Works Submission	Excel / Digital	SharePoint	Various
AMP Works Schedule (SoMW appendix)	Excel / Digital	SharePoint	AMP
LCC Survey	Excel / Digital	SharePoint	LCC Information
Asset Condition Survey LCC Template	Excel / Digital	SharePoint	AMP
AMP Spend Request Form	Word / Digital	SharePoint	AMP
AMP Change Control Record	Word / Digital	SharePoint	AMP
AMP Tracker	Excel / Digital	SharePoint	AMP
Asset records – reactive calls	CAFM entry / Digital	CAFM	N/A
Asset service records	Various / Paper based	Technical Library	Building Maintenance Folder
Historic Surveys	Various / Various	Various – R Drive, SharePoint, local drives	Various
Specialist Reports and Information	Word / Various	Various – Contractor, R Drive, local drives, individual knowledge & experience	N/A
Drawings and Photographs	Various / Various	Various – R Drive, SharePoint, local drives, Technical Library	Various
Design Development Survey Log	Excel / Digital	SharePoint	AMP
Tender Documents	Word / Digital	SharePoint	Various

The asset management programme (AMP) specific documents and templates were quite well organised. This was due to recent process development and the creation of new template documents. An AMP folder in SharePoint had been created and was well structured. However, existing supporting documents were located in a variety of locations.

Organisation A follow a programme of continuous improvement in line with their Estates Department Strategy. Building records / documents form one of the core contractual requirements and Estates actions to meet this requirement include:

- Document retention review
- Implement standard templates and document control
- Digitisation of archives and paper based records
- Asset data

The department's high level strategy, including such contractual requirements and high level Estates department actions is illustrated on the strategy document below.

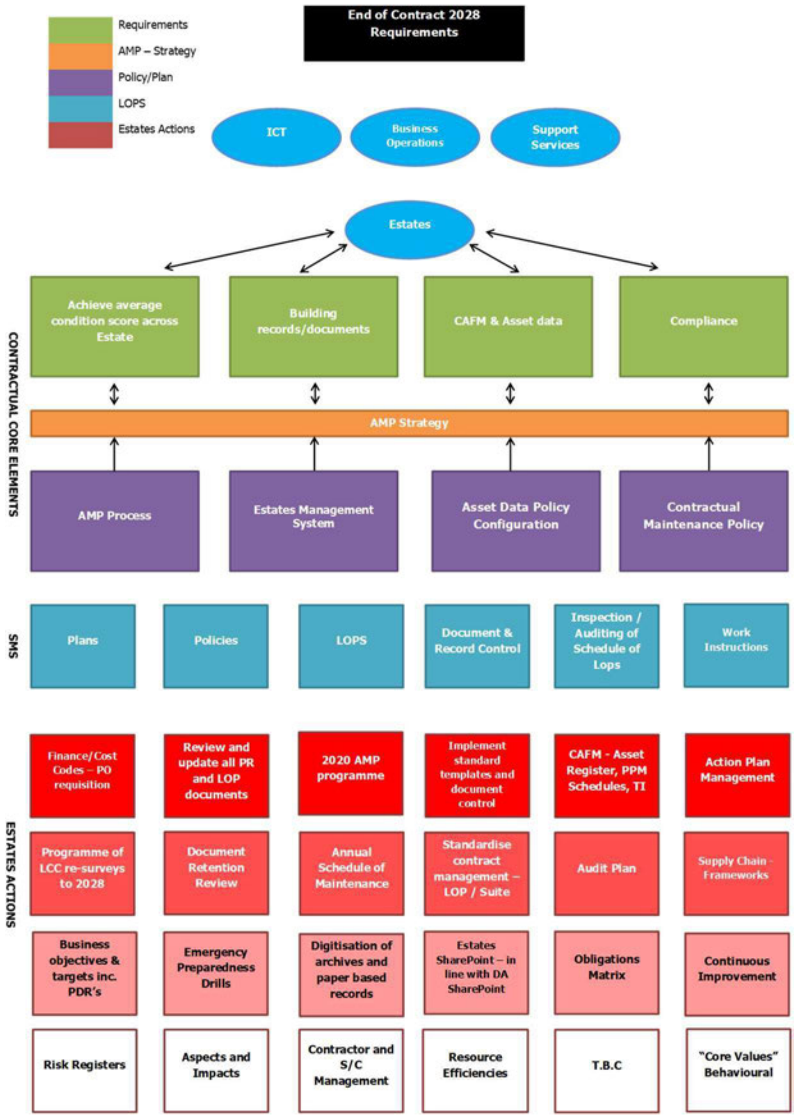


Figure 5.31 Organisation A Estates Department High Level Strategy (Source: Organisation A)

One of the Organisation's continuous improvement projects observed for research data collection was the development of a new Asset Information Model (AIM) SharePoint. In this process Organisation A had gone through a process of considering the 'critical' information required for O&M by looking at the existing folder structures in each of the existing systems;

• CAFM

• SharePoint

• R Drive

• Technical Library

They then considered the tasks undertaken within the department and the information used during these activities. Following this analysis a structure for the AIM SharePoint was developed which would form the 'tags' used to set up the SharePoint libraries. A set of 'tags' were created for the Estates Department in general, along with project 'tags'. A library would be set up for each building comprising these tags.

One of the issues identified at Organisation A was the duplication of files in SharePoint and R Drive, a common issue noted to affect this industry (Simeone *et al.*, 2018; Jordan-Palomar *et al.,* 2018). This results in a number of challenges. Duplicated files results in a large amount of unnecessary file storage. It became apparent that Organisation A had set business level limitations on their SharePoint system resulting in a 5000 file limit per folder or library. Whilst this was not an issue with R Drive, the Estates team encountered problems when project files were transferred into SharePoint as the file limits were being reached. Using *TreeSize Professional*, a piece of software that is a hard disk space manager and tool, to search drives, services and networks for old, large, temporary or duplicate files, a report was created that illustrated just how often files were duplicated in various systems. The report identified that 31,085 files had been duplicated.

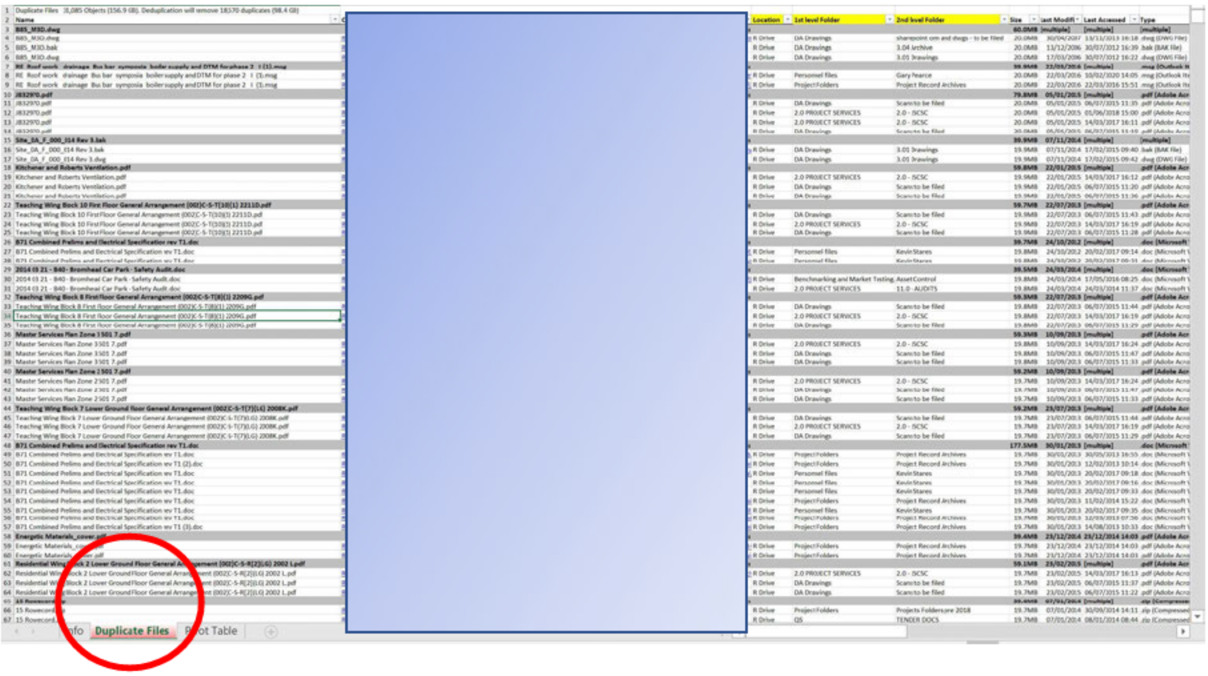


Figure 5.32 Extract of TreeSize report illustrating duplication of documents in R Drive (Source: Organisation A)

Witnessed through active participation, and illustrated within the TreeSize report, it became apparent that a number of members of staff were choosing to use R Drive to file building information and project documents instead of SharePoint as instructed. This raised questions regarding user competency, training requirements and system failures. Duplication identified a further issue relating to data integrity. With files being stored in numerous locations and multiple times, it was not possible to know if the information was current.

5.4.5 Summary

Organisation A is different from both UKAHT and the English Heritage Trust in the range of buildings it manages under contract X, the organisational structure and the contractual obligations for asset replacement/management as opposed to a custodian role with emphasis on preservation of historic assets. Unlike the heritage charitable trusts, Organisation A receives payment through the defined contract to carry out the asset replacement/management duties, with a specific budget allocated to this task across the life of the contract. Organisation A is profit making, and any AMP budget not spent at the end of the contract will be in part taken as profit. Like English Heritage, the dedicated Estates department comprises construction, maintenance and FM professionals with a wide range of skills and experience.

In relation to the organisation's asset management plan and processes, it is more akin to UKAHT in that there is no formal written AMP strategy or policy. In this sense, English Heritage's approach to asset management is more developed. Given that this organisation is a large, global company with central services and standard operating procedures, this finding is quite surprising.

In the development of their information management systems and processes, Organisation A had gone through a process of identifying the information required for asset management. It was not clear how English Heritage had gone through this process, or if it had naturally occurred based on the knowledge and experience of the individuals involved. It was however noted that some of the information requirements could be seen to relate directly to existing processes or policies such as the AMP matrix or the scheduled monument consent process. Similarly, UKAHT had created a document structure within SharePoint based on categories of information already being used but, it was not clear exactly how these had been arrived at or, if further consideration had been given to information requirements and the best way to access this.

The question that emerged from these findings is, 'What are the critical information requirements for CRM planning?'

6. Establishing critical information requirements for CRM planning

Chapter 6 is the second of four chapters that outline data collection and analysis. While others are directly related to the secondary research questions, Chapter 6 has been developed in response to the question that emerged from Chapter 5 and focuses on establishing the critical information requirements for CRM planning.

6.1 Introduction

In the previous chapter, 3 organisations were studied to understand the differences and similarities of asset management delivered in heritage and non-heritage contexts and some of the challenges faced. A high level summary of the findings is that each organisation 'does' asset management in slightly different ways, and for a number of reasons. Such reasons fall into several groups:

- The concept of value
- Funding and resource
- Types of data

All 3 groups are critical in the development of maintenance strategies and asset management plans, but each will determine or impact such strategies. It was noted that the concept of value, or the organisational goal, will determine how works are prioritised or planned. Where preservation is key, strategies will be based around emergency repairs and maintenance where there is a risk to historic fabric and significance.

Further, where an organisation acts as a custodian, there is emphasis on not only preservation of historic fabric and cultural significance but in conservation education, public engagement and income generation. Clear understanding of financial liability and budget planning play a big role in this approach and so accurate data in relation to defect liabilities and data analysis for CRM planning becomes more important in the heritage asset management strategy.

In Chapter 2, section 2.4, this was discussed in terms of a reduction in maintenance backlog as a key driver for maintenance strategies. In such cases plans will be informed by both technical assessment and economic or financial analysis. While it was considered that maintenance backlog might relate to aged maintenance tasks or incomplete works orders, in other contexts, particularly heritage, this is more likely to relate to the maintenance required to bring the condition of an asset to a certain level (Rødseth & Schjølberg, 2017). English Heritage's asset management strategy is based on reducing the maintenance backlog. In this sense, this related to the maintenance required to bring the heritage assets up to an agreed and acceptable standard. However, English Heritage have adopted their strategy to 'sustainable' conservation. Instead of calculating the maintenance backlog on the maintenance required to bring all assets up to an optimum condition rating, it is now based on achieving a sustainable state of repair, meaning risk and vulnerability are more important factors to consider within the strategy.

There is a cross over with heritage organisations that manage and operate heritage sites as visitor attractions and non-heritage organisations, in so much as their assets include operational buildings that must be maintained, repaired or replaced to meet operational requirements. In the case of Organisation A, it was noted that value was in relation to function, operation and service delivery and so, asset management strategies were based on ensuring assets remained in service, at the standard expected.

A common requirement of all organisations was the need for accessible and accurate building information to inform asset replacement and maintenance planning in line with asset management strategies. It was noted in all 3 cases that there is lots of data (building information) which is generally 'all over the place', but which data is critical for CRM planning?

While each organisation went through a process of compiling legacy data, they could not explain how they had decided which data was important, or how data structures had been developed. All 3 organisations have worked towards developing a central location for building information however, while English Heritage were using an asset management database, purchased to perform a number of tasks including document storage, condition recording, planned and preventative maintenance management, and asset management analysis and planning, both UKAHT and Organisation A were using a standard electronic document management system (EDMS) – SharePoint for document storage only.

The nature of the relational database used by English Heritage, and the range of data management meant there was some prescribed structure to the way data was managed, and specific pieces of data were a requirement of the system. However, in both SharePoint cases UKAHT and Organisation A were both still in the process of developing their structure for information management.

Missing from all cases is the actual identification of critical information requirements for CRM planning. In a heritage context personnel are dealing with legacy data that has built up over many years resulting in duplication, fragmentation and data reliability e.g. (Parato *et al.,* 2011; Gu *et al.,* 2014; Bruno & Fatiguso, 2018). Trying to pull out critical information requirements into a formalised structure, and reviewing or updating the data to ensure accuracy is a large and time consuming task. This was common to every case described in Chapter 5. A key point made by Cavka *et al.*, (2017) is that although information is required to perform facilities or asset management tasks, too much information, or information that is not critical to the task, can make it extremely difficult to manage.

Further, as noted above, critical information requirements may vary depending on the agreed asset management strategy. Without a strategy, identifying such requirements becomes almost impossible.

Here it is important to consider the boundary of this research. Critical information requirements for CRM planning are defined as those specifically required for analysis to inform CRM programmes, and will be based on the agreed heritage asset management strategy and those factors considered critical in the planning and prioritisation process such as risk, significance and condition (Lu *et al.*, 2020). Secondary to such information requirements are those required to support CRM action, types of materials and repair methods for example. Further discussion around these distinctions is provided within this chapter.

Considering the significant value of the UK's built heritage, and the reported issues in duplication of data, data accuracy, data overload, and data access noted above, there is considerable justification for the need to establish critical information requirements for effective and efficient planning of CRM. Identifying the tasks for asset management or CRM, the people involved and the information they may need and why are crucial. Understanding where this information can be found and, whether it even exists are critical as steps in the information management process.

6.1.2 Chapter aims and objectives

Having demonstrated the importance of identifying the critical information requirements required for analysis to develop effective CRM programmes in line with heritage asset management strategies, this chapter looks to the problems of data fragmentation, neglect and loss of relevance, along with a lack of standardised processes identified through the literature review. It is proposed that establishing critical information requirements for CRM planning is key to improving heritage maintenance strategies.

The objective of the chapter is as follows:

- Define the critical information requirements for heritage asset management

The aim of the chapter is to establish a standard framework of critical information requirements that may be developed into a set of conservation data parameters to support a standardised approach to digital heritage asset management processes, in particular CRM planning.

The study of the 3 organisations identified the wide range of information sources used by the heritage sector for heritage management, development of conservation management plans, and the planning of conservation repair and maintenance (CRM) but no clear guidance was evident in any of the organisations about what critical information requirements were required for CRM planning.

The chapter describes two layers of data collection and an iterative development approach borrowed from similarly themed research (Cavka *et al.*, 2017), to identify an initial standard set of conservation data parameters for CRM planning. The initial task undertaken by the researcher when trying to identify critical information requirements was analysis of secondary data to establish the range of asset data such as surveys, reports, drawings and photographs and, non-graphical data used in the process of CRM planning. The aim was to consider the type of information available within different documents, establish data categories and understand how this information would be used in the CRM process. Criteria for selection of documentation was established. After selection, 6 documents are analysed to understand key information requirements and these are grouped in categories. Where information requirements are common across 3 or more documents, these are defined as the initial set of 14 conservation data parameters.

Second, a case study of the UK Antarctic Heritage Trust is described. Through participant observation, active participation and document analysis, the Trust's processes for CRM planning (UKAHT Heritage Management Programme) are studied and 4 key data sources are reviewed to understand what information they hold and how this is used within the CRM planning process. Data is then mapped to the 14 conservation data parameters to answer two questions:

- Do heritage organisations have this information readily available?
- Are they using this information and is it successful?

Findings from this chapter suggest that while developing a framework of critical information requirements into conservation data parameters for a standardised approach to CRM planning is a relatively simple task, it is the retrospective compilation of historic building information that presents more of a challenge. Locating legacy data, understanding what information is available and what is missing, and obtaining additional data to ensure critical information is accurate, up to date and readily available for analysis might be a resource heavy and time consuming process that requires correct management. With this in mind it is important to consider information management processes, the people involved in such processes, and how they may be implemented effectively.

Having defined a standard set of conservation data parameters a pilot application of these in a BIM context are tested to consider how these might be used by UKAHT, or other heritage organisations. 3D parametric modelling has been identified as a potential barrier to implementation of BIM in a heritage context due to the complexities and cost of modelling historical architectural elements (Dore, 2017). The pilot test allows for consideration of this and whether conservation data parameters applied to a simple model might offer other benefits.

6.2 Information requirements for CRM planning

As explained, the research case studies described in the previous chapter have illustrated the lack of defined information requirements for CRM planning or, clear, standardised approach to information management and analysis.

It is noted that this research explicitly limits critical information requirements as those required specifically for CRM planning however, it is also acknowledged that a broad approach has had to be considered to take into account the fact that different organisations may have different heritage asset management strategies that rely on different factors and thus, different information.

6.2.1 Selecting secondary sources

Having reviewed asset management processes in both traditional and heritage contexts, a process of identifying critical information requirements and a lack of formality in defining these has been presented as a significant challenge. More specifically in a heritage context, organising large amounts of legacy data into useful information for heritage asset management continues to prove difficult. None of the organisations followed a standard process and none appeared to refer to formal guidance or industry standard.

Heritage organisations should be the leading bodies when it comes to CRM. It therefore seems obvious to look to the guidance published by these organisations to understand critical information requirements for CRM. An extensive search of freely available, published guidance was conducted using internet searches. There are a large number of publications available on the subject of conservation repair and maintenance, conservation philosophy and so on, along with great volumes of technical guidance in how to repair or conserve historic building materials such as stone, lime, stained glass, thatch etc. However, a specific search for *critical information requirements for heritage asset management* or *critical information requirements for conservation repair and maintenance* offered few results.

A review of the results found some documents that could prove useful in identifying critical information requirements but none specifically listed information for this purpose. A number of criteria were therefore defined to focus the search:

A Published by UK registered charity responsible for the management of national heritage

or

B Published by UK government advisor on the historic environment

C Guidance/Document aimed at those responsible for the management of national collections, heritage estates or heritage assets within local authorities rather than individual property owners

D Document title refers to heritage asset management, heritage assets or heritage management

or

E Document would be used in the process of heritage asset management or CRM planning

The criteria were carefully selected and are now discussed further.

Documents should be published by one of the large UK registered charities responsible for the management of national heritage or, a UK government advisor on the historic environment. Whilst very few documents were found that had been published by organisations outside of this category, some documents had been published by other government bodies, from Australia for example. These were intentionally ignored. While preventative maintenance is well understood as the best approach for the conservation of heritage asset (Dann & Cantell, 2008), and would suggest the large volume of literature and guidance available for heritage repair methods and approaches, it was also identified that information management and the planning of CRM lacked structure and strategic framework (Dann *et al.,* 2007). As a result of the Maintain our Heritage project, and research led by (Dann & Cantell, 2008), UK heritage organisations began to develop asset management strategies and related publications and so have been chosen as offering the most related guidance.

A quick summary of the organisations included in the search are provided below:

Historic England (HE)

Historic England is an executive, non-departmental public body sponsored by the Department for Digital, Culture, Media and Sport (DCMS). They are the government's statutory advisor on the historic environment, championing historic places, and helping people to understand, value and care for them. Historic England are responsible for protecting historic places through the listing system and they publish an extensive range of expert advice and guidance available publicly and free of charge, to help individuals care for and protect historic places.

The English Heritage Trust (EH)

English Heritage are a registered charity who care for over 400 historic buildings, sites and monuments in England. Their four major priorities are Conservation, Inspiration, Involvement and Financial Stability. In order to meet their Conservation priority English Heritage have developed an Asset Management Plan. The 2011 – 2015 Asset Management Plan was publicly available when this research began. The 2019 – 2023 Sustainable Conservation Strategy and Asset Management Plan was provided by English Heritage to inform this research. To deliver the conservation works identified in the asset management plan, English Heritage use an Asset Management Database called K2 to manage their data, and have a dedicated Estates department comprising Estates Management, Asset and Survey and Project teams.

Historic Environment Scotland (HES)

Like HE, Historic Environment Scotland (HES) is an executive, non-departmental public body responsible for investigating, caring for and promoting Scotland's historic environment. As well as making and maintaining lists of historically important sites and buildings, HES provide advice on the impact of planning and development on the historic environment. Like EH, they are also responsible for the maintenance of over 300 historic sites and have a dedicated conservation department consisting of architects, technicians and work teams. Conservation is based on their own research and they provide publicly available conservation best practice advice and guidance.

CADW

CADW is the Welsh Government's historic environment service, part of the Culture, Sport and Tourism department. Meaning 'to keep' or 'protect' in Welsh, CADW describes the exact objective of the organisation. The aim, an accessible and well protected Welsh historic environment. CADW help to care for the historic environment, promote the skills that are required to help look after the historic environment in the correct manner and, help people cherish and enjoy the historic environment.

Documentation produced by the chosen organisations was reviewed to establish those that met the rest of the chosen criteria. Documents were not limited to publicly available literature but included internal documentation used by the individual organisations in their asset management processes. This offered the best chance at understanding the full CRM planning process and identifying as accurately as possible the critical information requirements.

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.

6.2.2 Review of secondary data sources

Documents that provided the most useful information include: Historic England Scheduled Monument Consent (1); Heritage Assets Data Template as developed by Historic England (2); English Heritage Asset Management Plan 2011-2015 & Sustainable Conservation Strategy and Asset Management Plan 2019-2023 (3) (English Heritage, 2011); Historic Environment Scotland Asset Management Plan for the Properties in Care of Scottish Ministers 2018 (4), the English Heritage K2 Basic User Guide (5); and CADW - Managing Scheduled Monuments in Wales (6).

(1) Historic England Scheduled Monument Consent

Heritage and archaeological sites of national importance may be designated as a Scheduled Monument under the Ancient Monuments and Archaeological Areas Act 1979. This places statutory protection on the designated heritage asset and as such, no work can be carried out which might affect a monument either above or below ground level without approval by the Secretary of State for Digital, Culture, Media and Sport. Application for Scheduled Monument Consent (SMC) must be made and approved before any work can take place. This process is administered on behalf of the Government by Historic England. Historic England offer advice to the Government on each application, the long term aim being to safeguard the significance of protected sites. As part of the Schedule Monument Consent process, Historic England have produced a number of guidance documents that are all freely available on their website. These include;

- Scheduled Monuments – A guide for Owners and Occupiers
- Overview of SMC process
- Application for Scheduled Monument Consent

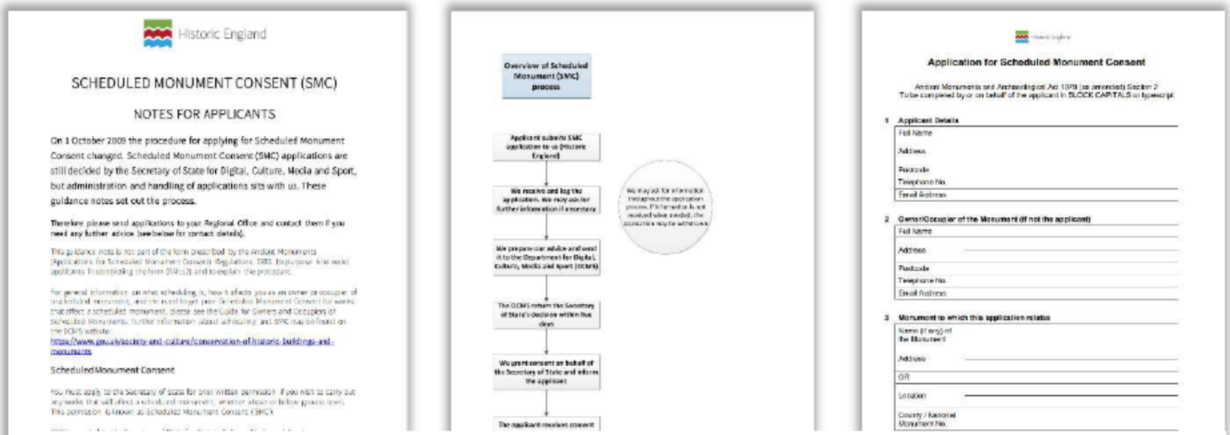


Figure 6.1 Extracts from Historic England Scheduled Monument Consent Application Form (www.historicengland.org.uk)

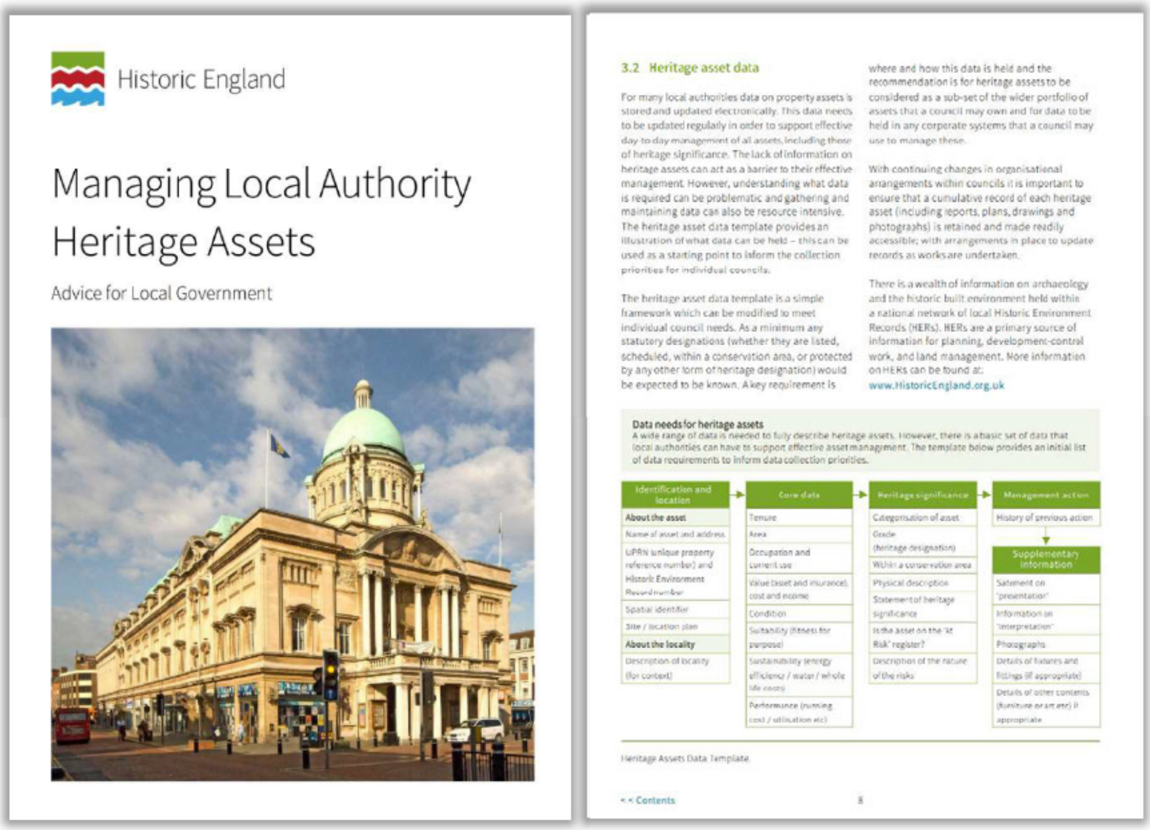
For the purpose of this research, this suite of documents have been classed as one document called *(1) Historic England Scheduled Monument Consent*. The document is aimed at anybody responsible for managing scheduled monuments, such as English Heritage. As a statutory requirement, this process and thus the document meet the following search criteria: B, C, E.

The document describes the information that will be required for the consent process, such as Name, Address and Location/Grid Reference of the monument. The application form requests a description of the proposed works however, a review of the guidance to Owners and Occupiers states that this description should be in sufficient detail to assess the impact on the monument. To describe in detail the impact that the work would have would suggest an understanding of the significance is also required. The guidance also suggests that a description of materials and methods used and justification for these should be provided. This would require an understanding and description of the materials and methods historically used. Finally, plans, drawings and photographs are requested to illustrate proposals and their impact.

While the SMC documents hint at the type of information that is required for a successful application, apart from the name and grid reference, the document is not prescriptive in the information requirements. This can be attributed to the targeted nature of the document which forms a single part of an asset management or CRM process rather than heritage asset management as a whole.

(2) Historic England – Heritage Assets Data Template

The Heritage Assets Data Template is a template produced by Historic England and appended to a number of documents found through internet search. Most importantly, it is included in the document; Managing Local Authority Heritage Assets – Advice for Local Government, published in 2017.


Historic England

Managing Local Authority Heritage Assets

Advice for Local Government

3.2 Heritage asset data

For many local authorities data on property assets is stored and updated electronically. This data needs to be updated regularly in order to support effective day-to-day management of all assets, including those of heritage significance. The lack of information on heritage assets can act as a barrier to their effective management. However, understanding what data is required can be problematic and gathering and maintaining data can also be resource intensive. The heritage asset data template provides an illustration of what data can be held – this can be used as a starting point to inform the collection priorities for individual councils.

The heritage asset data template is a simple framework which can be modified to meet individual council needs. As a minimum any statutory designations (whether they are listed, scheduled, within a conservation area, or protected by any other form of heritage designation) would be expected to be known. A key requirement is where and how this data is held and the recommendation is for heritage assets to be considered as a sub-set of the wider portfolio of assets that a council may own and for data to be held in any corporate systems that a council may use to manage these.

With continuing changes in organisational arrangements within councils it is important to ensure that a cumulative record of each heritage asset (including reports, plans, drawings and photographs) is retained and made readily accessible; with arrangements in place to update records as works are undertaken.

There is a wealth of information on archaeology and the historic built environment held within a national network of local Historic Environment Records (HERs). HERs are a primary source of information for planning, development-control work, and land management. More information on HERs can be found at: www.HistoricEngland.org.uk

Data needs for heritage assets
A wide range of data is needed to fully describe heritage assets. However, there is a basic set of data that local authorities can have to support effective asset management. The template below provides an initial list of data requirements to inform data collection priorities.

Identification and location	Core data	Heritage significance	Management action
About the asset	Tenure	Categorisation of asset	History of previous action
Name of asset and address	Area	Grade (heritage designation)	**Supplementary information**
UPRN (unique property reference number) and Historic Environment Record number	Occupation and current use	Within a conservation area	Statement on 'presentation'
Spatial identifier	Value (asset and insurance), cost and income	Physical description	Information on 'interpretation'
Site / location plan	Condition	Statement of heritage significance	Photographs
About the locality	Suitability (fitness for purpose)	Is the asset on the 'at Risk' register?	Details of fixtures and fittings (if appropriate)
Description of locality (for context)	Sustainability (energy efficiency / water / whole life costs)	Description of the nature of the risks	Details of other contents (furniture or art etc) if appropriate
	Performance (running cost / utilisation etc)		

Heritage Assets Data Template

<< Contents 8

Figure 6.2 Extract from Historic England publication – Managing Local Authority Heritage Assets (Historic England, p8, 2017)

The guidance is primarily aimed at local authority asset managers and provides a framework of 'best practice' for heritage assets within their care. Guidance is intended to be pragmatic and practical, and flexible enough for local authorities to adapt to suit their own management arrangements.

The guidance contains a set of 'tool kits' which local authorities are encouraged to modify and use to suit their local circumstances. One of these is the heritage assets data template. It is noted that a wide range of data is needed for the day to day management of heritage assets, including data on significance. It is acknowledged within the document that understanding what data is required, and gathering and maintaining this can be problematic and resource intensive.

The aim of the heritage assets data template is to provide a framework for a basic set of data that local authorities can use to support heritage asset management.

The heritage assets data template is a key document that meets most of the search criteria – B, C, D & E.

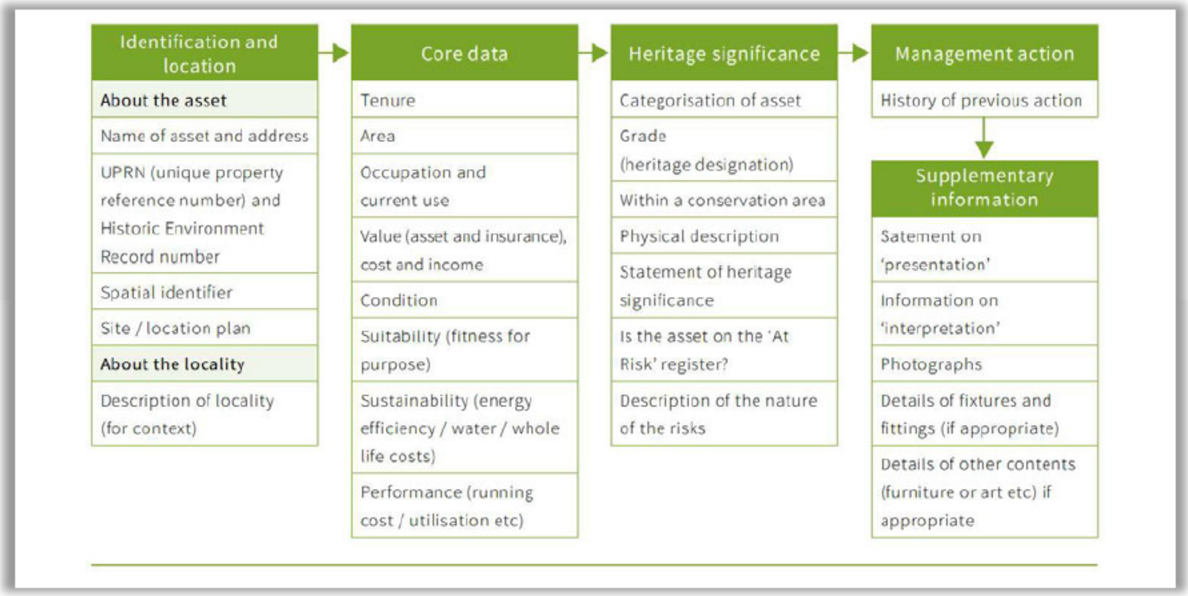


Figure 6.3 Historic England - Heritage Assets Data Template (Historic England, p8, 2017)

The data requirements identified in the heritage assets data template while limited to a core framework, are quite broad, indicating their intended use for the wider task of heritage asset management rather than CRM planning specifically.

A number of case studies identified in the *Managing Local Authority Heritage Assets* guidance suggest that the guidance has had a positive impact on a number of Local Authorities who have now developed Asset or Heritage Asset Management Strategies, including Gloucester City Council and Nottingham City Council.

(3) English Heritage Asset Management Plan 2011-2015 & Sustainable Conservation Strategy and Asset Management Plan 2019-2023

During the early years of this research (which commenced in 2016), the English Heritage Asset Management Plan (AMP) 2011-2015 was publicly available via the internet. As this document has now been superseded it is no longer available. The plan is replaced with the English Heritage Sustainable Conservation Strategy and Asset Management Plan (SCAMP) 2019-2023. Both documents are a useful source for analysis and for the purposes of the research are classed as one source. The plans are published by English Heritage who are responsible for the care of England's National Collection of heritage sites and details their approach to heritage asset management.

Figure 6.4 English Heritage Asset Management Plan 2011-2015 (Front Cover) (Source: English Heritage)

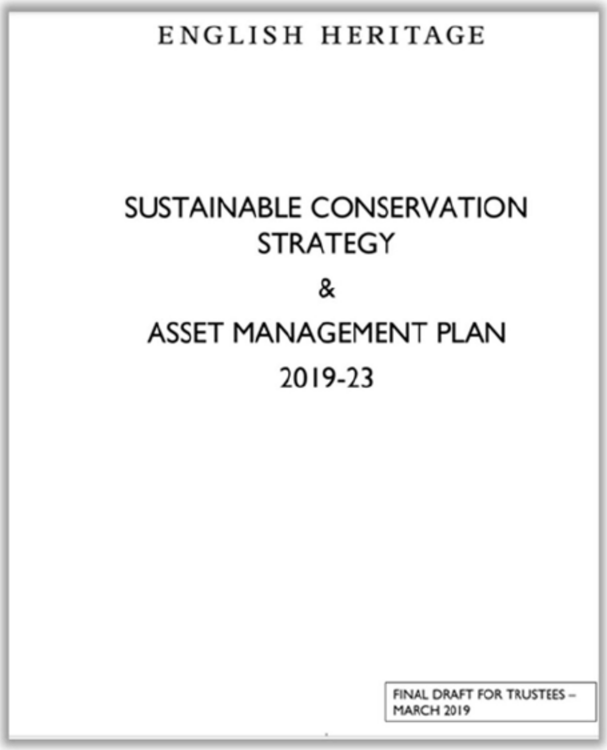


Figure 6.5 English Heritage Sustainable Conservation Strategy and Asset Management Plan 2019-2023 (Front Cover) (Source: English Heritage)

The AMP (2011-2015) was intended to provide a framework for action and to facilitate rational asset decision making based on identified needs and available funding. The SCAMP (2019-2023) sets out key objectives for the conservation and maintenance of the historic estate, and details their evidence based methodology for prioritising investment. The documents meets the following research search criteria; A, C and D.

Importantly for this element of the research is that across the two strategies, English Heritage have shifted the measurement of their success from a reduction in maintenance backlog and financial liability to an estate that achieves and holds a sustainable state of repair – 'sustainable conservation'. In both cases, this means there is an emphasis on the CRM element of heritage asset management within the documents and provides an insight into critical information requirements for prioritised, significance based CRM planning that are lacking in other documents.

With a strategic approach that uses condition survey programmes, estimated value of maintenance backlog and prioritisation of funding for CRM planning, English Heritage use significance, vulnerability and condition assessements resulting in an asset matrix scoring in the planning process and as such, these are presented as critical information requirements.

(4) Historic Environment Scotland Asset Management Plan for the Properties in Care of Scottish Ministers 2018

Similar to document (3), the Historic Environment Scotland (HES) Asset Management Plan for the Properties in Care of Scottish Ministers 2018 describes the organisation's approach to asset management. It is a detailed document that describes the organisation's asset management principles and 4 key objectives:

Figure 6.6 Extract from Historic Environment Scotland Asset Management Plan (Asset Management Objectives) (Historic Environment Scotland, 2018)

Figure 6.7 Historic Environment Scotland - Asset Management Plan for the Properties in the Care of Scottish Ministers 2018 (Front Cover) (Historic Environment Scotland, 2018)

The document is aimed at communicating the HES approach to asset management to a wide audience rather than being a guidance document for example. It does however provide useful insight into the organisation's processes and thus can offer some understanding of critical information requirements for CRM planning. It meets the following research search criteria; A, B, C and D.

Similar to English Heritage, HES describe an asset management workflow that is based on a cyclical approach of inspection, understanding, prioritisation, planning, delivery and continuous improvement. Development of monument condition indicators (MCI) which take into account urgency and risk, again similar to the approach taken by English Heritage, are key criteria used in the planning stages of CRM and help to identify critical information requirements that are specific to this risk and prioritisation approach to CRM.

The HES-SIGMA system (Tracey *et al.*, 2016) that is referred to in the HES Asset Management Plan is used by Historic Environment Scotland to store and present conservation and maintenance information and used for effective planning of conservation and maintenance programmes. Critical information requirements such as Description, Risk, Urgency and Condition are identified.

To support the reporting provided by the HES-SIGMA system, site or floor plans are also required. And further analytics can be provided if building materials and/or trades are collated as critical information requirements. Key to this approach, which mirrors the English Heritage approach, is the elemental structure of the data. Rather than collating data in relation to an overall building or asset, as might be the case in an Historic Environment Record (HER) used by Local Authorities, the data is assigned directly to building elements.

The result of this for HES is a ROY (Red, Orange, Yellow) diagram that provides an illustrated conservation strategy for the monument and supports the development of prioritised plans of work. As can be seen from the diagram below, cost is an information requirement that could also be built into the process.

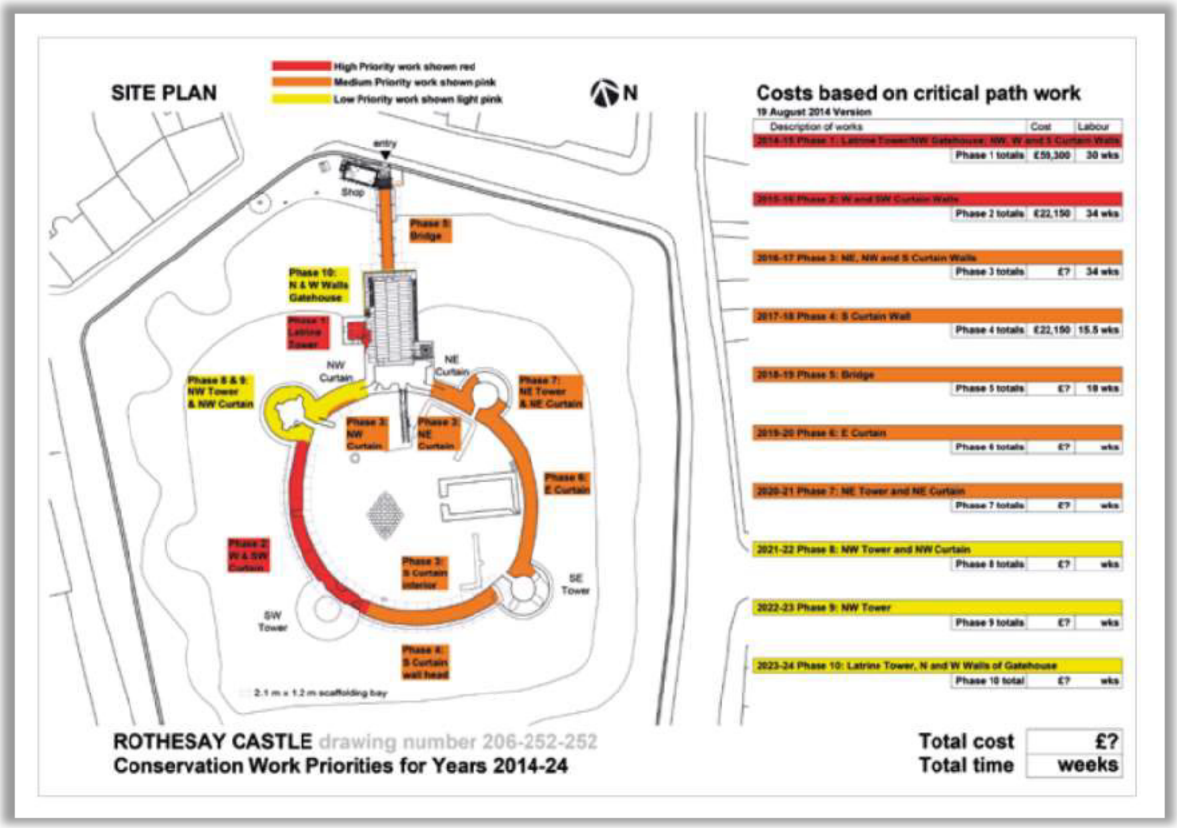


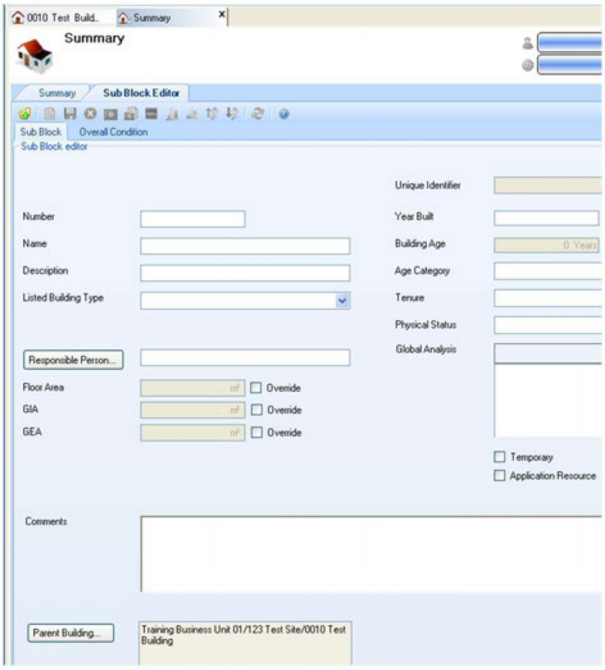
Figure 6.8 Rothesay Castle ROY Diagram (Source: Historic Environment Scotland)

Furthermore, the document describes the HES Properties in Care Asset Management System (PICAMS). It is noted that there is no specific heritage asset management system and so organisations either use existing asset management systems as best they can, or are required to develop something bespoke such as PICAMS. Further review of PICAMS identifies that the system comprises an interface through which a number of other databases, data or documentation is viewed. This provides further useful insight into critical information requirements.

(5) English Heritage K2 Basic User Guide

K2 is the asset management database used by English Heritage. The K2 user guide is an English Heritage document produced to support users of the system and was provided to the researcher during their placement with the organisation. The document describes the K2 system and specifically, how it is to be used by English Heritage. As the system is an 'off the shelf' product, not all functions of the system are used by English Heritage and, the way assets are 'built' in the system must follow the English Heritage Standard, EHS 0003/3:2013 *K2 Naming and Numbering Standard*. As the document is produced by English Heritage and relates to a system used for CRM planning it meets the following research criteria; A, C and E.

The document presents an element of repetition in terms of critical information requirements from the English Heritage AMP and SCAMP documents. However, the information requirements can be visualised as part of the process which offers a useful lens. As previously mentioned, some of the information requirements are prescribed by the system itself. It will not work if certain pieces of information are not included. However, in other cases, only information required for the organisation's process is included.



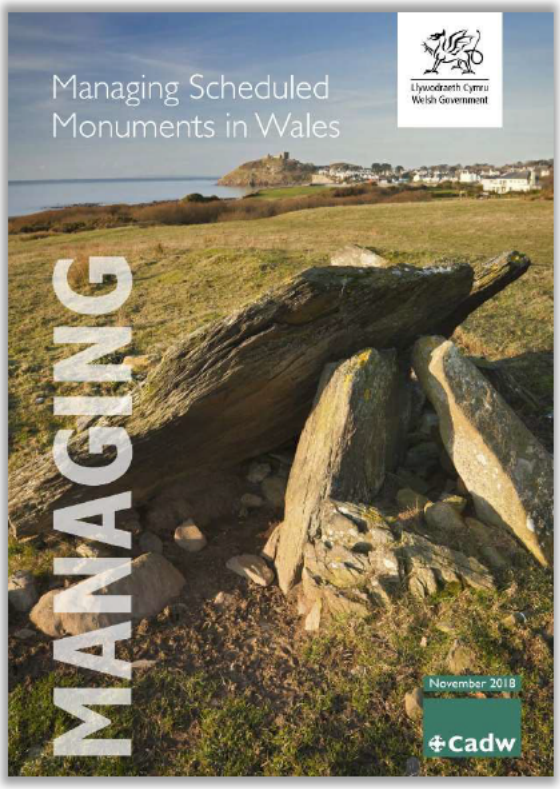
4.7.3 In the 'Sub Block Editor' that opens in the central work area, enter the Sub-block's 'Number' and 'Name'[4] as well as any additional information that needs to be recorded in the 'Comments' field. The 'Parent Building' field should be automatically populated, and since no further information needs to be entered finish by clicking 'Save' (the blue disk icon).

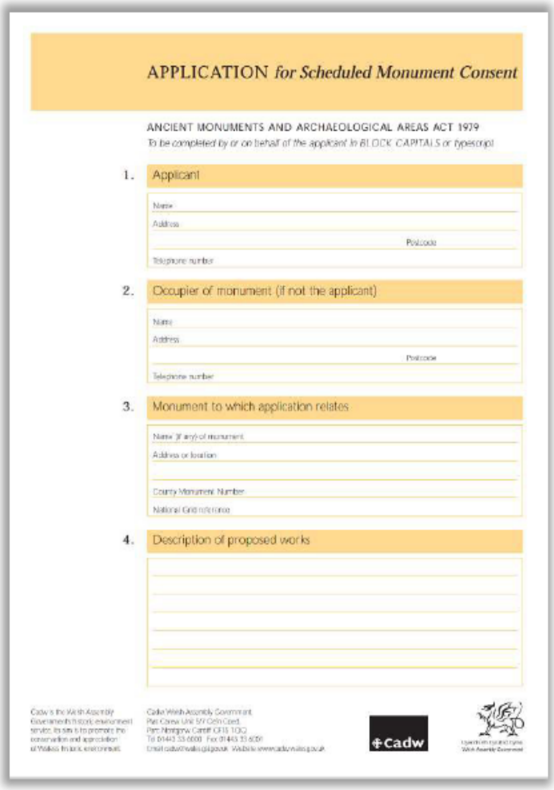
Figure 6.9 Extract from English Heritage K2 Basic User Guide (Source: English Heritage)

An example is provided on page 24 of the document, illustrated above. The guide suggests that the sub-block editor should be completed by adding the name and number. Sub-blocks refer to the elevations of the asset and so, each elevation is recorded with a name and number. The 'parent' building field is automatically populated. As can be seen in the example a number of further fields are available, such as Year Built, Physical Status, Floor Area and Responsible Person however, as they pieces of information are not used in English Heritage's CRM planning process, these fields are left blank.

(6) Cadw - Managing Scheduled Monuments in Wales (including application for Scheduled Monument Consent)

This document produced by Cadw sets out general principles for the management of scheduled monuments in Wales. It describes the scheduled monument consent process in Wales, including the roles and responsibilities of owners and Cadw. It is a best practice guidance document aimed at owners, occupiers and managers of scheduled monuments and therefore meets the following research search criteria; B, C, D and E.





APPLICATION *for Scheduled Monument Consent*

ANCIENT MONUMENTS AND ARCHAEOLOGICAL AREAS ACT 1979

To be completed by or on behalf of the applicant in BLOCK CAPITALS or typescript

1. Applicant

Name

Address

Postcode

Telephone number

2. Occupier of monument (if not the applicant)

Name

Address

Postcode

Telephone number

3. Monument to which application relates

Name (if any) of monument

Address or location

County Monument Number

National Grid reference

4. Description of proposed works

Cadw

Figure 6.10 Extract from CADW - Managing Scheduled Monuments in Wales inc. Application for Scheduled Monument Consent (CADW, 2018)

As well as a guidance document for owners and managers of scheduled monuments, the guidance should be used by decision making authorities in the planning process. Finally, those using the document should refer to Cadw's Conservation Principles document to achieve sensitive management of heritage assets.

The 'Managing Scheduled Monuments in Wales' document is not an asset management plan or strategy. Similar to the Historic England suite of documents for Scheduled Monument Consent, the documents explain what Scheduled Monuments are and the implications of the statutory protection, and give advice on completing a scheduled monument consent application. As the documents states, key to this is understanding the significance of the heritage asset, in particular, a full appreciation of the heritage values – Aesthetic, Historical, Evidential or Communal (English Heritage, 2008). The development of a statement of significance should be the starting point for heritage asset management, interpretation and any proposed changes or applications for consent as this will help to explain the significance to others and the impact that any works or changes will have on this significance. While the information requirements that can be gleaned from the scheduled monument consent documents is limited, it can be considered critical as without it, consent cannot be granted and works cannot commence.

A useful addition to this suite of documents is a table that describes different types of repair or maintenance, the risk presented by the activity, best practice and whether consent is required or not. Furthermore, Class Consents are described. This is where Cadw has precisely and narrowly defined a list of low risk works that may be carried out without scheduled monument consent.

6.2.3 Analysis of secondary data sources

A thorough search for industry guidance and documentation using the defined search criteria described in section 6.2.1, produced a limited number of documents. Those meeting the criteria broadly fell into two categories:

- Asset Management Plans/Strategies
- Consent Processes (Scheduled Monument Consent)

Despite this, the two themes provided useful information that could be considered critical for CRM planning. While not all heritage assets are designated as scheduled monuments, most will be designated in some way, whether listed or within a Conservation Area, and as such will be required to go through some sort of consent process. Each process is similar requiring certain information about the asset and in particular, a statement of significance that will help to illustrate how the proposed conservation, repair or maintenance will impact the heritage asset.

Guidance for developing asset management strategies, or the asset management plans of primary heritage organisations, have proven extremely useful in understanding the processes followed, particularly for the planning and prioritisation of CRM programmes and illustrate a number of information requirements critical to these processes.

To bring the findings together, data requirements identified from each of the documents were compiled in a spreadsheet under seven categories. Categories were identified using the structure of the scheduled monument consent application form and, adapted from the Historic England 'Heritage Assets Data Template' (Figure 6.3) which provided a useful framework (Historic England, 2015). Data within each category is further analysed to note why the information is required. The categories are detailed in Table 6.1.

Table 6.1 Categorised data requirements

Category	Reason
Owner/Occupier of Monument/Heritage Asset	Consent process requirement
Monument/Heritage Asset Details	Consent process requirement / Identification
Location	Consent process requirement / Identification
Heritage Significance	Consent process requirement / Prioritisation
Core Data	CRM Planning / Prioritisation
Management Action	Heritage management / Recording
Supplementary Information	Consent process requirement / CRM Planning

A key to the sources is provided in Table 6.2 and Table 6.3 illustrates 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 in grey. In other words, this initial set of conservation data parameters has been established based on those that appear most commonly. A limitation to this generalised approach is the risk that for some organisations, depending on their heritage asset management strategy (Historic England, 2015), a critical information requirement may have been missed. However, it is justified that as a general framework to support standardised approaches, this approach is acceptable. It offers a starting point for heritage organisations but is certainly not restrictive in that individual organisations cannot also define their own conservation data parameters.

Table 6.2 Key to Table 6.3

Key:
(1) Historic England Scheduled Monument Consent
(2) Historic England – Heritage Assets Data Template
(3) English Heritage Asset Management Plan 2011-2015 & Sustainable Conservation Strategy and Asset Management Plan 2019-2023
(4) Historic Environment Scotland Asset Management Plan for the Properties in Care of Scottish Ministers 2018
(5) English Heritage K2 Basic User Guide
(6) Cadw - Managing Scheduled Monuments in Wales (including application for Scheduled Monument Consent)

Table 6.3 Compilation of information requirements from secondary sources

Owner/Occupier of Monument	**Monument Details**	**Identification & Location**	**Heritage Significance**	**Core Data**	**Management Action**	**Supplementary Information**
Name **(1, 6)**	Name **(1, 2, 3, 4, 6)**	Location Description & Plan **(1, 2, 6)**	Categorisation of Asset **(2, 3, 4, 5, 6)**	Occupation **(2)**	Description of Proposed Works **(1, 6)**	Plans **(1, 2, 4, 5, 6)**
Address **(1, 6)**	Address **(1, 2, 5, 6)**	National Grid Reference **(1, 2, 6)**	Designation (Heritage Status) **(2, 5)**	Use **(2,5)**	History of previous action **(2, 5)**	Drawings **(1, 4, 5, 6)**
Telephone **(1, 6)**	County/National Monument No. **(1, 5, 6)**		Conservation Area **(2,5)**	Area **(2,5)**		Statement on Presentation **(2)**
Email **(1, 6)**	Unique Property Ref. No. (UPRN) **(2, 4, 5)**		Statement of Significance **(2, 4, 5, 6)**	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)**		

The compiled information requirements are presented as the initial set of conservation data parameters in Table 6.4, and are considered a starting point in the development of a final set of conservation data parameters that can be proposed to the heritage industry within a heritage information management workflow to support a standardised approach to heritage asset management, specifically CRM planning.

Table 6.4 Initial set of conservation data paramaters for CRM planning

Initial set of conservation data parameters for CRM planning	
1	Name
2	Address
3	Monument Number / Unique Identifying Number
4	Building / Asset Elements or Components
5	Location Description or Plan
6	National Grid Reference
7	Asset Categorisation
8	Statement of Significance
9	Condition Rating
10	Defect
11	Priority
12	Plans / Drawings
13	Photographs

If these are the key information requirements for CRM of heritage assets:

- Do heritage organisations have this information readily available?
- Are they using this information and is it successful?

To answer these two questions the researcher uses the UKAHT case study as a typical heritage organisation that, as demonstrated, is a small charitable trust responsible for several heritage assets and holds a large amount of historic building information which is generally fragmentary and poorly managed. Further, UKAHT are more typical of heritage organisations than English Heritage for example, which in contrast is a large, structured and well funded organisation with more developed asset management strategies and processes.

6.3 UKAHT Heritage Management Programme

Having defined an initial set of conservation data parameters it is important to understand if this information is readily available within heritage organisations and their existing documentation, and whether it is being used successfully for CRM planning.

To answer the two questions raised at the end of section 6.2.3, the second layer of data collection studies UKAHT and their heritage management programme to identify what information is used in their current CRM planning processes, how this compares to the 13 conservation data parameters, and if this information is used effectively.

This case study has been selected as it presents a typical case of a relatively small heritage trust who are trying to deliver a heritage asset management programme of prioritised conservation repair and maintenance (Savage, 2012; Clark, 2014). The site used for this case study is on Stonington Island, Antarctica. The basis of UKAHT's process for heritage asset management is a comprehensive survey, conservation and maintenance programme - the UKAHT Heritage Management Programme (later named the Antarctic Peninsula Heritage Conservation Programme). An element of development to this programme was to structure and digitise heritage building information required for the planning and prioritisation of CRM programmes.

While the trust had made attempts at identifying the information they require for successful CRM in the development of the New Field Season documents, they were still in the process of developing an efficient system for information management, data collection, and analysis. This allowed the researcher the opportunity to apply the analysed data from the first layer of data collection, and compare the 13 defined conservation data parameters with the information used in practical application by UKAHT.

Through both participant observation and active participation, and document analysis the researcher studies the building information used by UKAHT in the planning of CRM to identify which is aligned with the 13 conservation data parameters and where this information is located. Through this process, a gap analysis was conducted to identify requirements for data capture. As a reminder, fragmented, legacy data, and paper based, report style documentation causes loss of relevance and so, inefficiencies and ineffectiveness in CRM planning. This study will consider the information available to UKAHT, and that used for CRM planning but moreover, it will consider if they are using information as per the defined conservation data parameters and if this is successful.

A review of the effectiveness of such data in practical application allows the researcher to refine the set of conservation data parameters and propose a final framework to be used to support standardisation in heritage asset management and CRM planning.

6.3.1 Building Information used by UKAHT in the planning of CRM

In her study of the UK Antarctic Heritage Trust (UKAHT) the researcher noted that data sources compiled by the Trust were identified as 'relevant' and were categorised into a number of *types* of data rather than critical requirements as individual pieces of information. To distinguish between these terms this research refers to the Oxford English Dictionary. When describing data sources as relevant this means the data is closely connected or appropriate to what is being done or considered. On the other hand, critical information requirements may be thought of as facts that are provided or learned about something, an historic building in this case, that are of decisive or crucial importance to the success of CRM planning.

The Trust had identified the following data types as a *relevant data source* for their digital data management system:

- Building Reports
- Building Plans
- Conservation Management Plans
- Photographs
- New Field Season Records – (a variety of data; reports, spreadsheets, photographs)

Added to this through active participation is:

- Gazetteer

While Chapter 5 has spent time considering the CRM process to allow an understanding of similarities and differences to asset management in heritage and non-heritage contexts, participant observation, active participation and a document analysis methodology is employed here to analyse the various data sources of the UKAHT heritage management programme to answer the questions raised in section 6.2.3 in relation to the initial set of conservation data parameters:

- Do heritage organisations have this information readily available?
- Are they using this information successfully?

Photographs are not described as a separate 'document' type, instead noted as a data source that support the various other documents.

New field season records are intentionally ignored as these did not represent information used in practical application for CRM planning as required for this chapter.

Building Reports

Building Reports had been used to understand the key maintenance tasks required to prevent deterioration of the huts and preserve them for future generations. This had helped to create an annual programme of maintenance works. Desk based study is an important aspect of CRM planning. Information required to understand the condition of the historic assets, typical defects and failures, construction details, methods and materials are all vital in the planning of CRM work programmes and procurement. Since remoteness and lack of occupancy, albeit not always as remote as Antarctica, is not uncommon for historic sites, accessibility is an important factor in the planning process. Unlike conventional asset management in operational estates or buildings, it is not always possible to access heritage sites without significant planning to gather a piece of information or check a detail. Therefore, in preparation for upcoming Antarctic field seasons, this information was extracted from historic building reports. The use of historic reports or historic repair records is familiar in preventative conservation planning (Leep, 2015) however, this rich data can often be information poor (Gardner & Whitehead, 2003) and it can be extremely time consuming looking through reams of reports to pick out the one piece of information that might be helpful.

Between the 1940's and 1970's when the Antarctic huts were occupied year round by British Antarctic Survey (BAS) staff (formerly known as the Falkland Islands Dependencies Survey (FIDS)), the Base Leader of each Antarctic Hut would produce an end of season report that described the repair and maintenance projects that had been completed in and around the huts during the season. The reports are an interesting read, informative and often comical, generally beginning with an introduction summarising the main tasks that had been completed throughout the season with further sections providing more detail regarding these individual tasks.

The reports had a number of uses in UKAHTs existing Heritage Management Programme. They were used to help produce building plans as described later in this section and, to understand the materials used on site and those that should be used to carry out emergency repair and maintenance. They provide a good oversight of the routine maintenance tasks that were carried out when the stations were in use and that should be drawn into future maintenance programmes. Furthermore, they can be useful in identifying areas of concern that require further survey and planning for more significant conservation repair. Descriptions of building alterations provide a record of historical change and the age of certain parts of the buildings. Information such as this, along with other narrative within the reports, helps to build up a picture of the historical use of the huts and as such, the significance of various features. This is an important factor for a conservative approach to repair and maintenance and informs Conservation Management Plans. Table 6.5 illustrates a number of the Stonington Island Base E building reports and some of the extracts. The variety of uses of each extract is listed.

Table 6.5 Information uses from Base E building reports

Report	Item	Example	Use
1963 Building Report	Material specification and quantities for new extension	Stat Antarctic Psy = E/195/63 Ref R/T sked of 2nd September. Quantities of materials required for extension to new base hut. Roof and floor bearers 12 ft X 6 ins X 2 ins, qty 20. Joists, rafters etc 12 ft X 4 ins X 2 ins, qty 210. Pillars 9 ft X 4 ins X 4 ins, qty 18. Studs 9 ft X 2 ins X 2 ins, qty 36. Tongue and groove (planed) 12 ft X 5½ ins X ⅞ ins, qty 750. Coverstrips 1½ ins X ½ ins, qty 150 ft. Plywood, marine bonded 8 ft X 4 ft X ⅜ ins, qty 26. Hardboard 8 ft X 4 ft X ¼ ins, qty 50. Windows, double casement, 2 ft 6 ins vertical X 3 ft width, 4 panes, qty 7. Doors, standard refrigerator type, wedge shaped, 6 ft X 3 ft X 4 ins, qty 2. Stove, Jeunesse, qty 1. Ruberoid roofing felt, 36 ins width, qty 20 rolls. Aluminium foil, 30 ins width, qty 800 ft.	• Material specification • Record of historic change • Dating
1965 Building Report	Record of alterations to the hut	Alterations to the main hut consisted of the following - Removing the surgery and base office from the bunkroom and putting in shelves for personel gear. Redesigning the darkroom to make it more compact and easier to heat. x Extensive new shelving in the kitchen. Altering the old coal bunker and turning part of it into a broom cupboard etc. Removing the old geology office and using the space for an extension of the bathroom and living room. In the latter this was used for bookshelves, the lockers being removed and taken upstairs and the fire turned round to face xxxxxxx the centre of the room. The bathroom doubled in size, the fittings being rearranged and extra cupboards fitted. Water was also piped in to bath and sink though at first the hot and cold taps give out respectively warm and xx aired water. A Jeunesse fire was fitted with a drying rack round the chimney. The old workshop was turned into the base office by moveing the stairs to the bunkroom slightly and making a complete partition, cupboards and desks being fitted making it unrecognizable from the original workshop. The food store and varanda round the main hut were both fitted with false pitched roofs in an effort to divert the rain to the outside. The varanda was rubberoided but before being completly	• Record of historical change • Dating
1970 Building Report	Record of building defect – 'Sag in Chippy Shop Roof'	<u>Old generator shed</u> Interior, the main room was cleaned out and the space fitted out with new Dexian shelves which now hold all the chanderly equipment and magazines. b) one end of this room is used as a pup-feed prepation place and a meat mincher has been fixed to the bench there. c) were the chanderly was origianlly kept the shelves were removed and this place now is used for storing the gas and air cylinders. d) the pup pen area is still used for pupping bitches and their litters and is kept clean for that purpose. e) the chippy shop other than being reorganised has seen no new renovations and at the time of writing has developed a sag in the roof which will have to be fixed. <u>Old generator shed</u> Exterior, this was re-cresoted and the windowa and doors scraped and painted and, a small weather board erected over the entrance door.	• Defect Record

1971 Building Report	Temporary repair solution to sagging roof	is now in hand. Exterior of old and new huts creosoted. New Generator Shed Exterior:-No alterations or renovations made this year Interior:-Repainted. Old Generator Shed Interior:- The mademain room had no improvements this year Pup pens:-It has been decided by the pup man that these pens are impossible to keep sufficiently clean for the dogs so the pens have been dismantled and half the floor has been concreted and shelves have been put up. The other half will be completed as soon as we can remove the food stores at present occupying the space. This will be as soon as the new food store is built. Chippy shop:-A girder support has been put into the shop to control the sag, but this is still only a temporary measure to get the most out of the shed which is generally becoming weak. A clipboard to hold the tools was erected by B.Keith but as in previous years the tools still have the habit of walking to the hotel. Exterior:-No alterations or renovations have been made .	• Record of Repair • Material Specification
1972 Building Report	Chippy Shop is described as 'a bit small and scrotty, but could probably be improved by fitting some extra shelves and just generally being kept tidier than it is at present'	GENNY SHED, OLD GENNY SHED & CHIPPY SHOP. The genny shed is in good condition, and various small improvements have been made to the interior this year. The old genny shed is still reasonably sound, and is invaluable as a store for chandlery etc. The roofing felt looks fairly old, and although the roof seems watertight it may be worthwhile renewing it, especially as this will probably be the building that will house the new refridgerator. The chippy shop is a bit small and scrotty, but could probably be improved by fitting some extra shelves and just generally being kept tidier than it is at present.	• Condition Record

It appears that advice from the 1972 report was taken on board as the 1973 report noted that the building was largely unchanged apart from some general clearing out. With the base being closed down in 1974, and no mention of any repairs to the sagging roof, it is possible to suspect that there is still an issue and potentially a very weak structure that will require some substantial conservation repair to prevent a risk of collapse.

Building Plans

Current architectural building plans for the huts did not exist. Hut by hut the project Architects were therefore creating a full set of building plans, elevations and 3D drawings to be used by the conservation team for all future CRM projects. In July 2017 plans for 2 huts, Horseshoe and Stonington, had been produced to support the heritage management programme 'Phase 1' field seasons. Plans were compiled from design drawings and sketches within building reports from the BAS archive, along with historic photographs and those that had been taken by UKAHT staff during previous visits to the site and saved on the sharepoint system. For the Ground Floor plan of Base E, Stonington Island, 3 reports, a survey report and a collection of inspection photographs were used to produce the plan.

Figure 6.11 Historic sketches used to develop architectural floor plan of Base E (Source: UKAHT)

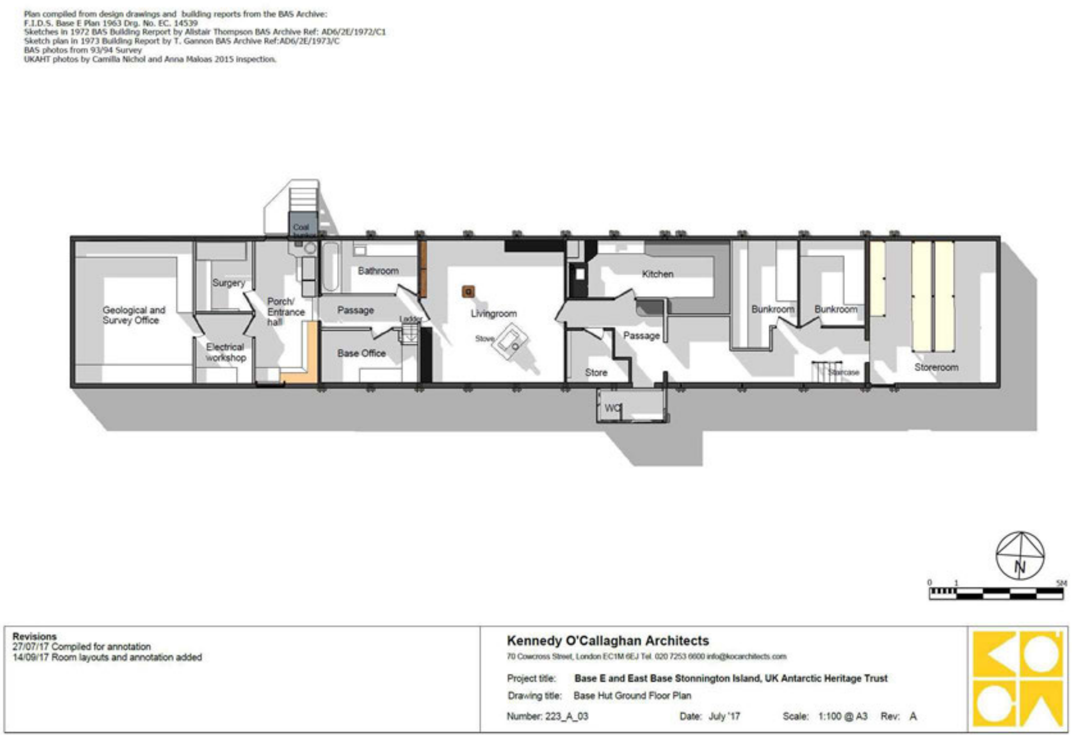


Figure 6.12 Completed architectural floor plan of Base E (Source: UKAHT)

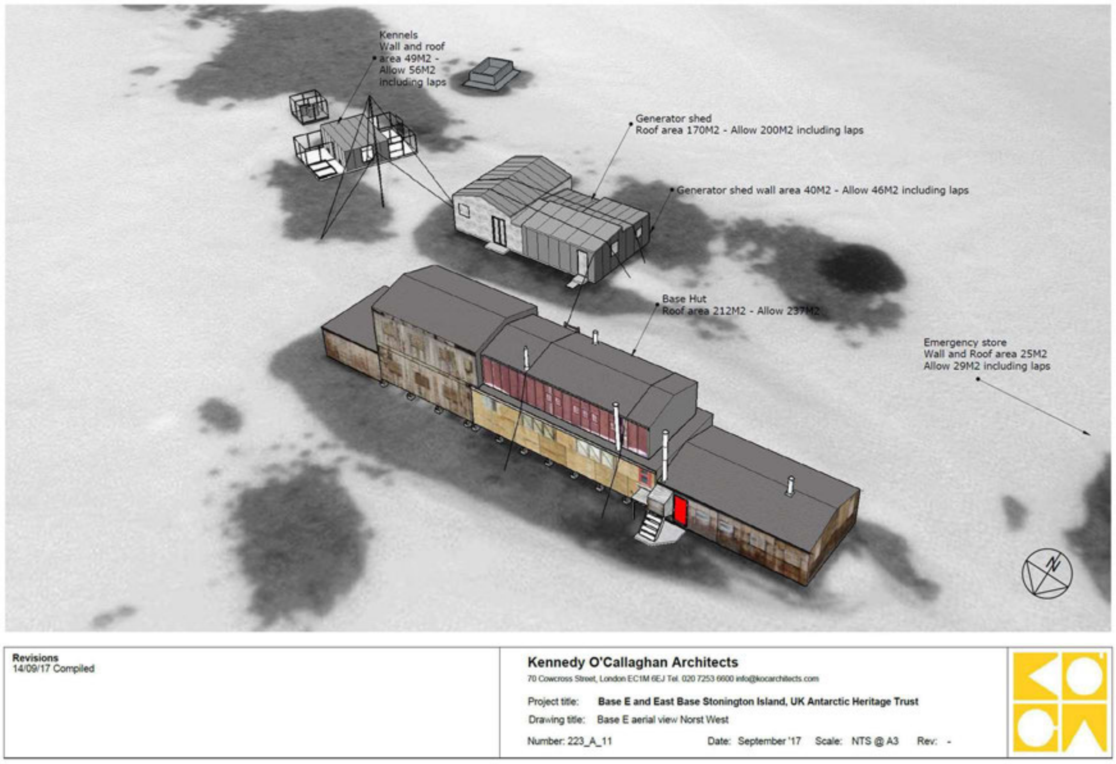


Figure 6.13 3D drawing of the Base E complex, Stonington Island (Source: UKAHT)

While a complex and time consuming process, having this information prior to the field season was vital to the planning of the project. Fairly accurate measured drawings assisted the procurement process. For example, knowing the approximate roof areas allowed for calculations of roofing felt for roof repairs to be calculated. Drawings also aided data capture in the field as they could be marked up on site.

Conservation Management Plans

The fragmented nature of UKAHT's building information is discussed however, in this Chapter the impact of this is further considered. Chapter 5 described situations where information required to complete the Conservation Management Plans for each site, starting with Horseshoe Island and followed by Stonington Island, was not readily accessible from the existing building information.

Conservation management plans (CMP) are commonly used in the heritage sector to provide information about an historic asset, such as, what is important about it and why. The CMP is used to develop management strategies and policies based on the significance of the asset detailing how future use, alteration or repair and maintenance will be carried out in order to minimise potential risk or harm to significance or historic fabric. It should be an accessible document that can be used for day to day management (Smith, 2005). In the absence of an overarching asset management plan, the CMP could be seen to fulfil this role. And where asset management plans have been developed for historic estates, such as English Heritage, CMPs are used as supporting documentation in the planning of CRM.

The chapter headings of the Draft Horseshoe Island and Stonington Island Conservation Management Plans included:

- Executive Summary
- History
- Location
- Understanding the Heritage
- Significance
- Risks and Opportunities
- Governance, management, funding and policy
- Conservation Principles
- Programme of Work

There are two points to note with these CMPs. While general conservation principles are discussed, the repair and maintenance philosophy (Smith, 2005) for the Antarctic huts had not been developed and was not yet included within the document. This identified the need to capture accurate information about the materials that had historically been used on site and the construction and repair methods used. While the historic reports might suggest that inspection of the roofing felt and patch repairs or replacement may be necessary, they did not stipulate the materials used for these repairs or the repair method to be used. This is an important element of conservation repair and maintenance and provides a departure from repair and maintenance in a traditional context. Dann *et al.*, (2007) reported that surveys and inspections of historic assets did not adequately consider issues of significance and vulnerability and, Worthing & Bond (2008) note a requirement on the conservation professional to understand the value and significance of an asset when making judgements and to ensure an informed approach when choosing the best course of action for conservation repair and maintenance. The philosophy should be developed to state the approach that is to be taken and this would be detailed in the yet to be completed conservation management plans. The plans would help answer questions as below:

- Should only historic materials and methods be used?
- How should modern repairs be identified as repairs?
- Is the approach to make all modern repairs obvious by using different materials?
- How is the existing, historic fabric to be protected?

UKAHT developed a relationship with the Building Research Establishment (BRE) who provided support in establishing the materials used, their condition (integrity, deterioration due to UV, weather, erosion, biological agencies) and their long term outlook. A step by step material sampling guide was prepared by BRE and provided to the UKAHT conservation team so that material samples could be taken on site, analysed in the UK and provide the necessary information required for the planning of future repairs and establishing conservation repair philosophies. The materials and issues are broadly summarised in Table 6.6.

Table 6.6 Material samples to be gathered from Base E and tests to be undertaken by BRE

Wood	• Is it treated, fire retardant, preservative, coatings • Glue bond integrity for composites (plywood)
Felt	• Membrane integrity • Deterioration to UV and ageing
Concrete	• Extent of carbonation • Composition
Metal	• Corrosion • Anchor integrity

In order to obtain the required information, as highlighted above, the following Phase 1, data capture, tasks were added to the task schedules:

- Visual asbestos survey
- Material sampling
- Window and door schedule
- Gazetteer recording

Gazetteer Recording

The UKAHT gazetteer is an appendix to the CMP and, is an extremely comprehensive document. A gazetteer is commonly used to provide a directory of all parts of an historic site or the individual elements of a heritage asset, identifying the significance of each element and providing information that is vital for the management of the asset. It is a reference tool separate from the textual and illustrative nature of the main body of the CMP. In this instance, the UKAHT gazetteer doubled up as a document within which to record the findings of condition survey and to record conservation and repair recommendations for the subsequent field season.

On the other hand, the gazetteer showed more promise as a single source of data providing critical information requirements. Gazetteers are typically used as a geographical dictionary however, in conservation practice often form part of the conservation management plan and provide a way to organise key information about a heritage asset (Heritage Lottery Fund, no date).

NEXUS HERITAGE

B3: Boscobel House (Farmhouse)

EH Asset number: 085-001

Type of Asset: standing building

Protection: Listed Building II* (1273964); Scheduled Ancient Monument (1003018)

HER number: 01078

Description: Two-storey brick farmhouse, abutting to the N of the W bay of B1. Two ranges, one at S end oriented E-W, the other (later) to N oriented N-S. N range contains former carriage archway suggestion originally non-domestic function. Later C19 single-storey extension with 'catslide' roof in NE apex of the two ranges. Generally associated with early C19 development of the site by the Evans family, but may contain earlier (ie. C18) fabric. Painted in 'black and white' to imitate timber framing, a c.1975 restoration of C19 scheme.

Interpretation: Nineteenth century farmhouse

Statement of significance: Although an important element of the complex formed by B1, B2 and B3, this element has no great intrinsic historical significance.

Criteria	*Value*	*Notes*
Survival / Condition	High	Generally good condition
Fragility / Vulnerability	Low	Some attention perhaps needed to flashings; nature of 1975 paint may inhibit breathability
Rarity	Low	A relatively common survival
Group Value	High	A key component of the farmyard ensemble
Diversity	Med	Several phases of construction and modification
Potential	Med	
Amenity value	Med	Ground floor currently in use as visitor 'introduction' room with interpretation panels, also wet-weather holding area for visitors whilst awaiting tours (in season).

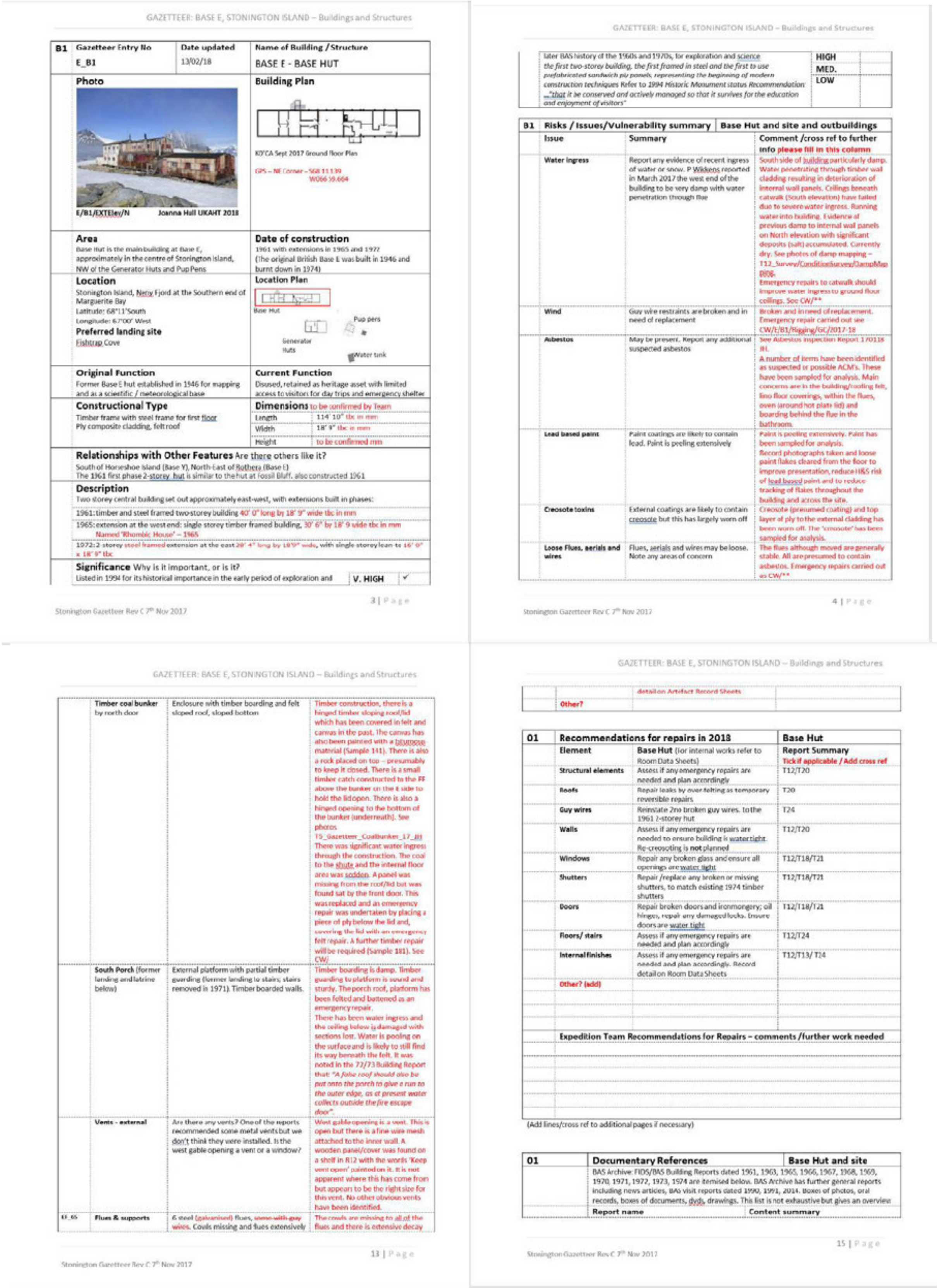
3139 – Boscobel House Conservation Management Plan
12 April 2013

II: **Gazetteer** – final report
8

Figure 6.14: Example Gazetteer from English Heritage (Source: English Heritage)

The sample English Heritage gazetteer shown above in Figure 6.14 might be considered a typical gazetteer. Key information including type of asset, protection, description and significance are described. The UKAHT example below however is a much more detailed document. In addition to the typical information found in the English Heritage gazetteer, risks, issues and vulnerability to the asset are given (Heritage Lottery Fund, no date). The biggest difference between the two gazetteers is that the UKAHT one takes a building component approach to give detailed descriptions of each component, along with a detailed condition survey of each. Instead of a single page gazetteer, the UKAHT Base E description extends to 15 pages.

The gazetteer provides a large amount of information but does it provide an efficient structure for heritage asset management?



GAZETTEER: BASE E, STONINGTON ISLAND – Buildings and Structures

B1	Gazetteer Entry No	Date updated	Name of Building / Structure
	E_B1	13/02/18	BASE E - BASE HUT

Photo

E/B1/EXTElev/N Joanna Hall UKAHT 2018

Building Plan

KO'CA Sept 2017 Ground floor Plan

GPS – NE Corner – S68 11139 W066 59.664

Area
Base Hut is the main building at Base E, approximately in the centre of Stonington Island, NW of the Generator Huts and Pup Pens

Date of construction
1961 with extensions in 1965 and 1972
(The original British Base E was built in 1946 and burnt down in 1974)

Location
Stonington Island, Neny Fjord at the Southern end of Marguerite Bay
Latitude: 68°11'South
Longitude: 67°00' West

Preferred landing site
Fishtrap Cove

Location Plan
Base Hut
Pup pens
Generator Huts
Water tank

Original Function
Former Base E hut established in 1946 for mapping and as a scientific / meteorological base

Current Function
Disused, retained as heritage asset with limited access to visitors for day trips and emergency shelter

Constructional Type
Timber frame with steel frame for first floor
Ply composite cladding, felt roof

Dimensions to be confirmed by Team	
Length	114' 10" tbc in mm
Width	18' 9" tbc in mm
Height	to be confirmed mm

Relationships with Other Features Are there others like it?
South of Horseshoe Island (Base Y), North-East of Rothera (Base E)
The 1961 first phase 2-storey hut is similar to the hut at Fossil Bluff, also constructed 1961

Description
Two storey central building set out approximately east-west, with extensions built in phases:
1961: timber and steel framed two-storey building 40' 0" long by 18' 9" wide tbc in mm
1965: extension at the west end: single storey timber framed building, 30' 6" by 18' 9 wide tbc in mm
Named 'Rhombic House' – 1965
1972: 2 storey steel framed extension at the east 28' 4" long by 18'9" wide, with single storey lean to 16' 0" x 18' 9" tbc

Significance Why is it important, or is it?
Listed in 1994 for its historical importance in the early period of exploration and | V. HIGH | ✓

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GAZETTEER: BASE E, STONINGTON ISLAND – Buildings and Structures

later BAS history of the 1960s and 1970s, for exploration and science
the first two-storey building, the first framed in steel and the first to use prefabricated sandwich ply panels, representing the beginning of modern construction techniques Refer to 1994 *Historic Monument status Recommendation: ..."that it be conserved and actively managed so that it survives for the education and enjoyment of visitors"* | HIGH / MED. / LOW

B1	Risks / Issues/Vulnerability summary		Base Hut and site and outbuildings
	Issue	Summary	Comment /cross ref to further info please fill in this column
	Water ingress	Report any evidence of recent ingress of water or snow. P Wilkens reported in March 2017 the west end of the building to be very damp with water penetration through flue	South side of building particularly damp. Water penetrating through timber wall cladding resulting in deterioration of internal wall panels. Ceilings beneath catwalk (South elevation) have failed due to severe water ingress. Running water into building. Evidence of previous damp to internal wall panels on North elevation with significant deposits (salt) accumulated. Currently dry. See photos of damp mapping – T12_Survey/ConditionSurvey/DampMap 0808. Emergency repairs to catwalk should improve water ingress to ground floor ceilings. See CW/**
	Wind	Guy wire restraints are broken and in need of replacement	Broken and in need of replacement. Emergency repair carried out see CW/E/B1/Rigging/GC/2017-18
	Asbestos	May be present. Report any additional suspected asbestos	See Asbestos Inspection Report 170118 JH. A number of items have been identified as suspected or possible ACM's. These have been sampled for analysis. Main concerns are in the building/roofing felt, lino floor coverings, within the flues, oven (around hot plate lid) and boarding behind the flue in the bathroom.
	Lead based paint	Paint coatings are likely to contain lead. Paint is peeling extensively	Paint is peeling extensively. Paint has been sampled for analysis. Record photographs taken and loose paint flakes cleared from the floor to improve presentation, reduce H&S risk of lead based paint and to reduce tracking of flakes throughout the building and across the site.
	Creosote toxins	External coatings are likely to contain creosote but this has largely worn off	Creosote (presumed coating) and top layer of ply to the external cladding has been worn off. The 'creosote' has been sampled for analysis.
	Loose Flues, aerials and wires	Flues, aerials and wires may be loose. Note any areas of concern	The flues although moved are generally stable. All are presumed to contain asbestos. Emergency repairs carried out as CW/**

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GAZETTEER: BASE E, STONINGTON ISLAND – Buildings and Structures

	Timber coal bunker by north door	Enclosure with timber boarding and felt sloped roof, sloped bottom	Timber construction, there is a hinged timber sloping roof/lid which has been covered in felt and canvas in the past. The canvas has also been painted with a bitumous material (Sample 141). There is also a rock placed on top – presumably to keep it closed. There is a small timber catch constructed to the FF above the bunker on the E side to hold the lid open. There is also a hinged opening to the bottom of the bunker (underneath). See photos T5_Gazetteer_CoalBunker_17_JH There was significant water ingress through the construction. The coal to the shute and the internal floor area was sodden. A panel was missing from the roof/lid but was found sat by the front door. This was replaced and an emergency repair was undertaken by placing a piece of ply below the lid and, covering the lid with an emergency felt repair. A further timber repair will be required (Sample 181). See CW/
	South Porch (former landing and latrine below)	External platform with partial timber guarding (former landing to stairs; stairs removed in 1971). Timber boarded walls.	Timber boarding is damp. Timber guarding to platform is sound and sturdy. The porch roof, platform has been felted and battened as an emergency repair. There has been water ingress and the ceiling below is damaged with sections lost. Water is pooling on the surface and is likely to still find its way beneath the felt. It was noted in the 72/73 Building Report that: *"A false roof should also be put onto the porch to give a run to the outer edge, as at present water collects outside the fire escape door".*
	Vents - external	Are there any vents? One of the reports recommended some metal vents but we don't think they were installed. Is the west gable opening a vent or a window?	West gable opening is a vent. This is open but there is a fine wire mesh attached to the inner wall. A wooden panel/cover was found on a shelf in R12 with the words 'Keep vent open' painted on it. It is not apparent where this has come from but appears to be the right size for this vent. No other obvious vents have been identified.
EF_65	Flues & supports	6 steel (galvanised) flues, ~~some with guy wires~~. Cowls missing and flues extensively	The cowls are missing to all of the flues and there is extensive decay

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GAZETTEER: BASE E, STONINGTON ISLAND – Buildings and Structures

		detail on Artefact Record Sheets	
	Other?		

01	Recommendations for repairs in 2018		Base Hut
	Element	Base Hut (for internal works refer to Room Data Sheets)	Report Summary Tick if applicable / Add cross ref
	Structural elements	Assess if any emergency repairs are needed and plan accordingly	T12/T20
	Roofs	Repair leaks by over-felting as temporary reversible repairs	T20
	Guy wires	Reinstate 2no broken guy wires. to the 1961 2-storey hut	T24
	Walls	Assess if any emergency repairs are needed to ensure building is watertight. Re-creosoting is **not** planned	T12/T20
	Windows	Repair any broken glass and ensure all openings are water tight	T12/T18/T21
	Shutters	Repair /replace any broken or missing shutters, to match existing 1974 timber shutters	T12/T18/T21
	Doors	Repair broken doors and ironmongery; oil hinges, repair any damaged locks. Ensure doors are water tight	T12/T18/T21
	Floors/ stairs	Assess if any emergency repairs are needed and plan accordingly	T12/T24
	Internal finishes	Assess if any emergency repairs are needed and plan accordingly. Record detail on Room Data Sheets	T12/T13/ T24
	Other? (add)		
	Expedition Team Recommendations for Repairs – comments /further work needed		

(Add lines/cross ref to additional pages if necessary)

01	Documentary References		Base Hut and site
	BAS Archive: FIDS/BAS Building Reports dated 1961, 1963, 1965, 1966, 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974 are itemised below. BAS Archive has further general reports including news articles, BAS visit reports dated 1990, 1991, 2014. Boxes of photos, oral records, boxes of documents, dvds, drawings. This list is not exhaustive but gives an overview		
	Report name	Content summary	

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Figure 6.15: UKAHT Gazetteer Template (Source: UKAHT)

Including the upcoming programme of work in the gazetteer or CMP is not usual practice and means that the documents must be reviewed and updated annually rather than serving the intended purpose of being an overarching reference document. The CMP should be reviewed and should state the significance, outline the risks and opportunities and set the philosophy for future use, alteration, repair and maintenance which is then used to develop separate management programmes (Heritage Lottery Fund, no date).

This identified the need to develop a number of subsequent documents that could be used more specifically for the planning of future CRM programmes, rather than for the purpose of stating how the work should be undertaken. This would support the Phase 3 (Planning) stage of the Heritage Management Programme. The three new field season documents are excluded from the data analysis in this chapter as they form part of a developing process for capturing missing data rather than identifying information that is currently used in practice.

6.3.2 Analysis of existing building information used by UKAHT for CRM planning

In the previous section 4 key data sources of existing building information used by UKAHT in their CRM planning are discussed. In some detail, the different sources are described, providing an illustration of the types of information available within the documents and how this was used by the UKAHT team in the planning of their CRM works.

As a summary, and to allow analysis against the two questions raised, this data is now mapped against the initial set of 13 conservation data parameters to identify which information UKAHT had, where the information was located, and if it was used effectively within Table 6.7.

The mapping exercise demonstrates that factual, identification information about the assets such as name, address and location are readily available to UKAHT. The information is structured and is in part used within the CRM planning process. The use however is limited to identification rather than information used for analysis to plan CRM works. This highlights a differentiation in the critical information requirements; those that are specifically required for CRM planning – that is, analysis of data in line with asset management or maintenance strategies to plan or programme CRM works, and those required to support the process of CRM delivery. For example, full asset location details, address etc are a requirement of the consent process but are not particularly required for data analysis and planning.

Table 6.7 Mapping of UKAHT building information against initial set of conservation data parameters

Initial Conservation Data Parameter - Ref.	Initial Conservation Data Parameter - Name	Do UKAHT have this information?	Where is this information found?	Is the data structured?	1. Was this information used? 2. What was the information used for? 3. Was it successful? 4. Could it be improved?
1	Name	Yes	HSM Listing	Yes	1. Yes 2. Identification 3. Yes 4. No
2	Address	Yes	HSM Listing	Yes	1. Yes 2. Identification 3. Yes 4. No
3	Monument Number / Unique Identifying Number	Yes	HSM Listing MODES database - references	Yes	1. Yes 2. Identification 3. Yes 4. No
4	Building / Asset Elements or Components	Yes	Historic Plans Photos Base Reports Diaries Existing Surveys Gazetteer	Yes	1. Yes 2. CRM Planning 3. Yes 4. Yes
5	Location Description	Yes	HSM Listing Existing Surveys Conservation Management Plans	No	1. No 2. N/A 3. N/A 4. N/A
6	National Grid Reference / Co-ordinates	Yes	HSM Listing	Yes	1. No 2. N/A 3. N/A 4. N/A
7	Asset Categorisation	No			1. No 2. N/A 3. N/A 4. N/A
8	Statement of Significance	Partial	HSM Listing Conservation Management Plan (where existing)	Yes	1. No 2. N/A 3. N/A 4. N/A
9	Condition Rating	Partial	Existing Surveys Base Reports Photographs	No	1. No 2. N/A 3. N/A 4. N/A
10	Defect	Partial	Existing Surveys Base Reports	No	1. Yes 2. CRM Planning 3. Yes 4. Yes
11	Priority	No		No	1. No 2. N/A 3. N/A 4. N/A
12	Plans / Drawings	Partial	Existing Surveys Base Reports Photographs	No	1. Yes 2. CRM Planning 3. Yes 4. Yes
13	Photographs	Yes	Historic Photos Photos	No	1. Yes 2. CRM Planning 3. Yes 4. Yes

Building elements/components were available in various locations and through introduction of the gazetteer, condition and defect data was being recorded at component level. This process was still in development. While a level of structure had been introduced, this was still spread across various documents and so the asset data capture spreadsheet was introduced as a way to capture building component information in one place. Information in the gazetteer format could be used for the planning of future CRM works but there was room for improvement.

Location description, national grid reference or coordinates and asset categorisation are parameters not used by UKAHT. It is suggested that the reason for this is that these were included as critical information requirements in the initial set of conservation data parameters as a result of the review of secondary data sources, particularly the scheduled monument consent process. As UKAHT are not required to follow this process, there was no requirement for this information in the CRM planning process. For the wider heritage sector, these should still be considered critical information requirements however, they are critical for CRM delivery and not specifically for CRM planning – this difference was introduced above.

Further to the parameters noted above, the statement of significance is not really used within the UKAHT CRM planning process. Significance based CRM is a standard approach in heritage asset management practice (Dann *et al.*, 2007; Jones and Leech, 2015) and so for the wider heritage sector, especially where a consent process must be followed, consideration of the significance and a description of the works and measures to mitigate risk to significance will need to be outlined. Furthermore, significance is often a factor used when calculating priority and thus planning CRM programmes. Although statements of significance are available for the UKAHT historic huts, and are incorporated into the conservation management plans, there was no clear evidence that significance and priority ratings are used in the planning and programming of CRM works despite this being noted as the Government of the British Antarctic Territory's (BAT) headline strategy for the conservation and protection of British Heritage in the BAT. It is important to consider that the unique nature of UKAHT, the remoteness of the sites and limited access opportunities contribute to challenges in the planning of CRM works which may not always result in the ideal approach.

Condition is a key parameter required for the planning of CRM works (Historic England, 2009). In relation to the UKAHT and Government of the BAT it was noted that conservation works would be prioritised on the the material state of any structure or artefact. UKAHT had this information available in a variety of sources but it was not particularly well structured. The implementation of the gazetteer, which also served as a document for structured condition survey data, offered an improvement and opportunity for the better planning of CRM works based on condition survey data but as discussed, this meant the gazetteer would need continually updating. UKAHT were developing a suite of new documents to improve this situation which included the asset data capture spreadsheet. Unlike English Heritage where condition ratings are assigned to building components, there was no rating or categorisation of condition within the UKAHT data rather, a description only. Information in this format takes time to interpret which can lead to inefficiencies.

With regards to the defect parameter, the condition survey data within the gazetteer provided very useful information, but similarly to the condition parameter, analogue/textual/report like information is inefficient when it comes to analysis. The development of the asset data capture spreadsheet was an attempt by UKAHT to improve this.

Plans/Drawings and photographs are noted in the initial set of conservation data parameters and in general, UKAHT had these available. They were used in the planning of CRM, in part due to the absence of other information, as they provide a good visual aid for planning and can help identify CRM requirements, materials and quantities. In general however, this information would be considered a requirement for CRM delivery more so than CRM planning.

Missing from the 13 conservation data parameters is repair technique/philosophy and material specification. It is important to ensure correct methods and materials are used to minimise the risk of loss or damage to historic fabric (Forster, 2010b; Ashworth, 2011). While these were not identified specifically in the analysis of secondary data sources, it is noted through the researcher's own knowledge of the scheduled monument consent process, that this type of information is required to justify the proposed conservation works. In terms of best conservation practice, repair technique and material are key to ensuring quality /effective conservation. But is this information required for analysis and CRM planning, or to support CRM delivery?

Data presented above is analysed and this question is considered to present the final set of proposed conservation data parameters for CRM planning in the next section.

6.4 Data Analysis – Conservation Data Parameters for CRM planning

The two layers of research data presented in this chapter have focused on heritage information used in the planning of CRM. A study of secondary data sources published by UK registered charities or government organisations that specifically referred to asset management or CRM planning, and were intended for use by those responsible for an estate or collection of heritage assets, identified a small number of useful documents that fell within two categories:

- Asset Management Plans/Strategies
- Consent Processes (Scheduled Monument Consent)

From this data an initial set of 13 conservation data parameters was proposed.

A study of a typical UK heritage trust (Savage, 2012; Humphrey-Taylor *et al.,* 2020) responsible for a small collection of heritage assets was also studied to identify the information they used in practice for the planning of CRM projects. This was summarised in section 6.3.2 and analysed by mapping the information to the initial set of conservation data parameters. The aim was to answer two questions. If these conservation data parameters are the critical information requirements for CRM planning:

- Do heritage organisations have this information readily available?
- Are they using this information successfully?

In summary, it was observed that the trust does have information about the building components, condition, and defects, and while this had not been previously well structured, improvements made by the trust to introduce the gazetteer and the programme of surveys has significantly improved this. In terms of analysis of the data, there were still improvements that could be made to make this task much more efficient.

The matter of whether an information requirement was critical to analysis for CRM planning, or whether it was a requirement to support CRM delivery was considered. In section 6.2.3 it was noted that using those information requirements from Table 6.3 found to be most common was a limitation of the research. Reference back to common asset management and maintenance strategies, particularly maintenance backlog, allows this approach to be reconsidered.

Maintenance backlog relating to bringing or maintaining an asset or estate to a particular standard or condition rating (Dann *et. al.*, 2007; Evdorides *et al.,* 2012) requires information on agreed conservation standards and risk. A second review of Table 6.3 identifies that 'risk' and 'minimum standard of repair' were identified but were not included in the initial set of conservation data parameters as they were not common across 3 or more of the documents. These are now added to the final set of conservation data parameters.

While UKAHT had some information regarding significance and vulnerability, this was within conservation management plans and was not well structured for CRM planning. Furthermore, they had not defined any minimum standards of repair/presentation, nor had they classified defects to give a priority to these. Despite a noted strategy of significance and priority based planning of CRM works, UKAHT did not follow this process. It is observed that while there were unique factors affecting UKAHT and the way they planned conservation projects (remoteness, access etc), this is a matter that should be considered for all heritage organisations responsible for the planning of CRM.

The culmination of the two layers of data collected and analysed in this chapter is the final set of conservation data parameters for CRM planning, and is presented in Table 6.8.

Table 6.8 Conservation Data Parameters for standardised CRM planning

Final set of conservation data parameters for CRM planning	
1	Monument Number / Unique Identifying Number
2	Building / Asset Elements or Components
3	Statement of Significance
4	Condition Rating
5	Minimum standard of repair / presentation
6	Defect
7	Risk
8	Priority
9	Material

It is proposed that, including these conservation data parameters in digital and formalised processes for heritage asset management will provide much needed standardisation and improve efficiencies in CRM planning (Dann and Wood, 2004).

6.5 Pilot application of conservation data parameters that could be adopted by UKAHT

In Chapter 2 the potential of digitisation to improve asset management practice was discussed and within the literature, BIM was considered critical to this (Berger, 2017). The use of data parameters assigned to building components is a BIM concept that could offer significant benefits. In the common BIM understanding, this might be closely linked to the use of parameters within models for analysis and planning.

With the final set of data parameters defined, the research considers how this could benefit UKAHT or other heritage organisations, and how these might be applied using parametric modelling. Using photogrammetry, a small heritage building was scanned to produce a point cloud (Figure 6.16). This was subsequently used to develop a parametric model using the Autodesk software – Revit. The model was drawn and schedules using parameters were created (Figure 6.18). Modelling of historical architecture can be complex and time consuming, requiring great skill. For the purposes of this test, a simple model was developed to consider how application may be applied, without the need for highly detailed 3D models.

Conservation Data Parameters were added to the simple test case model (Figure 6.19), including significance and condition, which were then colour coded to enable visualisation across the model:

Red Window = Poor Condition

Green Window = Good Condition

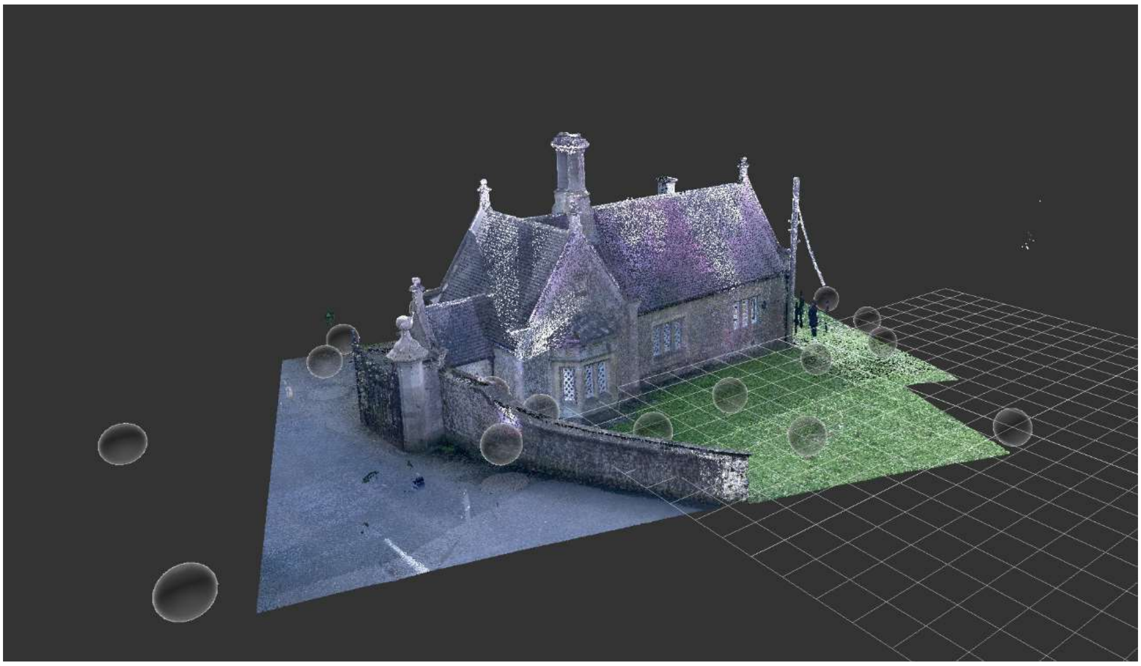


Figure 6.16 Point Cloud of simple heritage building (Source: Joanna Hull)

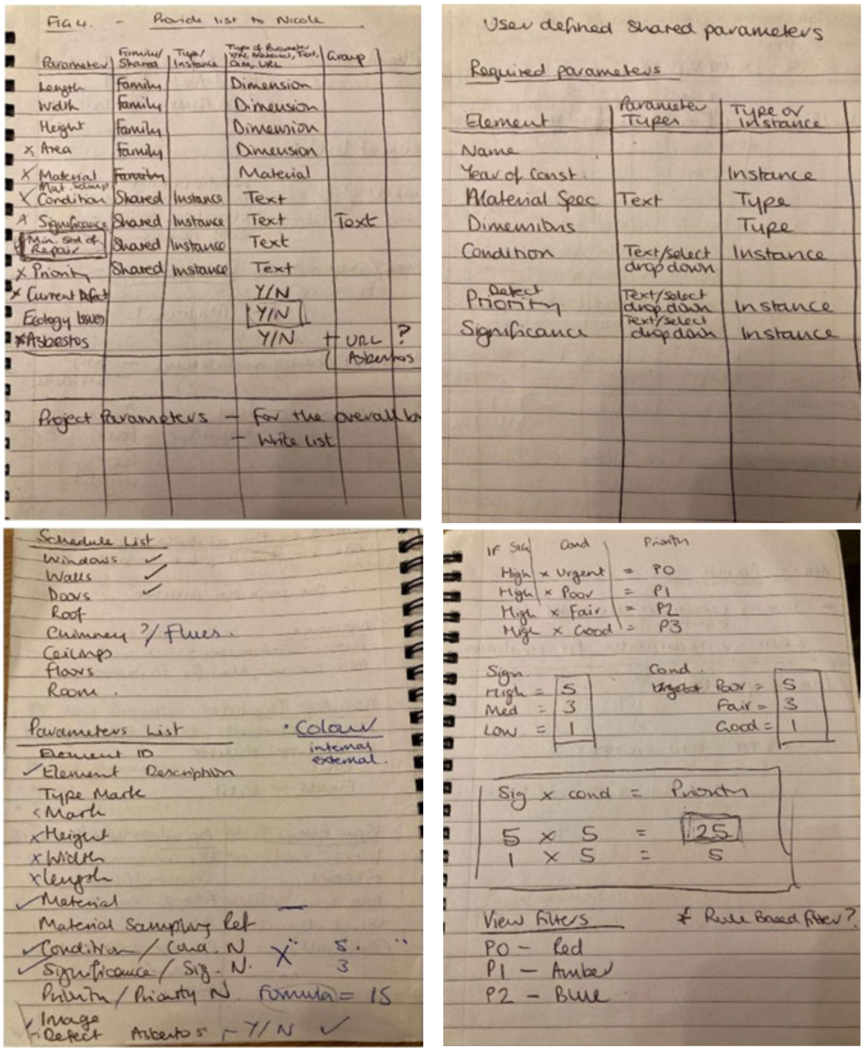


Figure 6.17 Developing schedules and data parameters for use in Revit – Research Notes (Source: Joanna Hull)

It is noted that while this approach uses BIM concepts, it is not dissimilar to that used by Historic Environment Scotland and the production of the ROY diagrams noted in section 6.2.2. The difference being the principal technology used. While the approach described above uses BIM parametric modelling, the ROY diagram uses GIS technology (Tracey *et al.*, 2016). This means that the colours are illustrated on building/site floor plans rather than as individual building components.

It could be argued that for the purposes of CRM planning, the ROY approach is satisfactory and may be less costly and technologically demanding for the heritage sector.

Furthermore, the cost, time and skills involved in the retrospective collection of 3D scan date, production of parametric models and subsequent addition of data to models to allow 3D visualisation might not be considered a cost effective approach.

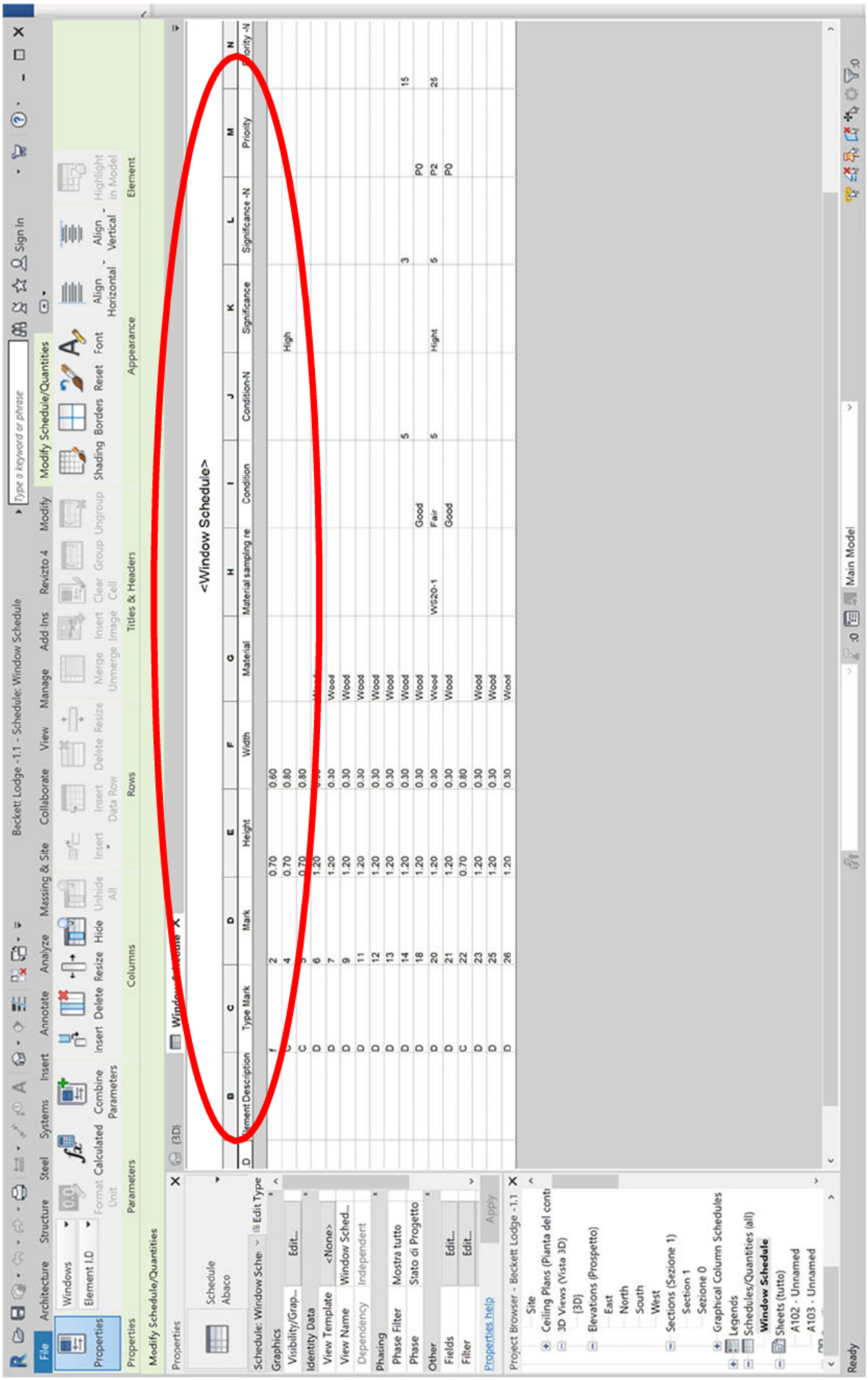


Figure 6.18 Revit Window Schedule with added conservation data parameters (Source: Joanna Hull)

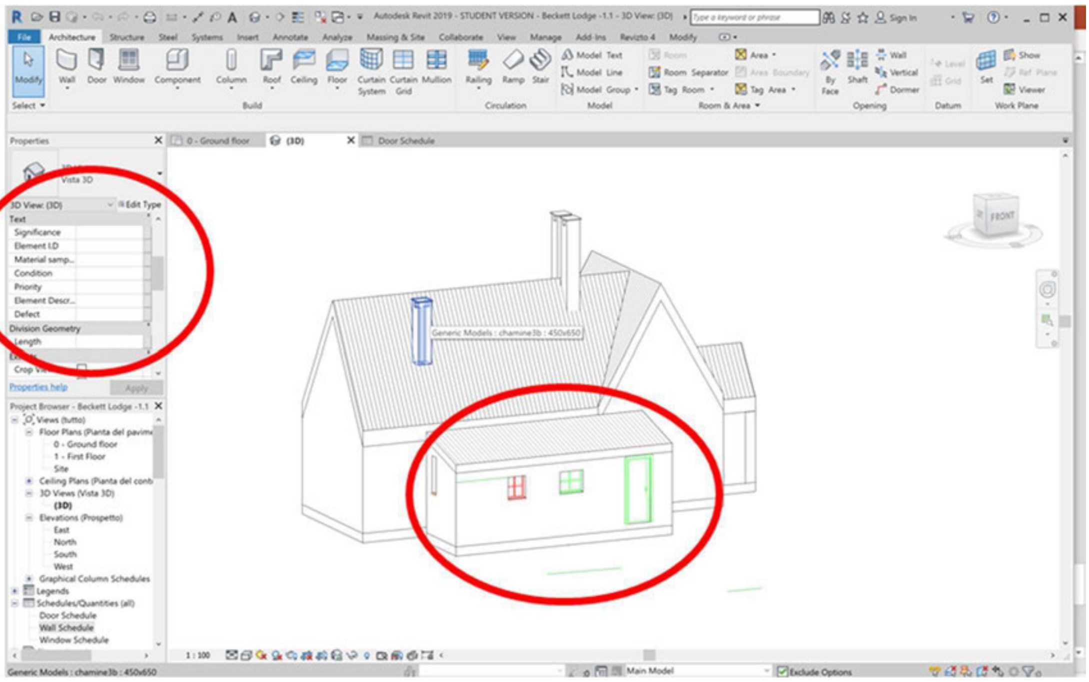


Figure 6.19 Using Conservation Data Parameters for visualised CRM planning in 3D model – Test Model (Source: Joanna Hull)

This is an important area for future research, but for the purposes of this research, the key idea to take away is that an agreed industry set of conservation data parameters has multiple benefits, no matter what analysis and CRM planning approach is taken. These are summarised below:

- Efficient and effective CRM planning based on accurate data
- Improved allocation of scarce financial resources
- Standardisation in CRM planning across the heritage sector

7. Implementing conservation maintenance strategies

This is the third of four data collection chapters presented to answer the secondary research question - '*How do people engage with formal process and guidance, and why do they not always follow it?*'.

7.1 Introduction

Having reviewed asset management in both heritage and non-heritage contexts it was identified that heritage asset management is based on programmes of significance based prioritisation of conservation repair and maintenance (CRM). A significant challenge experienced by the heritage industry is the identification of critical information requirements for CRM planning and subsequently, a formalised and structured process in which to use this information for efficient and effective planning. These factors have been considered as possible reasons that the heritage industry lacks best practice maintenance systems, industry guidance and common structured processes for heritage CRM e.g. (Dann and Wood, 2004; McGibbon *et al.,* 2018).

In the wider conservation context, relating to natural heritage rather than built heritage, Knight *et al.* (2006) documented an 'implementation crisis in conservation planning'. In summary they observed that operational models as conservation tools more often focus on conservation assessment rather than conservation planning and delivery initiatives and thus often fail to adequately address practical implementation issues, demonstrating issues that may also impact the implementation of conservation maintenance strategies. They note that the development of operational models using systematic conservation planning with quantifiable measures and targets, as those demonstrated in the English Heritage Asset Management Plan and the Historic Environment Scotland ROY process, as opposed to expert based planning, should be considered as an approach to improve implementation for conservation action.

The research case studies, particularly English Heritage and UKAHT, demonstrates intent within the industry to embed best practice and structured processes for conservation maintenance strategies, including systematic planning, but it has been discussed that when such processes are implemented success is variable (Forster & Kayan, 2009). Before common systems and processes can become well embedded in conservation practice, success needs to be demonstrated and reasons for processes failing should be understood. Academic literature that focuses specifically on issues that impact the implementation of conservation maintenance strategies is limited to just a few researchers and so it is acknowledged that the following discussion relies heavily on limited and dated literature. The apparent lack of newer research and literature on this subject, along with ongoing discussion in literature surrounding inefficiencies within the AEC industry and enquiries into the adoption of BIM methodologies to support both operation and maintenance practice, and within a heritage context, requires a review of the dated literature so that new research can build upon this.

Forster & Kayan (2009) specifically focused their research on understanding why, despite maintenance theory for historic buildings existing, it fails to be realised in practical application and implementation. It was noted that despite maintenance being a seemingly simple task, developing maintenance strategies for heritage assets causes difficulty and confusion resulting often in 'cost ineffective reactive maintenance' (Forster & Kayan, 2009). It is interesting to note that one exception (back in 2009) was English Heritage who had started to recognise some of the main issues surrounding effective maintenance strategies in their publications (Dann & Cantell, 2008). It is therefore not surprising to see English Heritage in this research leading developments in conservation maintenance strategy and processes. The review 'suggests that the ways in which maintenance is organised and financed often mitigates against its implementation' (Forster & Kayan, 2009). Three key themes impacting maintenance management were considered. While financial management and impact was discussed, the two themes that focus on the way maintenance is organised were strategic management and information management.

The heritage sector is heavily dependent on people from different backgrounds and with different skill sets e.g. (Chapagain, 2008; Watrall, 2019). Further, it has a long tradition of loosely controlled management and issues of data fragmentation e.g. (Dann & Wood, 2004; Jordan-Palomar *et. al*., 2018) which has been demonstrated in the case studies described. Evidence shows e.g. (Dore & Murphy, 2017; Bruno and Fatiguso, 2018) the industry is seeking to introduce better and digitally enabled data management, but barriers to implementation and reasons for failed strategy or process must be considered. Within the context of national organisations, such as Historic England or Historic Environment Scotland, there is enthusiasm over the potential for BIM to manage a disparate set of assets. However, as described previously, not all heritage organisations are managed at a national level. All of this results in an overlap between social organisations at different scales and their range of stakeholders, the implementation of technological innovations, practical issues, geographic variation and diverse user requirements such as public consumption, archives or CRM.

The purpose of this chapter is to consider how these things interact and affect each other. It uses anecdotal accounts from 2 case studies to illustrate the complex network of actors in heritage CRM projects and to acknowledge that actors will not always use new technologies in intended ways or indeed, adopt it.

Socio-technical network research using an ANT oriented approach was introduced as a positive method to analyse the implementation and adoption of new technology and processes. Actor network theory (Latour, 2005) allows the researcher to discover the human and non-human network elements involved in the implementation of conservation maintenance strategies and their action within the network (Schweber and Harty, 2010) for further analysis, and so provides great benefit to the research.

More specifically relating to CRM processes and a desire to create central repositories of validated data, a single source of truth for the planning of CRM programmes, it is further noted in some literature that whilst technological systems that include central repositories for information are helpful tools that can aide collaboration, it is people and 'stuff' that collaborate rather than the technological systems alone (Adamu *et al.,* 2015). Therefore, to understand how such processes will work and for implementation to be successful, the need for research from a social science perspective is reinforced.

Focusing more specifically on an 'organisational' or 'operational' element, Knight *et al.* (2006) have acknowledged that operational models – such as heritage asset management processes, must focus primarily on:

- People
- Organisations
- Process and practice

With this more targeted focus on people and process, a review of key factors affecting implementation are considered:

- Arranging and managing maintenance
- Shortage of skilled operatives for historic buildings
- Built Heritage Sector Professionals, Current Skills, Future Training
- Longevity of materials and maintenance
- Commercial maintenance and inspections services
- Owner based inspection

(Forster & Kayan, 2009)

7.1.2 Chapter Objectives

The aim of this chapter is to offer analysis of the issues identified when implementing conservation maintenance strategies. First hand observation of heritage organisations developing and implementing such strategies with a focus on the structured process for the management of their heritage building information, how they have used this for heritage asset management and specifically the planning of CRM projects or programmes, is used to consider how people along with other network elements impact implementation and effectiveness. The objective is to understand successes and failures in order to develop effective operational models or workflows for CRM planning that offer improvements where existing processes often fail.

The principal case studied is the new data management process established by UKAHT during their Stonington Island, Base E conservation project which formed part of their wider Heritage Management Programme. The Heritage Management Programme is described in detail, explaining the various phases. In this chapter, the people and processes involved in the implementation of Phase 1 of the programme are discussed. To provide a deeper understanding of the context an introduction to Stonington Island and the various sites and monuments was provided in Chapter 4. It was noted that the small island is home to an interesting complex of buildings forming both historic British and American bases. A map is provided here to illustrate how the various structures are located across the island.

Although UKAHT carried out conservation repairs to the American buildings during the field season, focus is placed on the British structures only, and the CRM processes relating to work carried out on these buildings. The case studies presented include the new Base E and Pup Pens in particular. On the map overleaf, both of these structures fall within the Base E complex.

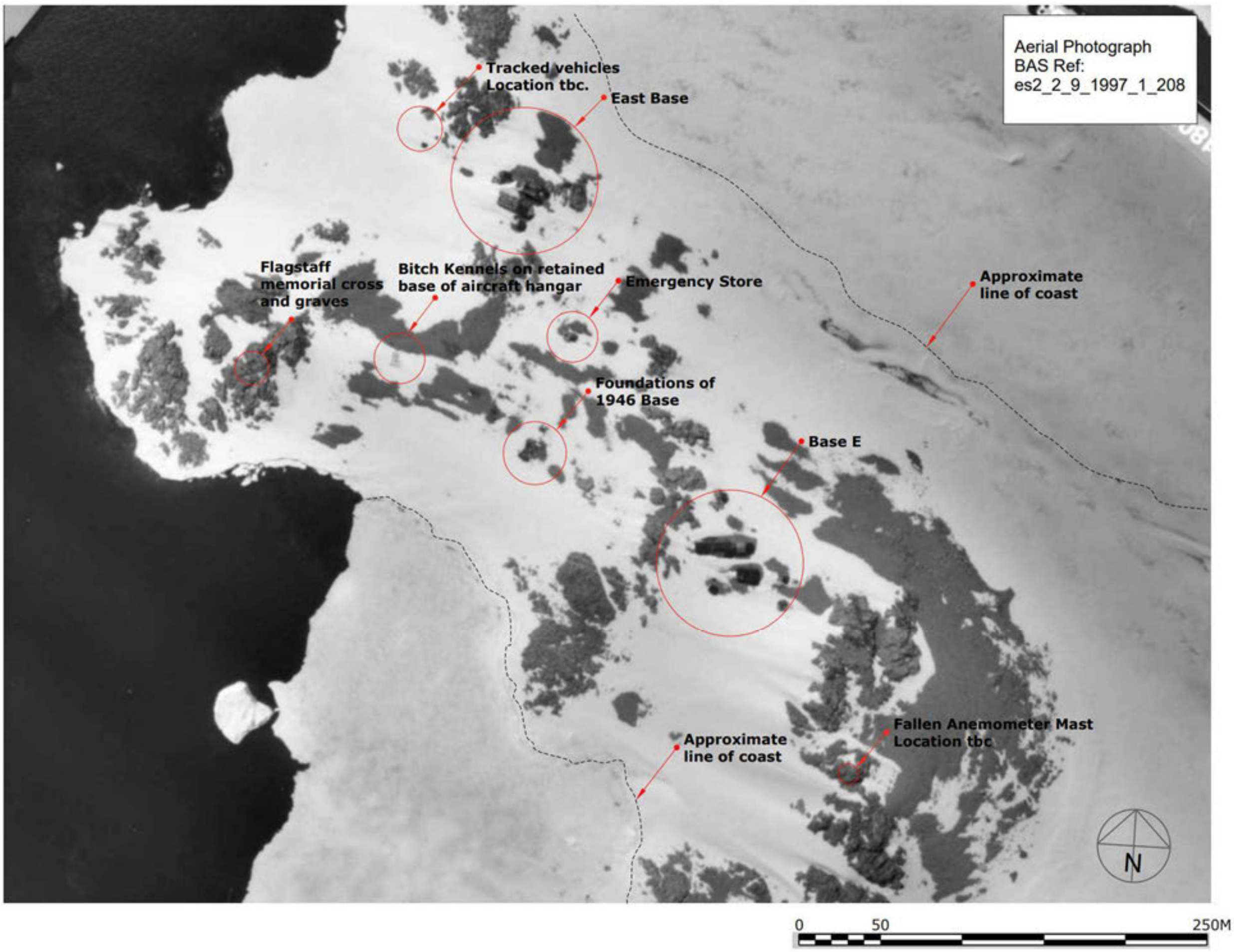


Figure 7.1 Aerial photograph of Stonington Island illustrating location of Base E and East Base (Source: UKAHT)

The second case involves data from the studies conducted at English Heritage and Historic England. Data was further analysed to see what additional information presented itself with regards to how people engage with formal processes and guidance. A mixture of interview, document analysis and participant observation were used to compile a series of field notes that were subsequently reviewed to identify data that related to CRM processes. This included observations of identifying stakeholders, information requirements and collaboration, defined processes compared to actual practice, and factors affecting the failure of processes.

These two examples provide an opportunity to see and discover common issues of implementation from a range of perspectives across two organisations that represent a similar range of organisational attitudes and structures within the sector. Both organisations are heritage trusts responsible for the conservation repair and maintenance of historic buildings. Both use conservation philosophy and significance based prioritisation as a basis to their maintenance strategies. The structure and personnel of each trust however is quite different, offering a range of perspectives for analysis. These personnel, or characters, are described in the two cases but it is acknowledged that these are quite different. The UKAHT characters are quite individual, with a range of skills, experience and background. The active participation method employed for this case study allowed the researcher to get to know individuals well, and so they are described in detail. On the other hand, personnel from English Heritage generally have similar skills and backgrounds, with heritage or history qualifications and a more ‘uniform’ career working within the heritage industry. The interview and participant observation methods used in this case study provided a less intimate understanding of the characters, and so the descriptions are based more on roles and interactions observed.

Examples in relation to UKAHT are presented as a series of vignettes, offering rich description of CRM processes and the related networks as observed through active participation. In contrast, but providing a broad range of data from a limited number of case studies, examples from English Heritage are presented as a discussion of the various sets of data. Interview responses and identified themes are presented in tables and further analysed. To provide consistency between the two sets of data the BIM research framework (Succar, 2009) is used. Data described in this Chapter is analysed using the BIM process field, acknowledging that the focus is purely on digital, formalised processes to support conservation professionals with conservation maintenance strategies and CRM planning. Data from both cases has been categorised into the 4 main steps identified in the CRM process and evidence has been structured as such:

- Survey and Data Capture
- Data Management – processing and storage
- Data Analysis – CRM planning
- Data Use – delivering CRM projects

Using a mixed methods approach across both organisations, the researcher witnessed an interesting network of actions that have been analysed and discussed.

The objectives of this chapter are to:

- Understand how people engage with formal process and guidance and why they do not always follow it
- Identify the specific challenges that conservation professionals face when engaging with digital, formalised processes

7.2 Conservation stakeholders in Antarctica

7.2.1 UKAHT conservation and maintenance team

The UK Antarctic Heritage Trust is responsible for the management of 6 historic sites and monuments on the Antarctic Peninsula. They carry out annual conservation maintenance at their flagship site, Port Lockroy, and have developed the UKAHT Heritage Management Programme as an informed and structured approach to the implementation of conservation action, and programme of CRM to the other sites.

The way historic building information is used for CRM planning, and process and documentation that had been developed to manage data was introduced in Chapter 5. Issues with data management and a lack in identifying 'critical information requirements' for CRM planning were observed and summarised. Phase 1 of the UKAHT Heritage Management Programme – data capture, survey and emergency repair, implemented during the 2017-2018 field season at Base E, Stonington Island is used to consider what the critical information requirements for CRM planning are and how they are used to develop a framework for strategic planning.

This case study builds upon those described before to consider the network involved in the implementation of developed processes for identifying critical information requirements and using information management processes for strategic conservation maintenance planning. The researcher undertook active participation during the course of the Stonington Island field season, whilst employed as Heritage Programme Manager for the UK Antarctic Heritage Trust. The researcher was immersed in the heritage management programme and was active in the development of the phases and direct management of Phase 1. The active participation method combined with a 'follow the action' style for the writing of research field notes and diaries provided data that was subsequently analysed to understand the challenges associated with the introduction of the new processes and data capture objectives of the project. Recurring issues and themes were discovered and recorded for further analysis. Active participation further allowed the researcher to get to know stakeholders at a deeper level, including their skills and experience, and attitudes to conservation processes.

The UKAHT management team, consultant team and annual conservation team were briefly introduced in Chapter 5 but some time is spent here considering the characters in more detail. In the construction, BIM, and heritage sectors stakeholders have been considered to fall into a number of different categories. Doloi (2013) considered construction stakeholders in 3 main categories: Client, Consultant and Contractor. UKAHT and their staff are both Client and Contractor, using only directly employed labour to carry out conservation repair and maintenance to the buildings within their care. In addition to the direct UKAHT staff, consultants are employed for specialist advice. As there is no clear Client/Contractor split, stakeholder categories are not specifically discussed in this research, instead choosing to use just the overarching stakeholder lens. Within the BIM research framework, and BIM fields of Policy, Process and Technology, a stakeholder lens may be used within any of the fields (Succar, 2009). These cases have been structured using a 'process' field and so only stakeholders, or actors, linked to the CRM process are described, thus remaining consistent with the 'follow the action' approach.

Chief Executive (Character A)

The UKAHT Chief Executive has worked in the museums and heritage sector for more than 20 years. With degrees in Geology and Museum Studies she went on to work with a diverse range of museum collections and became Head of Collections for Leeds Museums and Galleries. The Chief Executive has overall accountability for the Trust and its operations, including the Heritage Management Programme. The Chief Executive's experience is well suited to managing the Antarctic artefacts and collections, and in presenting the historic huts as 'living museums'. Her experience is less so in building conservation or building conservation philosophy and so Consultant Architects and advice from building conservation professionals helps the Chief Executive make informed decisions in relation to the Heritage Management Programme.

Antarctic Operations Manager (Character B)

Character B has extensive experience in managing complex operations in remote locations, with expedition leader experience in China, Tibet, Mongolia, Russia and Central Asia. Prior to joining UKAHT, Character B had worked as the Operations and Product Manager for a UK travel adventure company. Character B is responsible for all field operations, including staffing and logistics and, is responsible for H&S management of all operations – including H&S for all CRM activities. Character B worked closely with team members during the 2017-2018 season to ensure all team members had sufficient training including wilderness medical training and bespoke Asbestos and Working at Height training required for the CRM activities such as roofing and felting repairs. With no experience in Construction or Heritage Conservation, Character B relies on input from the wider conservation team to ensure the correct H&S training is provided.

Antarctic Operations Assistant (Character C)

Character C started his career as a Geography teacher but wanting a career in the outdoor world he then worked as an expedition guide and field assistant in the polar regions for 17 years. Having worked as a field assistant and winter station manager for the British Antarctic Survey, Character C then worked for the US Antarctic Programme as a contract mountaineer. For UKAHT, Character C is responsible for organising the Antarctic Operations – staffing, travel, equipment – including tech and stationery, and of course tools and materials used in the CRM process. Character C has some knowledge of the types of tools and equipment required for such programmes of work, but specific materials were informed by the wider conservation team following material sampling work with the Building Research Establishment (BRE) and from the specific knowledge of the 'conservation carpenters' and the consultant architects.

Consultant Conservation Architects (Characters D)

The Consultant Conservation Architects are a husband and wife team with over 25 years' experience and with specialist Conservation Architect accreditation from the Royal Institute of British Architects (RIBA). They have a wealth of knowledge and experience in conserving and altering listed buildings and scheduled monuments. The Architect team are responsible for providing overarching architectural and conservation advice and contribute to the heritage management programme in the development of conservation management plans and task instructions for the CRM programme. They provide architectural drawings to be used in the CRM process and have been key in the early development of survey and data capture processes.

Conservation Carpenter 1 (Character E)

Character E started his career as a Marine Biologist and then changed paths to become an IT/IS Project Manager. He found his niche when he combined his love for historic buildings, and passion in working with wood and retrained in traditional oak heavy timber frame carpentry. Character E spent over 10 years working with new build oak frame buildings but then spent 3 years specialising in the conservation and repair of historic timber buildings. This practical experience serves Character E well for working with Antarctic timber huts but, with limited experience or training in conservation philosophy, this lead remained with the Consultant Architect team. Like Character C, Character E had a lifelong passion for Antarctic and in 2016, prior to the UKAHT 2017-2018 field season, was employed as a conservation carpenter by the New Zealand Antarctic Heritage Trust (NZAHT).

Conservation Carpenter 2 (Character F)

Character F has been a carpenter since he was a boy, working in Antarctica for almost his entire career. He has extensive knowledge of Antarctica, Antarctic huts and Antarctic conditions. While originally his work would have covered routine repair and maintenance, since joining UKAHT the focus of the work has turned to conservation repair and maintenance which is somewhat different. UKAHT have used consultants and training to educate and communicate these differences and the required approach to CRM carried out under the Heritage Management Programme.

The Conservation Carpenters contribute to the planning of the Heritage Management Programme, advising on tools and materials required, timescales and programming and of course, carrying out the CRM directly in Antarctica. They also contribute to survey and data capture and recording of completed works.

Consultant Heritage Project Manager (Character G)

In the 2017-2018 season, UKAHT employed a consultant Heritage Project Manager. The contract brief noted their aim to improve the standard of their practices in caring for the historic sites, the development of detailed conservation management plans and implementation programmes for each site, and an intention to embrace the benefits of digital technology where it might enhance their ability to manage the sites and engage people with the ongoing conservation programme. The brief requested the services of a Project Manager/Building Surveyor to coordinate the Heritage Management Programme. The researcher was appointed as Character G. Character G had a degree in Building Surveying, a master's degree in the Conservation of Historic Buildings and a career in facilities and project management for large UK heritage organisations. During the field season, Character G was responsible for overall management, programming and survey and data capture.

New Zealand Antarctic Heritage Trust Programme Manager (Character H)

UKAHT have a Memorandum of Understanding (MoU) with the New Zealand Antarctic Heritage Trust (NZAHT), through which they share ideas and some resources, including the support of the NZAHT Programme Manager – Character H. Character H has considerable expertise and knowledge of Antarctic, and the conservation of historic Antarctic huts.

Field Camp Coordinator/Camp Manager (Character I)

The Field Camp Coordinator was a Norwegian ski resort Operation Manager and Ski Patrol who had started his career as a border guard in Northern Norway. He had a degree in Arctic Nature Guiding and had worked as a guide and field assistant in Arctic regions for a number of years. He was also completing an apprenticeship in Norwegian timber framing and restoration of historic timber buildings. Character I is passionate about polar regions, a keen mountaineer and has a real love for historic buildings. His studies had included conservation philosophy so he brought a good range of skills to the team. Character I provided input into the planning of the field season, including materials and tools for various tasks, camp management and was also directly involved in survey and data capture and CRM activities.

Artefact Conservator (Character J)

Character J works as the Artefacts Programme Manager for the NZAHT but provides support to the UKAHT through the MoU for artefact conservation. Character J has a diploma in Craft Design and a postgraduate diploma in Conservation of Library and Archival Materials. Much of her experience lies in book conservation.

Port Lockroy 2017/2018 Team (Characters K)

The 2017/2018 Port Lockroy Team comprises of 4 women who were selected to manage the base, run the shop, post office and museum, greet visitors and carry out routine annual maintenance tasks. Each of the team have a passion and fascination for polar regions and Antarctica, with all having visited or worked in Antarctica previously. Past careers of the team members include; Finance, Marine Zoology, Marketing, Wilderness Guide, Teaching, Dental Practitioner and Dog Handling. All are extremely well travelled individuals who have taken part in charity or self-organised expeditions, tours and working around the world. One of the team members had spent a previous season on the Port Lockroy team. None of the individuals come from a conservation, construction, facilities, or project management background, instead being chosen for their experience of global work and travel, particularly in polar regions. The Port Lockroy team therefore rely on the information provided in the maintenance handbook to describe how to complete the annual maintenance tasks.

Table 7.1 Summary of UKAHT characters – conservation and maintenance team

Character	Role	Primary skillset/qualification
Character A	Chief Executive	Museum & Collection Management
Character B	Antarctic Operations Manager	Expedition Leader & Operations Manager
Character C	Antarctic Operations Assistant	Teacher & Expedition Guide/Field Assistant
Characters D	Consultant Conservation Architects	Conservation Architect
Character E	Conservation Carpenter 1	Timber Frame Conservation Carpenter
Character F	Conservation Carpenter 2	General Carpenter
Character G	Consultant Heritage Project Manager	Building Surveyor and Heritage Conservation Professional
Character H	NZAHT Programme Manager	Conservation of Antarctic Huts
Character I	Field Camp Coordinator	Field Guide and Apprentice Conservation Carpenter
Character J	Artefact Conservator	Conservator of Library and Archival Materials
Characters K	Port Lockroy Team	Expedition and tour experience

Table 7.1 Summary of UKAHT characters – conservation and maintenance team is intended as a reference for the next section of this chapter however, an initial glance illustrates that the main experience of those involved in the UKAHT Heritage Management Programme can be split into just 4 categories:

- Museum and Artefact Management and Conservation
- Expedition Leader or Field Assistant
- Carpentry – with some conservation experience
- Building Conservation

It should be noted that the only formal building conservation/conservation philosophy education comes from the two consultant parties – Characters D and Character G. Practical building conservation experience is also present in Characters E, H and I.

When reviewing processes and roles and responsibilities, the range of skills and qualifications, and the authority for defining processes, setting standards and making decisions should be considered.

7.2.2 CRM process network actors

In the previous section only stakeholders, or human actors, linked to the CRM process are described. Accepting that a socio-technical networks oriented approach should not privilege the social over any other network element/actor (Latour, 2005; Dankert, 2012; Callon, 2012), this section is used to introduce other network actors that were discovered through active participation and subsequent analysis of data, and that will be described in the following vignettes.

1. The researcher has defined network actors as those that presented as essential to the network – those with a defined identity.
2. The network is defined as the CRM process.

The terms network element or network actor have to this point been used as one in the same thing. The term network 'actor' will be used going forwards. The reason for this is to emphasise that these elements all play a part in the network, or all 'act' within the network. A network actor is only relevant so long as it has an active role within the network. This is an actor network theory concept that can be described as a 'process of translation' (Callon, 1986).

Four ANT concepts of this process are repeated here as a reminder, and are used to analyse the data:

- problematisation
- interessement
- enrolment
- mobilisation

It was previously noted that the interests of each actor must be identified, or in other words, their identity must be defined to understand their part in the network and to complete the process of translation.

Table 7.2 below illustrates the actors that have been defined by the researcher and the way in which they are associated with the problematisation.

Table 7.2 Table of non-human actors and defined identities

Actor	Defined Identity
Future recommendations report	Provides the means for data to be structured in a step towards an asset management system for future interrogation and conservation planning
Weather Solar Panels Batteries Laptop Camera	Directly impacts the work that is undertaken by the conservation carpenters. Unless the carpenters agree to complete the reports when requested by the HPM, bad weather is required to force this action Cold weather impacts the charging of laptop and camera batteries Cloud, lack of sunlight and snow affect the effectiveness of solar power which is used to charge batteries Laptops and cameras will only work if the batteries are charged. The laptop is required to use and complete the future recommendations report Cameras are required to take vital records during survey and for completing the future recommendations report. Provide power to batteries required to run laptops and cameras
Jerry Can	Carries the fuel required to run generators that provide power to charge batteries for laptops and cameras when solar power is not effective

Whilst stakeholders noted in section 7.2.1 may have accepted given identities within the network, the weather, solar panels, batteries, laptop, camera and jerry cans, do not share the objective to achieve a collection of structured data for interrogation and future conservation repair and maintenance planning. Whilst these entities do not share the common goal, they are indispensable to the problematisation and Character G must attempt to build alliances between them. How can any of the Characters negotiate with the weather? How can they negotiate with a battery that chooses to either charge or not to, in part, dependent on the weather?

The network actors are discussed in the following sections, noting how they impact the CRM process. The network of actions surrounding this will be subsequently analysed to gain understanding in why processes may fail or how they are best implemented. The aim is to use this knowledge for the development of a Heritage Information Management Workflow that takes into consideration socio-technical networks and is designed in such a way that it offers improvements where existing processes often fail.

7.3 How do network actors in Antarctica engage with a new digital, formalised process for CRM?

Having been introduced to the range of conservation stakeholders and network actors above, and using Table 7.1 and Table 7.2 as a reference point, anecdotal evidence gathered by the researcher (Character G) through participant observation and active participation is described in a number of vignettes below. In studying the implementation of new digital, formalised processes to support the UKAHT heritage management programme the researcher has aligned with a BIM process field as the research framework. Vignettes have been divided into 4 identified process themes that are representative of any CRM process;

- Survey and Data Capture
- Data Management – processing and storage
- Data Analysis – CRM planning
- Data Use – delivering CRM projects

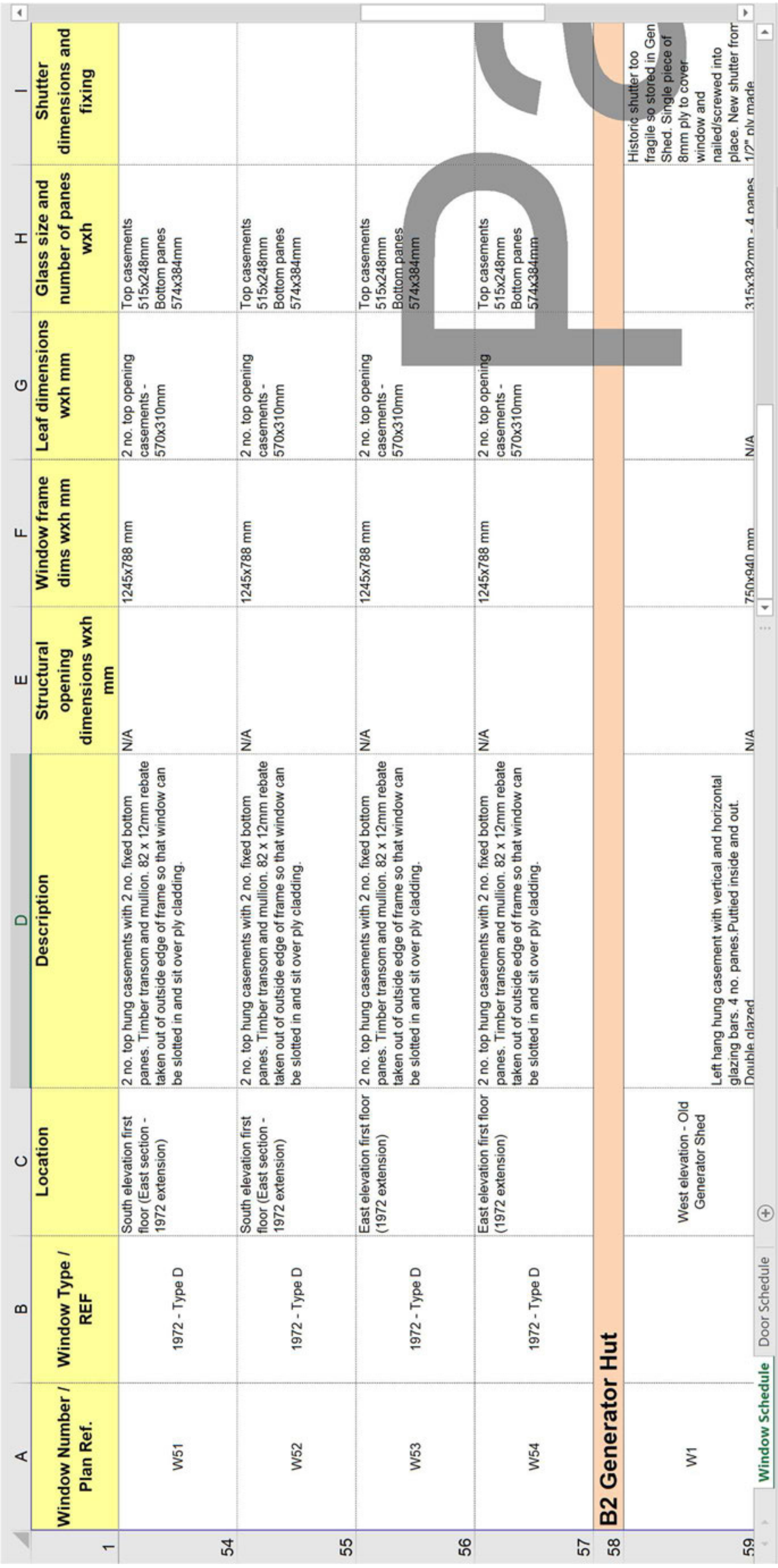
The examples selected within each theme are presented to demonstrate representative examples of behaviour, issues and solutions. Due to the large amount of data collected in relation to the 4 CRM processes above, a set of criteria was established to help with this selection process. These included:

- Illustrates an action that can be followed
- Involves individual decision making
- Demonstrates ‘surprises’ – where practice is contrary to process

The aim here is not to analyse the data, but instead to illustrate the conservation stakeholders introduced in section 7.2.1 and how they interact with the process, the technology and any other factors, or actors. Rich description offered through the vignette style of writing is particularly useful in revealing interests and actions, negotiations, and alliances that can be studied in terms of a process of translation and supports analysis using ANT concepts.

7.3.1 Survey and data capture

Phase 1 of the UKAHT Heritage Management Programme included surveying and data capture to produce a base set of data about each historic site or monument which was to be structured and digitised for the planning and prioritisation of CRM programmes. While the trust had made attempts at identifying the information they require for successful CRM, and a framework of conservation data parameters, they were still in the process of developing an efficient system for collating, structuring and managing the data. One of the data collection tasks was the completion of a window schedule that would be incorporated into the master asset data capture spreadsheet and used to uniquely identify each window, the type, whether it had a shutter, the condition and dimensions etc. An example of the window schedule is provided at Figure 7.2 below.



	Window Number / Plan Ref.	Window Type / REF	Location	Description	Structural opening dimensions wxh mm	Window frame dims wxh mm	Leaf dimensions wxh mm	Glass size and number of panes wxh	Shutter dimensions and fixing
54	W51	1972 - Type D	South elevation first floor (East section - 1972 extension)	2 no. top hung casements with 2 no. fixed bottom panes. Timber transom and mullion. 82 x 12mm rebate taken out of outside edge of frame so that window can be slotted in and sit over ply cladding.	N/A	1245x788 mm	2 no. top opening casements - 570x310mm	Top casements 515x248mm Bottom panes 574x384mm	
55	W52	1972 - Type D	South elevation first floor (East section - 1972 extension)	2 no. top hung casements with 2 no. fixed bottom panes. Timber transom and mullion. 82 x 12mm rebate taken out of outside edge of frame so that window can be slotted in and sit over ply cladding.	N/A	1245x788 mm	2 no. top opening casements - 570x310mm	Top casements 515x248mm Bottom panes 574x384mm	
56	W53	1972 - Type D	East elevation first floor (1972 extension)	2 no. top hung casements with 2 no. fixed bottom panes. Timber transom and mullion. 82 x 12mm rebate taken out of outside edge of frame so that window can be slotted in and sit over ply cladding.	N/A	1245x788 mm	2 no. top opening casements - 570x310mm	Top casements 515x248mm Bottom panes 574x384mm	
57	W54	1972 - Type D	East elevation first floor (1972 extension)	2 no. top hung casements with 2 no. fixed bottom panes. Timber transom and mullion. 82 x 12mm rebate taken out of outside edge of frame so that window can be slotted in and sit over ply cladding.	N/A	1245x788 mm	2 no. top opening casements - 570x310mm	Top casements 515x248mm Bottom panes 574x384mm	
58	B2 Generator Hut								
59	W1		West elevation - Old Generator Shed	Left hang hung casement with vertical and horizontal glazing bars. 4 no. panes.Puttied inside and out. Double glazed	N/A	750x940 mm	N/A	315x382mm - 4 panes	Historic shutter too fragile so stored in Gen Shed. Single piece of 8mm ply to cover window and nailed/screwed into place. New shutter from 1/2" ply made

Figure 7.2 Extract from the UKAHT window schedule – (screenshot) (Source: UKAHT)

The first step for this task was to number the windows. As the conservation carpenters (Characters E & F) 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, marking up a set of architectural drawings that had been provided to the team by the Characters D. This would be the first task that highlighted the unknowns and surprises that can be encountered when surveying or recording building information. Whilst Character G assumed that windows would all be numbered with a 'W' prefix (W for Window), which had been 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 (Figure 7.3). Whilst both approaches were logical, 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, Character G had expected window numbering to start on the North elevation. Again, this was an assumption based on previous working practices and surveying conventions but, had not been provided as an instruction. As such, the data was collected in the way that felt most appropriate to Characters E & F who were carrying out the task. It also 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. The window numbering could be easily rectified by changing the prefix but it did require a small amount of additional work.

This example illustrates that with only one team member coming from a building surveying background, standard surveying practices might not be followed unless expressly instructed as part of a formal process. Furthermore, without fully discussing the wider data management process and need for recording in a particular manner, the individual characters undertook tasks in the manner that felt most appropriate to them. It could be suggested that in the process of translation this is failed enrolment.

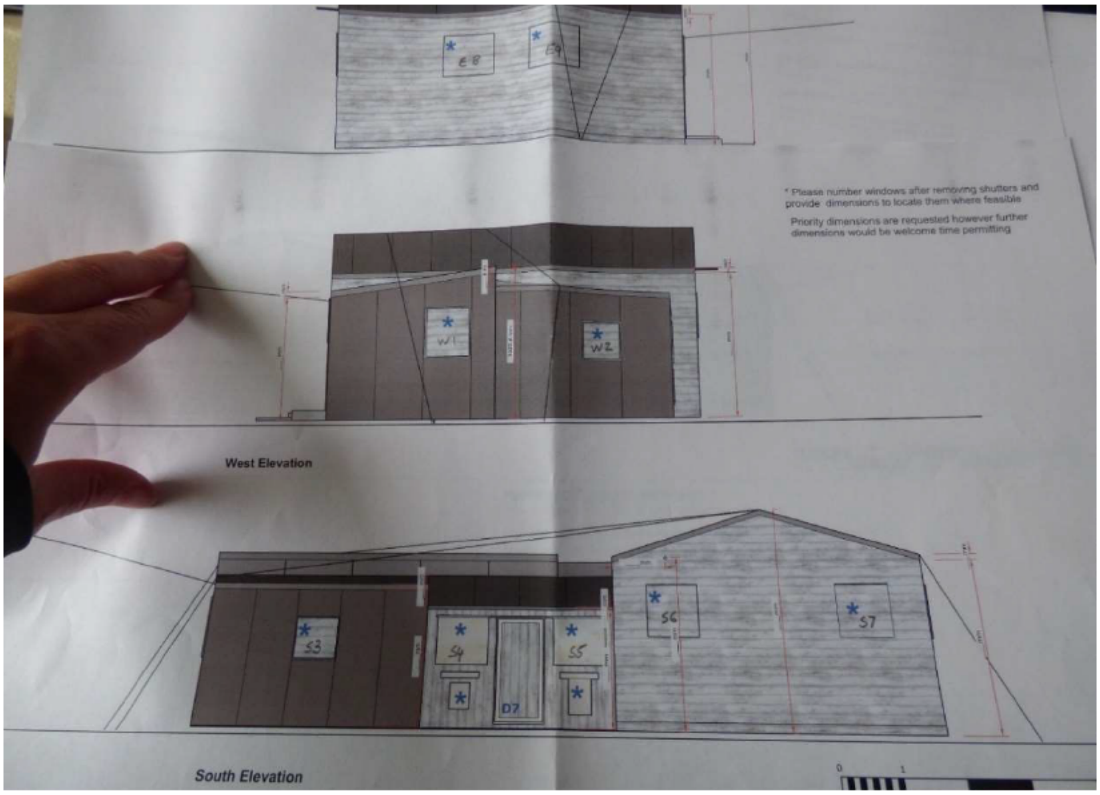


Figure 7.3 Photograph of drawings annotated with window numbering (Source: Joanna Hull)

7.3.2 Data management

Another of the surprises to present itself during the survey and data capture phase was in the general act of recording and information management 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.

In addition to the creation of a window and door schedule, as introduced above, the conservation team were to carry out building material sampling across the site to build up a record of materials, paint colours etc so that these could be correctly specified for future CRM projects. The intent was that samples would be given a unique identifying number, and a naming convention had been devised and communicated to the team to ensure samples were provided with the correct name. The naming convention was as follows:

Site Reference / Building or Structure Number / Location / Location Detail / Aspect / Feature

The convention was developed using the same format used by the NZAHT team and so was common across both Trusts. With Character J having a large amount of artefact cataloguing to complete, it made sense that naming conventions across the different tasks were aligned. Samples should be entered into the Master Sampling Worksheet with a further unique number added to the beginning of each sample. A snapshot of the material sampling worksheet is provided overleaf.

While Character H was used to this process, and despite the team having been provided with paper based and digital recording templates, information was rarely entered directly into these, instead being scribbled on sample bags, white boards or sheets of ply before being passed on to Character G for further processing. Furthermore, while Character H was generally consistent at labelling samples using the correct, or almost correct naming convention, despite these having been established prior to the field season, this was generally missing from the samples provided by Characters E and F. For example, material samples were often initially collected with a scribbled record of the contents. Characters G and I undertook a large amount of the sampling, particularly paint sampling, and so with Character G leading the information management processes, the master template and naming conventions for sampling bags was used well.

Where naming conventions had not been used, these were either added at a later date when the information was typed up in documents by the various project team members or, would be added by Character G during data management. This information then had to be rerecorded using the standard conventions on both the sample bag/tag and, within the material sampling spreadsheet/database. In relation to both operation and maintenance practice more generally, and heritage CRM, it has been discussed that duplication, poor management and unstructured data are all issues that contribute to inefficiencies in practice (Simeone *et al.,* 2018; Jordan-Palomar *et al*., 2018). Despite attempts to introduce structure with the use of spreadsheets and naming conventions, these were only used by certain team members. This demonstrates how success of implementation is variable (Forster & Kayan, 2009).

Sample Number to be added by JH	Site Ref	Building / Structure Number (xx) eg B1 Base Hut	Location (xx) eg. Room ref No R*/ EXTRoof/EXTElevation/EXTfoundation/ENV*gridref	Location detail (xx) eg. Window ref, Floor, etc	Aspect (e.g. wall aspect = N ,S,E,W; Floor = F; Ceiling = C; Structure = St; Window = W*; Door = D*)	Feature (e.g., door jamb, skirting, Flue, etc. and unicode or feature code if known)	Material Type (eg. Roofing felt, glass, ply with CISFB Unicode if known)	Photo Information (file location ref)	Date DD/MM/YYYY	Sampler (initials)	Other Notes
1	E	B1	R1	Floor	F	Floor covering	Lino	T14a_LinoSampling	27/01/18	JLH	
2	E	B1	R2	Floor	F	Floor covering	Lino	T14a_LinoSampling	27/01/18	JLH	
3	E	B1	R6	Floor	F	Floor covering	Lino	T14a_LinoSampling	27/01/18	JLH	
4	E	B1	R10	Floor	F	Floor covering	Lino	T14a_LinoSampling	27/01/18	JLH	
5	E	B1	R10C	Floor	F	Floor covering	Lino	T14a_LinoSampling	27/01/18	JLH	
6	E	B1	R11	Floor	F	Floor covering	Lino	T14a_LinoSampling	27/01/18	JLH	
7	E	B1	R13	Floor	F	Floor covering	Lino	T14a_LinoSampling	27/01/18	JLH	
8	E	B1	R25	Floor	F	Floor covering	Lino	T14a_LinoSampling	27/01/18	JLH	
9	E	B2	EXTElevation / EXTRoof	Generator Shed Walls/Roof	EXT	Hardware	Felt Clouts		26/01/18	AF	
10	E	B2	EXTRoof	Generator Shed Roof	EXT	Hardware	Batten Nails		26/01/18	AF	
11	E	B2	EXTElevation	Generator Shed Walls	EXT	Hardware	Bargeboard Nails - Large		26/01/18	AF	
12	E	B2	EXTElevation	Generator Shed Walls	EXT	Hardware	Bargeboard Nails - Small		26/01/18	AF	
13	E	B2	EXTRoof	Dog Kennel Roof/Old Generator Shed	EXT	Roof Covering	Canvas		26/01/18	AF	
14	E	B2	EXTElevation / EXTRoof	Generator Shed Walls/Roof	EXT	Felt	Felt		26/01/18	AF	
15	E	B2	EXTElevation / EXTRoof	Generator Shed Rigging - East End, South	EXT - E	Rigging Wire	Rigging Wire		26/01/18	AF	
16	E	B2	EXTElevation	Generator Shed Rigging - West Wall, North	EXT - W	Tie Down Wire	Tie Down Wire		25/01/18	AF	
17	E	B2	EXTElevation	Generator Shed Rigging - West Side, South	EXT - W	Tie Down Wire	Tie Down Wire		25/01/18	AF	
18	E	B2	EXTElevation	Generator Shed Rigging	EXT	Rigging Wire	Rigging Wire		26/01/18	AF	
19	E	B1	R21	D18 - Door	D	Seal around door	Seal around door		03/02/18	AF	
20	E	B2	R1	Bench - North Wall	N	Artefact	Sheet material on bench		03/02/18	AF	
21	E	B14	Science Building	Door to Science Building	D	Seal around door	Seal around door		03/02/18	AF	
22	E	B1	R1	Wall	N	Wall	Paint		09/02/18	TO/JH	
23	E	B1	R1	Wall	E	Wall	Paint		09/02/18	TO/JH	
24	E	B1	R1	Window	NW Window	Window Outer Frame	Paint		09/02/18	TO/JH	
25	E	B1	R1	Window	NW Window	Window Inner Frame	Paint		09/02/18	TO/JH	
26	E	B1	R1	Window	SE Window	Window Frame	Paint		09/02/18	TO/JH	
27	E	B1	R1	Ceiling - North Half	C	Ceiling	Paint		09/02/18	TO/JH	
28	E	B1	R1	Ceiling - South Half	C	Ceiling	Paint		09/02/18	TO/JH	
29	E	B1	R3	Door	D1	Door Panel - R1 side	Paint		09/02/18	TO/JH	
30	E	B1	R3	Door	D1	Door Panel - R3 side	Paint		09/02/18	TO/JH	
31	E	B1	R3	Wall	S	Wall	Paint		09/02/18	TO/JH	
32	E	B1	R3	Table	N	Table Legs	Paint		09/02/18	TO/JH	
33	E	B1	R3	Window	Window - S Wall	Window Frame	Paint		09/02/18	TO/JH	
34	E	B1	R3	Ceiling	C	Ceiling	Paint		09/02/18	TO/JH	

Sample Info | Summary Info

Figure 7.4 Extract of material sampling worksheet – (screenshot) (Source: UKAHT)

While clearly the way people work, how processes are defined, communicated and managed has an impact on the survey and data capture process, further factors were identified during the season that had an impact on the information management tasks.

Figure 7.5 Unique and novel ways of recording material sample and building information (Source: Joanna Hull)

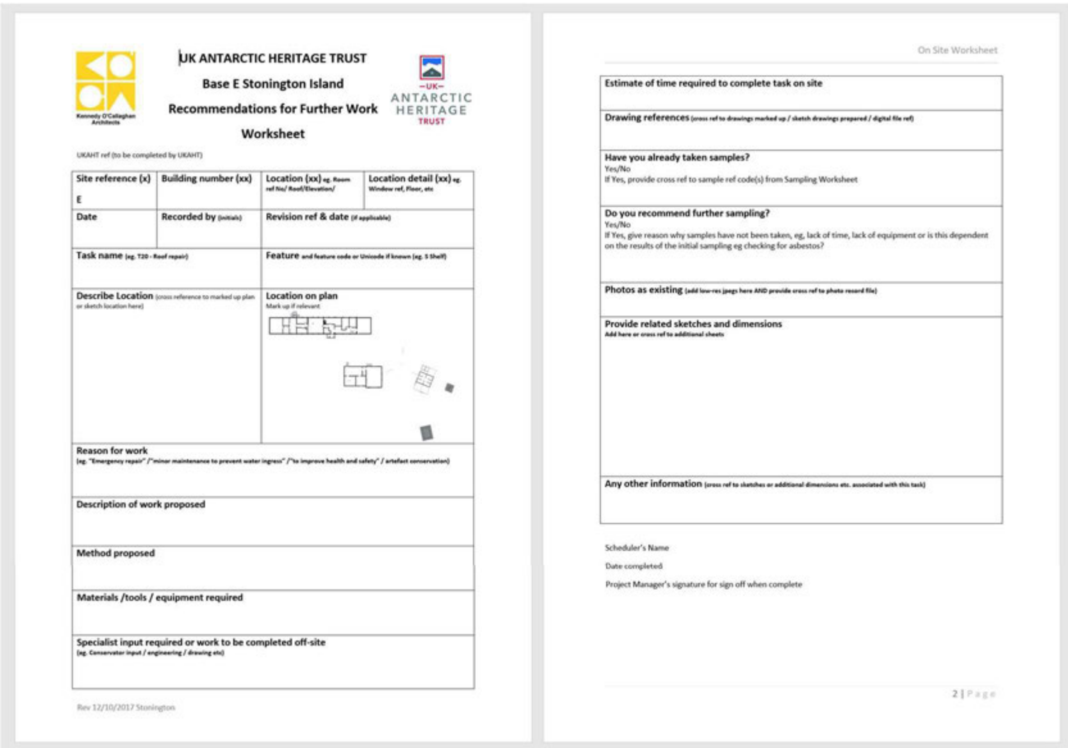
Laptops were used to process and file digital images, to record all survey data and, to complete the template documents. They were powered by two methods - generator and solar panels. On the journey south, 2 days into the crossing of the Drakes Passage, it was identified that the team's fuel supply was missing. In the reformatting 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 on the Falkland Islands. With a number of e-mails back and forth, thanks to the Royal Navy officers onboard HMS Protector, 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 2 laptops were provided to the team of 6 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.

From an ANT perspective, this vignette is important in exposing non-human network actors that are critical in understanding how and why new technology or processes may or may not be successful. In the process of translation weather, batteries, solar panels and jerry cans, do not share the objective to achieve a collection of structured data for interrogation and future conservation repair and maintenance planning but all impact the network. Characters need to try and build alliances between the actors so as a collective they achieve the common goal. How can Character G negotiate with the weather? How can she negotiate with a battery that chooses to either charge or not to, in part, dependent on the weather? The actions of these entities cannot be altered and so displacement takes place. The other actors must reconfigure and work around these issues.

7.3.3 Data Analysis – CRM Planning

In Chapter 5, section 5.2.4, the development of a number of new documents to support UKAHT's CRM planning and building information management were discussed. It was noted that for the effective planning of conservation works, analysis of condition survey data is paramount. The 'Future Recommendations Report' was created based on advice from Character H and existing practices used by the NZAHT. This report would be structured in such a way that it would provide information about condition, repair or maintenance requirements, repair methodology, materials, and resources required to complete the work and, so that it could be imported into an asset management type database system at a later date. Once structured, this data could then be interrogated in order to plan for a later conservation project.



UK ANTARCTIC HERITAGE TRUST
Base E Stonington Island
Recommendations for Further Work
Worksheet

UKAHT ref (to be completed by UKAHT)

Site reference (x)	Building number (xx)	Location (xx) eg. Room ref No/ Roof/Elevation/	Location detail (xx) eg. Window ref, Floor, etc
E			
Date	Recorded by (initials)	Revision ref & date (if applicable)	
Task name (eg. T20 - Roof repair)		Feature and feature code or Unicode if known (eg. S Shelf)	
Describe Location (cross reference to marked up plan or sketch location here)		Location on plan Mark up if relevant	

Reason for work (eg. "Emergency repair" /"minor maintenance to prevent water ingress" /"to improve health and safety" / artefact conservation)

Description of work proposed

Method proposed

Materials /tools / equipment required

Specialist input required or work to be completed off-site (eg. Conservator input / engineering / drawing etc)

Rev 12/10/2017 Stonington

On Site Worksheet

Estimate of time required to complete task on site

Drawing references (cross ref to drawings marked up / sketch drawings prepared / digital file ref)

Have you already taken samples?
Yes/No
If Yes, provide cross ref to sample ref code(s) from Sampling Worksheet

Do you recommend further sampling?
Yes/No
If Yes, give reason why samples have not been taken, eg, lack of time, lack of equipment or is this dependent on the results of the initial sampling eg checking for asbestos?

Photos as existing (add low-res jpegs here AND provide cross ref to photo record file)

Provide related sketches and dimensions
Add here or cross ref to additional sheets

Any other information (cross ref to sketches or additional dimensions etc. associated with this task)

Scheduler's Name
Date completed
Project Manager's signature for sign off when complete

2 | Page

Figure 7.6 UKAHT Recommendations for Further Work Worksheet – (screenshot) (Source: UKAHT)

Reports such as the Future Recommendations Report provided a significant improvement in structuring data for future analysis but would require individuals to read other documents before being able to put plans together for CRM works, suggesting that the report itself would have an impact on the wider network relating to CRM planning.

In this section, the impact of documents as network actors, and subsequent data analysis is considered further to provide understanding for the development of a Heritage Information Management Workflow.

As previously noted, using the NZAHT documents as an example, Character G worked with Characters D to develop new report templates to be used by the conservation team during the 17/18 field season. Having taken the advice of Character H, he was already in support of the process prior to arrival on site and was proactive in promoting the benefits of the approach to the other team members. One conservation carpenter, Character E, who had previously worked for NZAHT was already used to working with similar documents. However, tensions arose during the season around completion of the future recommendations report.

Field seasons in Antarctica are relatively short. Some visits may be fleeting, just a couple of days while passing on an onward journey to another research base. Seasons are completed in the Austral Summer, between November and March and time on site is often only several weeks. The UKAHT conservation team spent 9 weeks on Stonington Island but this was considered a long season. As can be expected, seasons can also be affected by bad weather conditions and so not every day is productive. 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 for days on which the weather made it impossible to work outside. The season happened to see 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. This was accepted by Character G however, there was a desire for at least one draft report by each carpenter to be completed so that these could be reviewed to ensure the information being recorded was sufficient. The concern of the Character G was that if information was missing from the reports, the forward planning of conservation repair and maintenance would not be effective. This approach was supported by Character H who was also keen for the future recommendations report to be used and wanted to know that information was being recorded effectively.

In a field diary entry from 24th February 2018 (Appendix 4) it was noted that there had been significant snow cover, cloud cover was 8/8ths and the temperature was 0.4 degrees. The team had allocated time on this day to complete future recommendations reports, along with a report on the completed generator shed roof refelting. Character G was tasked with reminding the team of naming conventions to be used when completing reports, and Character H had offered to hold a 'training' session in how to complete the reports. During the field season Character H left site to return to the NZAHT and was replaced by Character J. It is noted that motivation to complete the future recommendations reports dropped after Character H's departure and Character G struggled to maintain progress with the reports.

A complete review of all field diaries identified that the topic was raised on a number of occasions. This is illustrated in Table 7.3.

Table 7.3 Summary of field diary entries relating to the completion of completed works and future recommendations reports

Date:	Diary Entry:
25/01/2018	Future recommendations reports not done yesterday as weather was fine – move to tomorrow Character J confirmed to Character G that based on progress so far the emergency repairs should be completed within a couple of weeks of him leaving, leaving plenty of time for recommendations and other CMP work to be completed.
29/01/2018	Character G to complete: Recommendations for future work report – Lino
30/01/2018	Main Hut Roof Works – 2 days roofing, 1 day rigging, 1 day report writing left
03/02/2018	Character H's last team meeting – leaves site
10/02/2018	Reporting – due to weather conditions
22/02/2018	Report writing if weather is bad Character G reminded team that 'we don't have much time in the programme for report writing and we do need to be confident that we have all of the info required for the reports before leaving'
24/02/2018	Report writing continued – none complete yet.
01/03/2018	Reports to complete – still not finished, none 100% finished. Character J stepped in and asked what the guys (Character E & F) plan was, doesn't want to have this conversation again. Character G said 'we need to sit down together, look at what has been completed in the reports, pull a list together of the outstanding pieces of information or items to complete and then keep a record of this. Formatting/photos etc can be completed off site but measurements info and samples etc will need to be finished whilst on site'.
02/03/2018	Character G asked that a report by either Character E or F is written to explain how we can carry out the final conservation repair of the door when we return.
06/03/2018	East Base or Report Writing – weather depending
15/03/2018	Last diary entry

Towards the end of February it is noted that Character G was requesting an update on completed reports at each team meeting. On 1st March 2018, with little motivation or plan offered by Characters E and F for the completion of the future recommendations report, Character J intervened and asked that a plan was resolved so that this did not keep needing to be discussed on a daily basis. With a number of reports complete, Character G accepted that reports would not be completed whilst on site and that these would need to be provided post season. At the end of the field season, just 7 future recommendations reports were completed. Noting the dates of each, most had been completed while Character H was still on site, or shortly after Character H had left.

Name	Date modified	Type	Size
FW_E_B1_Glazing_MDP_2017-18	10/02/2018 16:03	Microsoft Word Doc...	395 KB
FW_E_B1_LinoConsolidation_JH_2017-18	10/02/2018 11:55	Microsoft Word Doc...	1,824 KB
FW_E_B2_ChippyShopRoof_GC_2017-18	10/02/2018 17:40	Microsoft Word Doc...	1,407 KB
FW_E_B2_EXTCladding_AF_2017-18	10/02/2018 11:49	Microsoft Word Doc...	7,584 KB
FW_E_B2_Glazing_MDP_2017-18	10/02/2018 15:46	Microsoft Word Doc...	4,180 KB
FW_E_B2_R4Roof_MDP_2017-18 (1)	23/02/2018 17:15	Microsoft Word Doc...	107 KB
FW_E_B2_Rigging_AF_2017-18	29/01/2018 14:31	Microsoft Word Doc...	3,857 KB

Figure 7.7 Record of completed future recommendations report at the end of the field season (screenshot) (Source: UKAHT)

This demonstrates that Characters G, H and J who are used to the reporting process, and importance of such information for analysis and future planning are motivated in completing the task. The priorities of Characters E and F are however different. Using the ANT concepts described in section 7.2.2 to analyse this data, in the early part of the season Character G uses devices of interessement such as persuasion and negotiation to try and build alliances with the other actors. Attempts for Character H to act as spokesperson and encourage the carpenters to adjust their priorities are made. Negotiations are made in which work on reports will be undertaken on bad weather days however, with few days like this and, the added obstacle resulting from non-charging batteries, further negotiation is made in that reports will be completed post season. Of course, force could also be used however, this would result in further negative outcomes and as such is not an option.

As can be seen from the example, alliance between entities is never guaranteed and if this is not successful, enrolment is not achieved. Despite the use of interessement devices, the ultimate result is that the future recommendations reports are completed post season and review of these will now take place 'off site'. The design and process for use of the reports in the field and, how this eventually integrates with the digital data system will be reviewed and the process of translation will begin again. The vignette offers a good illustration around failed enrolment, and trails of strength between human and non-human network actors that result in a different outcome than that intended by Character G.

The researcher did not work with UKAHT post the 17/18 field season and therefore had no access to observe how the collected data was used and analysed for the planning of future field seasons in detail. Clearly the main worksheets that had been developed and completed with building information would provide a much more efficient way to access information required for planning.

7.3.4 Data Use – Delivering Conservation Repair and Maintenance

Following the *BIM research framework* and the 'process field', data use is the final step in the CRM process. While data has been gathered in previous steps for CRM planning, this section considers how the data is subsequently used in the delivery of planned CRM. There is some overlap here between planning and delivery as there are ongoing decisions to be made in the CRM delivery phase that rely on data and information. Depending on the workflows used by heritage organisations, and whether they have conservation management plans in place or not, this delivery phase in the UKAHT context might actually be considered a planning phase within an organisation such as English Heritage, where such decisions will be made prior to works commencing on site.

CRM is based on significance and priority. Common conservation principles include minimal intervention, maximum retention of historic fabric, reversible and honest repair which are well embedded in conservation legislation and practice e.g. (Earl, 2003; Meul & Stulens, 2010). Before any CRM is undertaken, the repair approach and materials used should be carefully considered. This requires verified and accurate data.

For those heritage assets covered by statutory protection, such as Scheduled Monuments or Listed Buildings, CRM work is carefully monitored through the statutory consent process. While the Antarctic huts are designated as historic sites and monuments, there is no similar consent process to monitor the CRM works undertaken. This means that in the past, incorrect materials and repair techniques have been used. As already noted from Character G's contract brief, UKAHT were keen to improve the standard of their conservation practice. While the Conservation Management Plans that would define correct repair philosophy and materials were not yet complete, Characters D and Character G worked together (remotely) during the 17/18 field season at Stonington Island to discuss identified repairs and agree the conservation approach based on existing building information.

On 7th February 2018 a discussion developed regarding some 'emergency' conservation repairs to the Pup Pens.

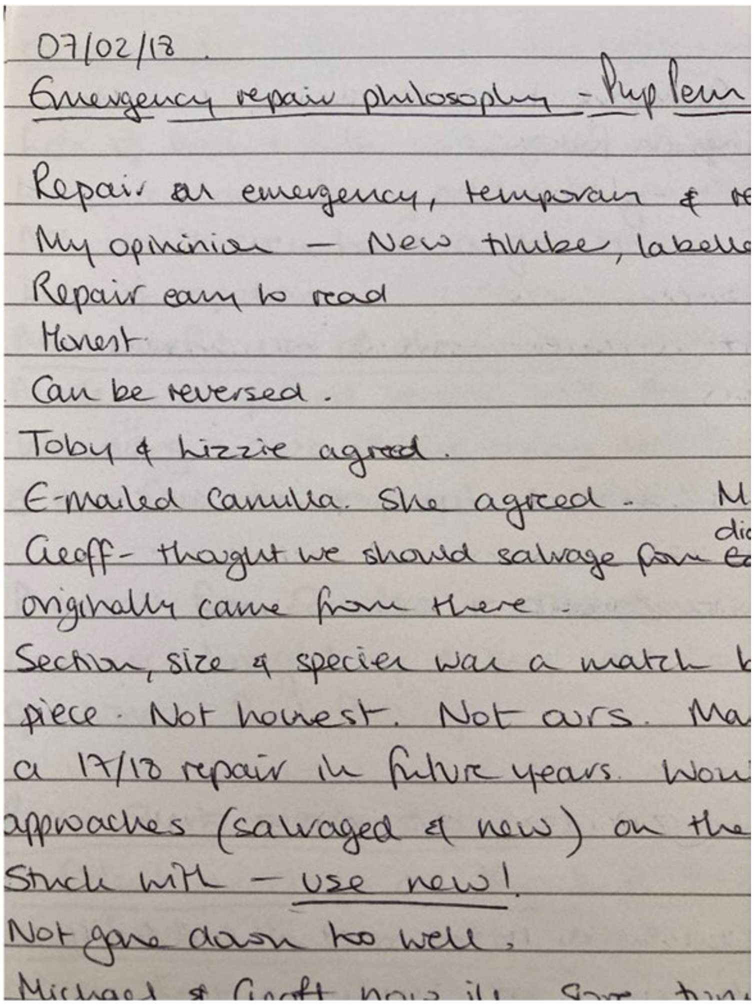
Figure 7.8 Photo of Base E, Stonington Island - Pup Pens (Source: Joanna Hull)

Stonington Island, although being one of the most difficult to access due to varying sea ice conditions, was of strategic importance due to the fact until the 1980's it still had access to the Plateau via a steep 100 yard wide ice ramp leading to the North-East Glacier. The Glacier provided an effective airfield and Base E provided an ideal base for a research station particularly one from which to carry out large scale mapping. Huskies played a vital role in this and there were as many as 150 dogs on the Island at any one time. The presence of the Glacier and Plateau at Stonington however can generate katabatic winds that can last for a number of days and blow up without warning. With such severe weather conditions crude kennels and pup pens were erected, although it is noted that 'these were spurned, the dogs choosing to sit and sleep on top of them where they had a better view of all that was going on around them' (Walton & Atkinson, 1996)

The dog kennels and pup pens across the island are clearly of great significance to the historic site and so conservation repairs needed to be considered carefully. Character G made diary notes about the thoughts on the approach that should be taken and discussed with various members of the team to come to an agreement.

The diary notes included:

- Temporary and reversible repair
- Honest repair with new timber labelled UKAHT 17/18 in a hidden location
- Repair should be easy to 'read'



07/02/18.
Emergency repair philosophy - Pup Pen
Repair as emergency, temporary & re
My opinion — New timber, labelle
Repair easy to read
Honest
Can be reversed.
Toby & Lizzie agreed.
E-mailed Camilla. She agreed. M
dic
Geoff - thought we should salvage from E
originally came from there.
Section, size & species was a match t
piece. Not honest. Not ours. Ma
a 17/18 repair in future years. Wou
approaches (salvaged & new) on the
Stuck with — use new!
Not gone down too well.
Michael & Geoff

Figure 7.9 Field diary notes relating to the emergency repair philosophy for the Pup Pens (Source: Joanna Hull)

While Characters A, F, I and J agreed with this approach, Character E believed that timber should be salvaged from East Base, the American hut on site. The thought behind this was that based on historical data, and physical evidence, timber had historically been salvaged from East Base to build kennels, pens and carry out repairs to Base E. With this case put forward, Character F then also decided that this should be the approach.

Character G was meant to be the conservation lead, responsible for decision making but with both Conservation Carpenters disagreeing with the approach further input from Character A and Characters D had to be sought.

Character G suggested that while the section, size and species of timber may be a match to that used in the pup pens, a salvaged piece was not the ‘original’ piece and could be seen as misrepresentation. Furthermore, it was intended that repairs would be carried out to East Base later in the season and the timber should therefore be saved and used on the building from which it had fallen.

If further repairs were to be undertaken to the pup pens in future years, and there was no timber left to salvage from East Base, this would result in new ‘dated’ timbers having to be used and therefore would result in two different repair approaches.

The final decision made by Character G, with input from others, was to use new timber, date it and complete the repairs as ‘honest repair’.

The example demonstrates that without the defined and agreed conservation philosophies and CRM approach of the Conservation Management Plan, decisions need to be made during CRM delivery which are affected by various network actors. While there is a common goal between human network characters to carry out repair, without a guiding document the conservation approach can be subjective, leading to a difference of opinions. Furthermore, with no formal consent process in place, CRM activity is not monitored and so leaves the door open for different approaches to be adopted without scrutiny.

Despite UKAHT's intention to improve the standard of conservation practice (the problematisation), it could be suggested that despite the discussions held by Character G with the other character's within the Conservation Team in an attempt to define, impose and stabilise the identity of the other actors in the network (intressement), enrolment was not achieved. Non-human network actors such as the Conservation Management Plan and a Consent System may be necessary to achieve enrolment and mobilisation.

With this in mind, following the 17/18 field season, UKAHT looked to develop an 'internal' consent process so that they could undertake their own monitoring – an approach that works towards improving their standards in practice.

Character G worked closely with Character A and Characters D to develop a process for internal monitoring of CRM proposals and delivery. An outline process was developed but it is not known if this has been adopted or implemented. A brief summary of the proposed process is given below:

- Stage 1 proposals for conservation intervention or repair are developed with the application of expertise, experience and judgement. A range of experts including surveyors, architects, conservation carpenters, ex base staff and Antarctic building specialists are involved in the development of proposals.
- Stage 2 review and approval of proposals is undertaken by a design team including a range of professionals and stakeholders. The range and depth of understanding and assessment will be sufficient to inform and justify decisions whilst being efficient and proportionate in the use of resources.
- The 2 stage process allows for a transparent and consistent approach to conservation decisions that are documented in order to inform future management.
- The 2 stage process is followed by requests for permit approval from the FCO as required.

An example of a partially developed intervention proposal is provided at Appendix 5.

Both the conservation management plan and consent process are identified through this vignette as critical network actors for CRM planning and subsequent delivery and should therefore be considered in the development of new workflows that support digital, formalised processes for CRM planning.

7.4 The English Heritage CRM actor network

The case study above describes the UK Antarctic Heritage Trust and their attempts to develop, implement and improve processes to support their Heritage Management Programme. This included processes to undertake survey and capture data required for the planning of CRM programmes, processes to improve data management, data analysis and the delivery of CRM with improved standards of practice. Data was collated through active participation as a member of the UKAHT conservation team and so the perspective is of the researcher working within the team to develop the CRM processes.

To offer some comparison for analysis, this second case study is based on English Heritage, where the heritage asset management process is already developed. As English Heritage and Historic England have a shared services agreement, there is some overlap between departments and stakeholders of the two organisations, with some impact on the CRM process; the production of architectural drawings or the shared use of drawings for example, or a shared use of 3D data such as point clouds for structural monitoring, or to be used to create 3D images for guidebooks.

A range of data gathered using different methods, such as participant observation, document analysis and interview (Silverman, 2013), is presented. This offers the researcher the opportunity to present a variety of perspectives on CRM processes, issues and the effectiveness of implementation from a small number of cases.

7.4.1 Identifying actors

The researcher undertook a 2 month placement with Historic England in the Geospatial Imaging Team in York during May and June 2017 with further short placements during 2018. During this time the researcher used the opportunity to study different departments across both organisations and the variety of information needs involved in the wider field of conservation and heritage management (Davies and Harty, 2012), but with a specific interest on those that crossed over with CRM information management or processes. During a team meeting on 10th May 2017 during which all ongoing and upcoming projects were discussed, it was observed that there had been lots of queries from different stakeholders wanting outputs from the team, but it became clear that none of them really knew what information or output they wanted, or how to request it. They were aware that the Geospatial and Imaging team could conduct laser scanning, and produce 2D drawings and 3D data, but the stakeholders did not really know what they wanted or the information already available to them. Having previously worked as a Conservation Maintenance Project Manager for English Heritage, the researcher was already aware of K2 – the asset management database however, during the course of the placement with Historic England, the researcher observed a number of requests for information from the Geospatial and Imaging team that could have been accommodated by information already stored within K2, or information that should have been stored within K2, should the different stakeholders have known about this existing central repository.

Throughout February, March and April 2019 the researcher met with a number of English Heritage staff, principally those working in the Estates department, and carried out semiformal interviews with a view to understanding the different roles undertaken and, how heritage information is collected, managed and used for the planning of CRM. A range of questions were asked to each participant and notes about the conversation were made, the direction it took and the information that it revealed. During the 3 months spent with English Heritage the researcher interviewed 4 stakeholders involved in CRM planning and users of the K2 asset management database. The trust also provided a number of documents they have developed that support their asset management plan. The researcher was shown in detail the computer system (K2 software) used to manage condition survey data and historic building information, organisational processes, and was able to observe the way individuals worked and interacted with the technology and data.

Key network actors (Dankert, 2012) are described below. The actors have not however been described in the same way as the UKAHT example. Human and non-human actors are grouped together rather than being discussed separately. The actors are placed into 3 different categories – person, technology, object/document. Further, human actors are described in terms of their role and collaboration with other actors in the CRM process rather than more specifically as individuals. This is due to the participant observation and interview method employed rather than the active participation method used for the UKAHT case study. The researcher was not able to understand the actors as intimately with these methods and so, while consistency in the data presentation approach is maintained where possible, there is a requirement for some differences.

As the research was limited to informal interview with particular stakeholders, and observation of systems and documented processes, the stakeholders do not include a full project team as described in the UKAHT case study. Furthermore, English Heritage is different to UKAHT in the respect that they do not directly employ staff to carry out the CRM activities. The English Heritage staff are responsible for surveying, data capture, information management, analysis and CRM planning, but unlike UKAHT, they procure the services of conservation professionals, crafts people and Contractors to deliver the CRM projects.

Human Actor 1 - Guide Book Manager (Person)

The Geospatial and Imaging Team had been asked by the Guide Book Manager to produce scan data for 2D plans of Bowes Castle to be developed for use in the Bowes Castle Guide book. The Guide Book team had a further idea that they may use the scan data to produce 3D images to be used in the guide book and as digital content for the English Heritage website. The researcher met the Guide Book Manager on a site visit to Bowes Castle on 8th June 2017 where the project was discussed and the team's plans for using the data. During the discussions it became apparent that the Guide Book team had little knowledge of, or collaboration with, different departments within both English Heritage and Historic England. For example, in one discussion it was noted that the team would like to procure some drone photography of the castle to be used in the guidebook. The researcher noted that the English Heritage National Survey Team already undertake some surveys for CRM planning via drone and as such, may have a library of drone photography that could be shared by different departments.

Human Actor 2 - National Project Manager (Person)

During several team meetings project requests from National Project Managers were discussed. These required the team to carry out a site visit, conduct laser scanning to produce scan data and then use this data to produce accurate sets of architectural drawings for the National Project Managers to provide to their design team, and to be used for large capital projects. Capital projects do not strictly fall into CRM as in most cases, rather than large scale conservation repair or maintenance, they involve the development of historic sites or the construction of new facilities such as new tea rooms, installations such as the new bridge at Tintagel or new visitor museum, interpretation or access facilities. It was noted that neither the

National Project Manager or the Geospatial Imaging Team had liaised with the English Heritage Survey and Asset Management teams to identify if drawings already existing. Firstly, they were not aware of K2 as a central repository of information and secondly, they had not considered that both departments might be using the same information.

Human Actor 3 - Curatorial Team (Person)

While on placement the researcher received a call from the curatorial team, requesting support from the Geospatial and Imaging team with measured drawings and floor plans of a number of sites. The reason was that they wanted to set up some exhibition cases at a number of sites and needed to know the dimensions of the rooms and doorways so that they could plan the space and the access. The researcher advised the team that floor plans were available for every site in K2 however, these were not measured drawings and so would not provide accurate information for the purposes of their planning. To get the drawings they wanted would require the Geospatial team to carry out survey and produce the measured drawings.

Non-Human Actor 4 – K2 Asset Management Database (Technology)

K2 is the asset management database used by English Heritage. The type of information stored in K2 was detailed in Chapter 5, particularly in relation to considering the critical information requirements for CRM planning but, observations during the placement identified some shared information needs of other stakeholders. A number of different collaboration attempts between departments, and a number of attempts at collaboration that failed were identified. Observations also highlighted that there was a lack of information sharing between departments and stakeholders, resulting in duplication of work. This is a common issue identified in relation to information management within the heritage sector (Simeone et al. 2018; Jordan-Palomar et al. 2018).

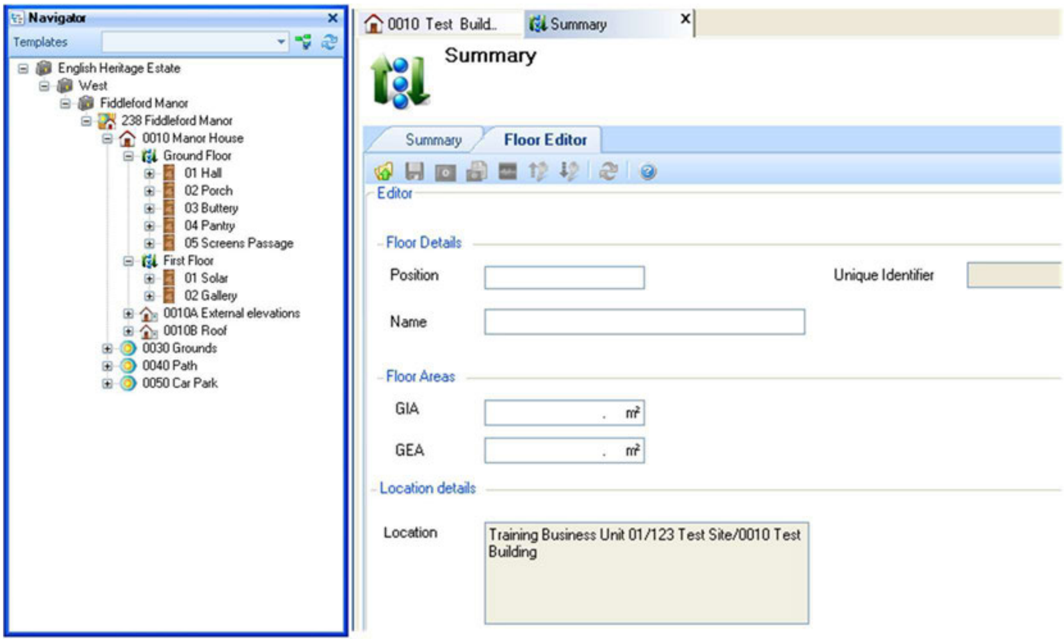


Figure 7.10 K2 Asset Management Database – (screenshot) (Source: English Heritage)

Human Actor 5 - Survey Data Manager (Person)

The survey data manager works within the Survey and Asset Management Team and is responsible for a team of survey data administrators who procure surveys, compile survey data and update building records within the K2 asset management database.

Human Actor 6 - Building Conservation Manager (Person)

The building conservation manager role is a facilities management type role. Each Building Conservation Manager is responsible for a certain territory and the assets within it. They manage the programmes of cyclical maintenance, along with reactive maintenance.

Human Actor 7 - Head of Survey and Asset Management (Person)

This person is responsible for the survey and asset management team which includes building surveyors, and survey data management. They define elements of the asset management plan, survey programmes and standards and work alongside other senior managers to plan programmes of CRM

Human Actor 8 - Territory Project Manager (Person)

The Territory Project Manager is responsible for delivering an annual programme of CRM projects as defined by the senior management team.

Figure 7.11 English Heritage Territory Project Manager on site reviewing progress of CRM works (Source: Joanna Hull)

Human Actor 9 – Heritage Building Surveyor (Person)

Heritage Building Surveyors are responsible for undertaking a programme of condition surveys and collating data at building element level, such as condition, defect, remedial action, cost etc which can then be uploaded into the K2 asset management database for subsequent reporting, analysis and planning.

Non-Human Actor 10 – K2 Condition Survey Template (Object/Document)

The survey template is used to capture all survey data collated by historic building surveyors or external/third party surveyors to ensure consistency and standardisation of data that is uploaded to the K2 asset management database. It supports a more efficient process.

Edvin Loach Old Church | Site No: 215 | Site Type: Minor remains | EHS 0004/2 2006 Appendix 3.0 Status Issued (V.1.3)

Site No	Item no	Asset No	Asset Name	Asset type	Block / location	Sub-block / location	Item location	Description: Element 1	Element 2	Free text	Condition	Recommendations	Package reference	Quantity	Unit of measure	Rate	Costs: Access and protection	Recording	Prelims	Total	Urgency	Fragility	Severity of exposure	Significance of element	Statutory	Security	Special maintenance liability	Comments	Review Code	Review Priority
215	1	215-001	Church Ruins	81 Ruin (mainly over 2 metres)	Nave/ Chancel	South wall	Outer buttress west of the entrance doorway1	Ruined structures	Structure, including chimney breasts	Stonework	There is vegetation growing out of the stonework, which is currently soft, but starting to turn woody in nature	Carefully remove all vegetation from stonework immediately. Make good affected stonework. Establish an ongoing maintenance programme of annual vegetation removal	A	1.00	no	350.00	100.00		50.00	500.00	1	no	no	no	no	no	no	The extent and state of the vegetation is subject to variation. Once current vegetation has been removed, a programme of annual vegetation removal should be established and suitable means of discouraging vegetation should be sought		9
215	2	215-001	Church Ruins	81 Ruin (mainly over 2 metres)	Nave/ Chancel	South wall	Ledge of the remains of the high-level slit window immediately to the east of the entrance doorway.2	Ruined structures	Structure, including chimney breasts	Stonework	There is a substantial amount of vegetation growing out of the stonework, which is already starting to turn woody in nature	Carefully remove all vegetation from stonework immediately. Make good affected stonework. Establish an ongoing maintenance programme of annual vegetation removal	A	1.00	no	350.00	100.00		50.00	500.00	1	no	no	no	no	no	no			
215	3	215-001	Church Ruins	81 Ruin (mainly over 2 metres)	Nave/ Chancel	South wall	East of the remains of the high-level slit window immediately to the east of the entrance doorway.3	Ruined structures	Structure, including chimney breasts	Stonework	There is a substantial pocket of vegetation growing out of the top of the wall. This is starting to turn woody in nature	Carefully remove all vegetation from stonework immediately. Make good affected stonework. Establish an ongoing maintenance programme of annual vegetation removal	A	1.00	no	350.00	100.00		50.00	500.00	1	no	no	no	no	no	no			
215	4	215-001	Church Ruins	81 Ruin (mainly over 2 metres)	Nave/ Chancel	South wall	Ledge of the E window, & the top of the remains of pier to E of this window opening4	Ruined structures	Structure, including chimney breasts	Stonework	There is a substantial amount of vegetation growing out of the stonework, which is starting to turn woody in nature	Carefully remove all vegetation from stonework immediately. Make good affected stonework. Establish an ongoing maintenance programme of annual vegetation removal	A	1.00	no	350.00	100.00		50.00	500.00	1	no	no	no	no	no	no			

Figure 7.12 K2 Condition Survey Template – (screenshot) (Source: English Heritage)

Actor 11 – Drawings (Object/Document)

Architectural drawings and plans are a network actor in so much as they are used by different network actors in different ways. While for some this is specifically for the CRM activity, there are other stakeholders who require the same information for alternative tasks – for use within guide books for example as illustrated overleaf. From an ANT perspective, following the use of architectural drawings by different stakeholders helps to trace network relationships and also illustrate failed enrolment into particular networks.

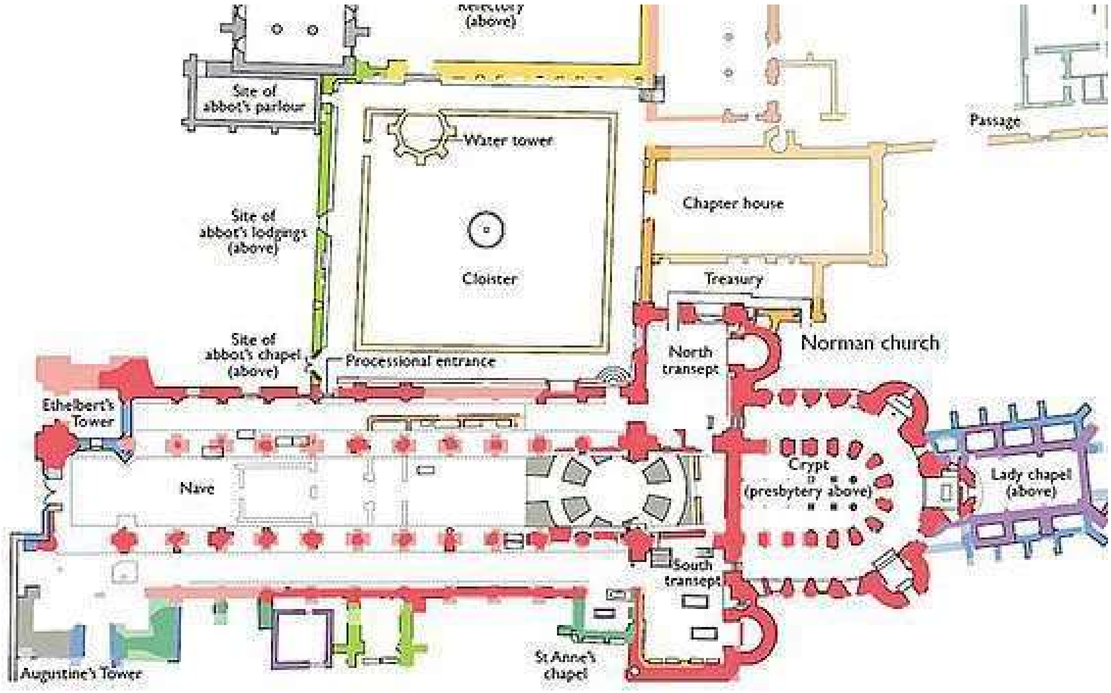


Figure 7.13 Guide Book drawing of St. Augustine's Abbey (Source: English Heritage)

Actor 12 External Condition Survey (Object/Document)

External condition surveys are procured by various stakeholders. Third party surveyors will complete the required survey but this might be in a non-standard format. Surveys might be as a programme of cyclical survey or, project specific.

Actor 13 Territory Shared Network Folder (Technology)

It was identified that in addition to K2 (Actor 4) asset management database, territory shared network folders were being used as a 'local' shared area for the management of historic building information.

Actor 14 Heritage Building Information (Object/Document)

While Actors 11 and 12 have been noted as specific actors based on their specific role within the network, the wider collection of heritage building information is referred to for ease as one actor. Actor 14 comprises all other heritage building information that might be required in the CRM planning process.

Actor 15 K2 Prioritisation Report (Object/Document)

The Prioritisation Report is used by senior managers to extract condition and defect data from K2 for the planning of CRM programmes.

Actor 16 K2 C SET – Component Condition Audit Report (Object/Document)

The C Set report is used by Territory Project Managers (Actor 8) for the planning and scoping of CRM projects.

Actor 17 Conservation Management Plan (Object/Document)

The conservation management plan is a document used to describe significance and define conservation repair philosophy and methodology.

Actor 18 Scheduled Monument Consent Process (Technology)

The Schedule Monument Consent Process is the process that ensures the philosophy and quality of CRM works to mitigate the risk of damage to significance.

Through interview and initial identification of actors it was identified that collaboration and information management processes were lacking in the wider organisations, even where there was overlap between stakeholders and CRM information. This led the researcher to look more closely at the existing processes. In the following section these processes and the various connections and actors will be described. They are referred to by a mixture of their Actor name, and number, whichever is more appropriate within the discussion. Associations between actors are traced and a network diagram is provided for each step in the CRM planning process. These network diagrams are collated into a final diagram that covers the full CRM planning process which is discussed in the chapter summary.

7.5 How do stakeholders collaborate and engage with an existing heritage asset management process?

Through a study of the range of stakeholders and actors involved in CRM processes, or who share heritage building information needs across two large heritage organisations with a shared service agreement, issues of collaboration, fragmented data and duplication were identified. This was first mentioned in Chapters 2 and 3 where issues of collaboration are noted as a problem in the wider AEC industry (Hautala *et. al.,* 2017) as well as the heritage industry more specifically (Jordan-Palomar et al. 2018). The issue of fragmentary data across the AEC industry in general was discussed e.g. (Miettinen & Paavola 2014), along with data fragmentation in the operation and maintenance stage of a building's lifecycle.

It is noted that both the wider construction industry (Gu *et al.*, 2014), and the heritage industry more specifically e.g. (Forsyth, 2007) must find ways to improve collaboration and information management. The cases described in Chapter 5 illustrate how organisations currently carry out asset management, some with formal processes in place, and others with processes in development. With this still an evolving field, and to help answer the research question that asks how digital, formalised processes might support conservation professionals, it is critical that people are considered as part of the process, rather than separate to it.

To help understand how people adopt or engage with existing formalised processes, the survey and asset management processes, and planning of CRM works within English Heritage has been studied and observations are detailed below. Rather than a series of vignettes, data in the following sections is compiled from the mixed methods approach used. A mixture of interview responses grouped thematically, along with field note data following participant observation is provided.

An ANT approach is used within the English Heritage examples so that a comparative analysis of data can be made. A follow the actor method (Latour, 2005) was used while conducting participant observation, and in the use of informal interviews, allowing the researcher to trace associations and factors affecting the CRM processes. The ANT 'process of translation' is used to allow a common language between the sets of data.

While the vignettes used in the previous section offered a rich description of interactions that brought actors into being and allowed for detailed descriptions of the process of translation, the mixed methods approach is less illustrative. For this reason, in this section actor network diagrams are provided to illustrate the interactions between various human and non-human elements which bring actors into being within the network. The use of such diagrams proves to be a more useful visual aid in support of the mixed methods data presented.

Actor network diagrams have been designed to illustrate actors and the specific interaction that brings them into the network. Interactions are illustrated using arrows and the direction of the arrow illustrates which actor has instigated the interaction. Dotted arrows are used to illustrate intermittent interactions and thus, a particular point of failure.

The BIM process field (Succar, 2009) is again used to structure the data into the four identified CRM process themes, therefore providing an opportunity for comparison of data from the two data sets.

Separate actor network diagrams are provided for each of the CRM process themes. Each is complex, and analysis and illustration is difficult without the use of a diagram. The individual diagrams are integrated in section 7.5.4. In this diagram the addition of a green line (green for 'Go') is added to illustrate the delivery of CRM works. It illustrates that despite a single outcome, there are a complex network of actors that must be enrolled in the vision if successful mobilisation is to be achieved.

7.5.1 Survey and Data Capture

The researcher used informal interview techniques to talk to various stakeholders and used the discussions to follow action. Problems, decision points, or difference in practice were the primary actions that prompted further discussion. Data was gathered that could be used by the researcher to identify the network actors, and trace associations and negotiations within the survey and data capture process to understand its success.

First, considering the actors, it was identified that the survey and asset management team, led by the Survey Data Manager (Actor 5), are responsible for procuring surveys on a national level so that this activity is centrally coordinated and to ensure survey data is centrally collated and entered into K2, the asset management database (Actor 4). A programme of surveys is developed by Actor 7 based on existing survey data and input from English Heritage Building Surveyors (Actor 9), or to inform the extent of works for planned projects.

For the programme of surveys, Actor 5 and their team will be responsible for procuring and coordinating the surveys and the subsequent data input into K2 (Actor 4). For consistency, standardisation, and to make the process more efficient, surveyors are issued with a survey template (Actor 10) so that information is compiled in the correct format and can be easily uploaded into K2 (Actor 4). Surveyors may be Actor 9 or, an external third party.

Where surveys are required specifically for projects that are being delivered the correct process would be to engage with Actor 5 to procure and manage this. Discussion with Actor 5 found that the team felt that when the correct survey process was followed, management of the survey data and import into the asset management database (Actor 4) works well. Through informal discussion with Actor 5 it was further identified that there are occasions where

Territory or National Project Managers (Actors 8 and 2) will procure surveys directly as part of their project work (Actor 12). Actor 5 stated that:

'some PM's ask us to get surveys done for them'

'some PM's don't realise' [this team is here to procure surveys on their behalf]

In such cases, whether the data gets passed to the survey team for upload to K2 is variable. This can be difficult to manage as the survey team aren't necessarily aware that new data has been produced so, heavily relies on the Project Managers passing the information to the survey team. Furthermore, where surveys are procured outside of the survey team, the format in which the survey data is received may not be aligned to the fields in the asset management database and so would require rework before it could be uploaded.

In contrast to the views of Actor 5, an interview with Actor 8 led to the following comments:

'*people don't communicate with the survey team'*

'the survey team don't have enough knowledge of the surveys being undertaken'

'in theory you would ask the survey team for a survey and they'd get it done. It never works that way and you end up telling them what to do and they facilitate the admin'

'I don't know if that survey then gets uploaded into K2, probably not!'

Informal interview helped the researcher identify that where Actors 8 or 9 procure surveys, the survey data is generally not in the format required by Actor 4, and that Actor 10 is not used to support the process. Further, the data often is not passed to Actor 5 or Actor 4. This represents a failing in the intended actor network and goal of a centralised management of survey data which is an important example for consideration when looking to introduce digital, formalised processes.

To offer a deeper exploration of actor networks in the survey and data capture process, the researcher traced the actions surrounding the management of architectural drawings (Actor 11). In section 7.4.1 above, it was noted that one of the critical information requirements requested by a wide range of stakeholders is architectural or measured drawings, and that these documents might be found in K2 (Actor 4) as they are key to CRM. Collaboration between departments might find that this information can be shared and thus reduce duplication.

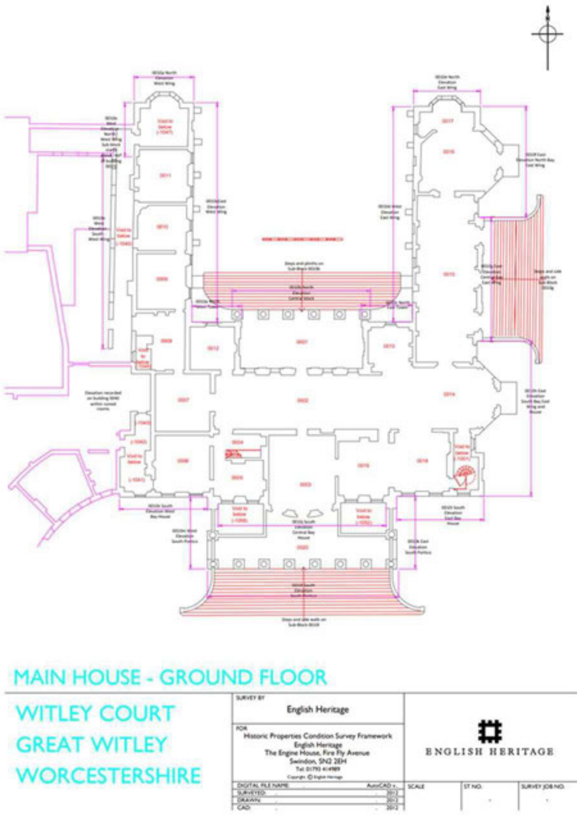


Figure 7.14 English Heritage - Witley Court Floor Plan (Source: English Heritage)

Despite the collaboration potential offered by Actor 4, informal interviews held with the English Heritage Estates department members highlighted that the process for the central management of drawings (Actor 11) is not always followed correctly. In a similar fashion where surveys are not always procured through the central team, project records including O&M files and as built architectural drawings (Actor 11) do not always make their way from either the Territory Project Managers (Actor 8), or National Project Managers (Actor 2), so that they can be collated in the centralised system – K2 (Actor 4). The results in, and adds to, the ongoing issue of data fragmentation and duplication or work where surveys or drawings are reproduced when information cannot be found.

Actor 5 noted that:

> *'different people provide different information [at the end of a project]'*
>
> *'the survey team usually find out a project has finished [somewhere down the line or by word of mouth] and then ask the Project Managers for the plans. Occasionally the PM will send them'*
>
> '*National Project Managers rarely contact the survey and asset management team post project to provide information'*

Research identified that despite there being a Survey and Asset management team and Survey Data Manager (Actor 5), that is dedicated to this data management, and confirmation that stakeholders such as Actor 2 and Actor 8 have been informed of the correct process, enrolment in the process has failed and so mobilisation is not fully achieved.

Actor 1	Guide Book Manager	**Actor 10**	K2 Condition Survey Template
Actor 2	National Project Manager	**Actor 11**	Drawings
Actor 3	Curatorial Team	**Actor 12**	External Condition Survey
Actor 4	K2 Database	**Actor 13**	Territory Shared Network Folder
Actor 5	Survey Data Manager	**Actor 14**	Heritage Building Information
Actor 6	Building Conservation Manager	**Actor 15**	K2 Prioritisation Report
Actor 7	Head of Survey & Asset Management	**Actor 16**	K2 C Set Report
Actor 8	Territory Project Manager	**Actor 17**	Conservation Management Plan
Actor 9	Heritage Building Surveyor	**Actor 18**	Scheduled Monument Consent Process

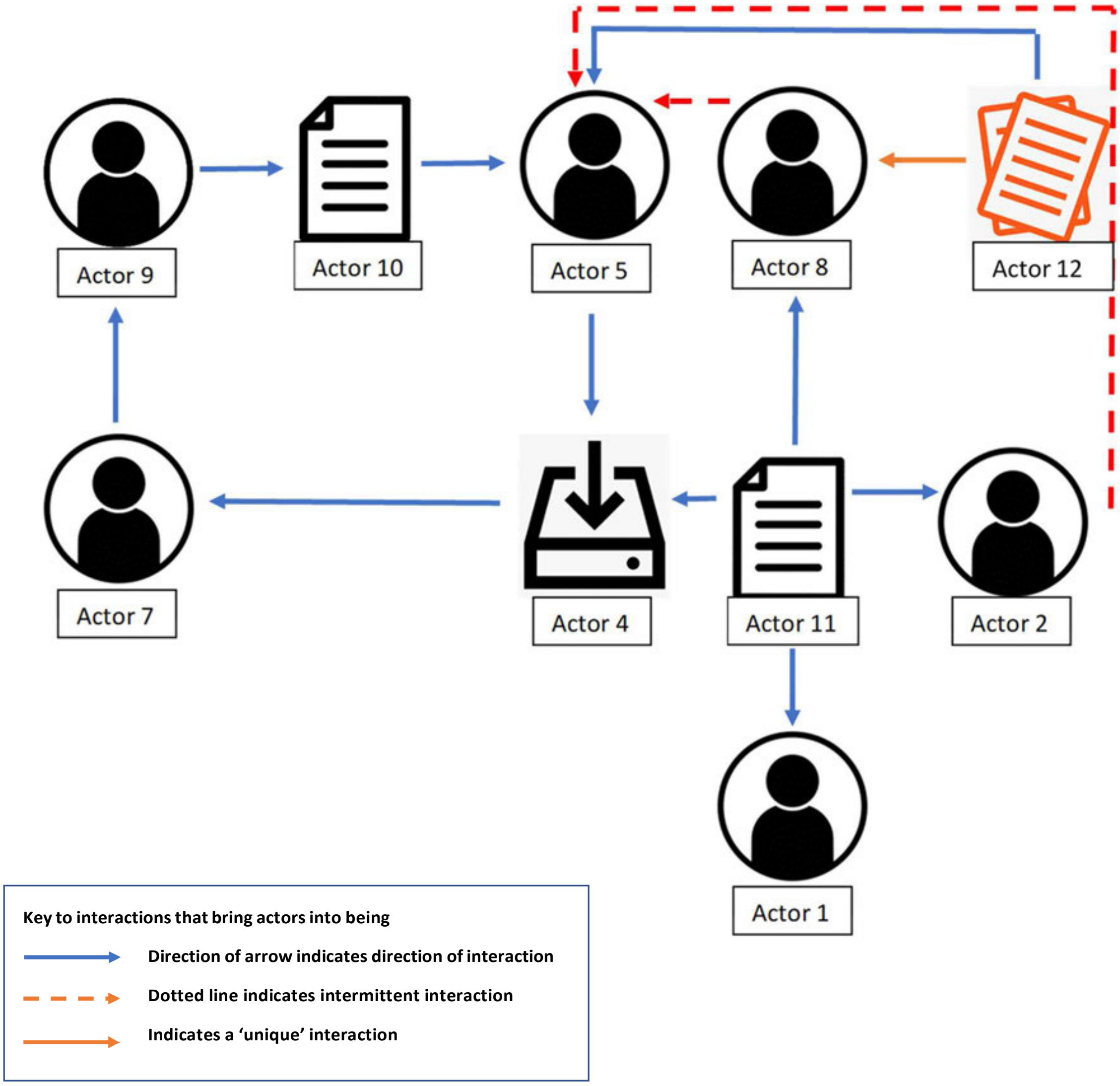


Figure 7.15 English Heritage Survey & Data Capture Actor Network Diagram developed by the Author

The two examples in this section are important when considering the implementation of new processes, and illustrate specific issues that have been encountered when introducing digital, formalised processes to support conservation professionals. Individual actors impact the mobilisation of a process, resulting in negotiations and displacement that transform the process.

A network diagram is provided on the previous page illustrating interactions between various human and non-human actors which bring the various actors into being (Callon and Law, 1982) within the network. Arrows illustrate interactions and the direction of the arrow defines which actor has instigated the interactions. For example, in Figure 7.15, Actor 7 takes information from Actor 4. On the other hand, Actor 5 provides information to Actor 4. Three distinct actors are illustrated. These include – person, technology and object/document. The network diagram illustrates that data/documents (Actors 10, 11 and 12) are generally only uploaded to the K2 asset management database (Actor 4) when they have passed through the Survey Data Manager/Team (Actor 5). Dotted lines illustrate where this happens on only some occasions, therefore illustrating a breakdown in the network.

Further, the diagram illustrates that in the survey and data capture process, Actor 4 only provides information to one actor and instead is expected to receive data. While Actor 1 and 2 require data that could be obtained from Actor 4, they instead bypass this.

7.5.2 Data Management - A central hub of data?

Focusing on a key point drawn from the review of the survey and data capture processes, discussions during the informal interviews were directed to get a better understanding of K2, the information in it, the way information was used by the user and any challenges that they encountered. It had been noted that survey data was not always filed in the central data management system, and that drawings were being obtained from a number of different sources rather than a central source. To understand this further, and why despite having a digital system in place to manage a centralised information model, interview responses from the interviewees have been collated in Table 7.4 and grouped thematically to understand the effectiveness of K2 (Actor 4) in providing a central repository for all heritage building information, and some of the common challenges that users faced.

Table 7.4 Interview responses about information in K2 grouped thematically

Information can't be found	Information is missing	Information is not useful	There is useful information available that is not on K2	User is not aware of the available information	There is no management of the data	There is duplication of data
It is not always in the most logical place.	*Often, the information I am after is not there or, stuff that is not useful is there.*	*Often, the information I am after is not there or, stuff that is not useful is there.*	*We just cleared out our drawers and found loads of stuff that could be useful on K2.*	*I asked the National Project Manager how much you use K2 for planning capital projects and they said they don't use it.*	*I have developed a back up folder of K2 documents as there is nothing to stop people deleting stuff off.*	*Often you find that 'stuff' is saved in 5 different places.*
Often you find that 'stuff' is saved in 5	*If information is not there*	*I asked the National Project*	*Often you find that 'stuff' is saved in 5*		*The survey team usually find a project*	*Project managers use local drives for individual*

different places.	*we just 'work around it'.*	*Manager how much they use K2 for planning capital projects and they said they don't use it.*	*different places.*		*has finished and then have to ask for the updated plans. The project manager rarely uploads them.*	*project documentation.*
I get asked a lot of questions about how to find information.	*The survey team usually find a project has finished and then have to ask for the updated plans. The project manager rarely uploads them.*	*I think the wrong 'stuff' is on K2.*				*When I have time I send completed project files to the Archives team.*

Interviews carried out with the English Heritage Estates team identified that whilst K2 (Actor 4) is meant to be the central repository for heritage information it is not used to its full potential and, that critical information for CRM is still fragmented, data rich but information poor (Gardner & Whitehead 2003). It was noted that the system is generally easy to use and information can be found, as long as it is in the system. However, during interviews it became apparent that the different territory offices have their own working practices and use alternative locations to store heritage information. For example, it was noted that in the North office there is a folder on the shared network for each site that has related site information in it. The Trust have recently gone through a process review that has shown the same thing to be true in other Territory offices.

It became apparent that whilst the database is intended as a central hub of heritage data, the system users were often finding that it did not meet their needs or were choosing to work in other ways. A further actor network diagram is used here to demonstrate the findings:

Actor 1	Guide Book Manager	**Actor 10**	K2 Condition Survey Template
Actor 2	National Project Manager	**Actor 11**	Drawings
Actor 3	Curatorial Team	**Actor 12**	External Condition Survey
Actor 4	K2 Database	**Actor 13**	Territory Shared Network Folder
Actor 5	Survey Data Manager	**Actor 14**	Heritage Building Information
Actor 6	Building Conservation Manager	**Actor 15**	K2 Prioritisation Report
Actor 7	Head of Survey & Asset Management	**Actor 16**	K2 C Set Report
Actor 8	Territory Project Manager	**Actor 17**	Conservation Management Plan
Actor 9	Heritage Building Surveyor	**Actor 18**	Scheduled Monument Consent Process

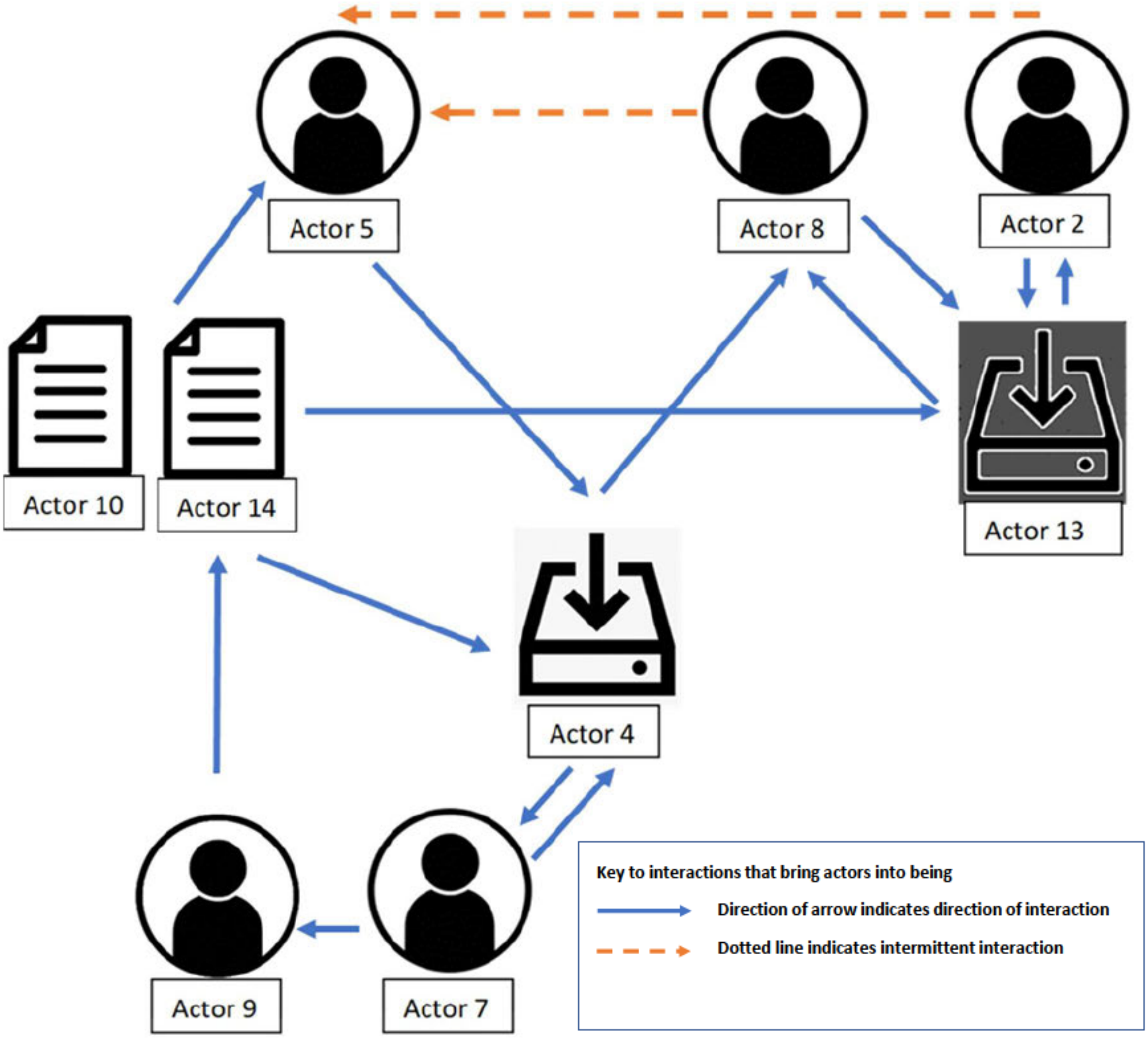


Figure 7.16 English Heritage Data Management Actor Network Diagram developed by the Author

Similar to the Survey and Data Capture Actor Network, where other actors engage with Actor 5, the network holds together. However, as with Actors 2, 8 and 12 in the Survey and Data Capture Actor Network, in this Data Management Actor Network the introduction of Actor 13 results in failed enrolment and mobilisation of the central data hub.

The Head of Survey and Asset Management (Actor 7) had commented during informal interview with the researcher that:

> *'I have a plan to improve the data in K2. I have a list of documents (in my head) – info to inform a project'*

At the time of undertaking the research, this list of documents was not available but it is interesting to note that this was an individual person who appeared to be suggesting what the list needed to be. Developing a framework of critical information requirements for CRM planning, and subsequent retrospective compilation of this data is a critical activity for heritage asset management but the process for this and the stakeholders involved needs consideration. While English Heritage had a standard list/framework for documents in K2, which was closely aligned to the conservation data parameters framework developed as part of this research (Hull and Ewart, 2020), data presented in this Chapter demonstrates that even with the formalised process, or framework for data, there are still many factors that affect implementation.

From the 7 themes identified in the interview responses, requirements to improve or support the process (or network) can be proposed. The table below considers the 7 key issues, proposed solutions to these, and finally, whether English Heritage had implemented these solutions.

Table 7.5 Information management issues and proposed solutions

Information management issue	Proposed Solution	Implemented in the English Heritage Process?
Information cannot be found	Single location Agreed structure Agreed naming convention Mandatory process	No
Information is missing	Identified critical information requirements Agreed structure Retrospective data collection	No
Information is not useful	Identified critical information requirements	No
There is useful information but it is not in K2	Identified critical information requirements Single location Agreed structure Retrospective data collection	No
User is not aware of the available information	Single location Identified critical information requirements Mandatory process	No
There is no management of the data	Information manager roles Single location Agreed structure Mandatory process	Yes No
There is duplication of data	Single location Agreed structure Identified critical information requirements	No

Data presented in Table 7.5 above illustrates common requirements for a proposed solution that should be considered when designing and introducing new systems or processes. The role of the information manager is key and had been implemented in the English Heritage process however, the actor network diagram demonstrated that even with this role in place, without agreed structures and mandatory processes, the network can still fail.

Two further requirements are proposed if networks are to be successful, achieving enrolment and mobilisation:

- Training
- Control – system and data

7.5.3 Data analysis

While data analysis and data use are described in quite some detail in regard to the UKAHT case study, participant observation and interview methods gave the researcher less opportunity to study these steps in the English Heritage CRM process. For consistency, and to allow comparison of data sets, the steps are included here but it is acknowledged that the information they provide for analysis is lesser.

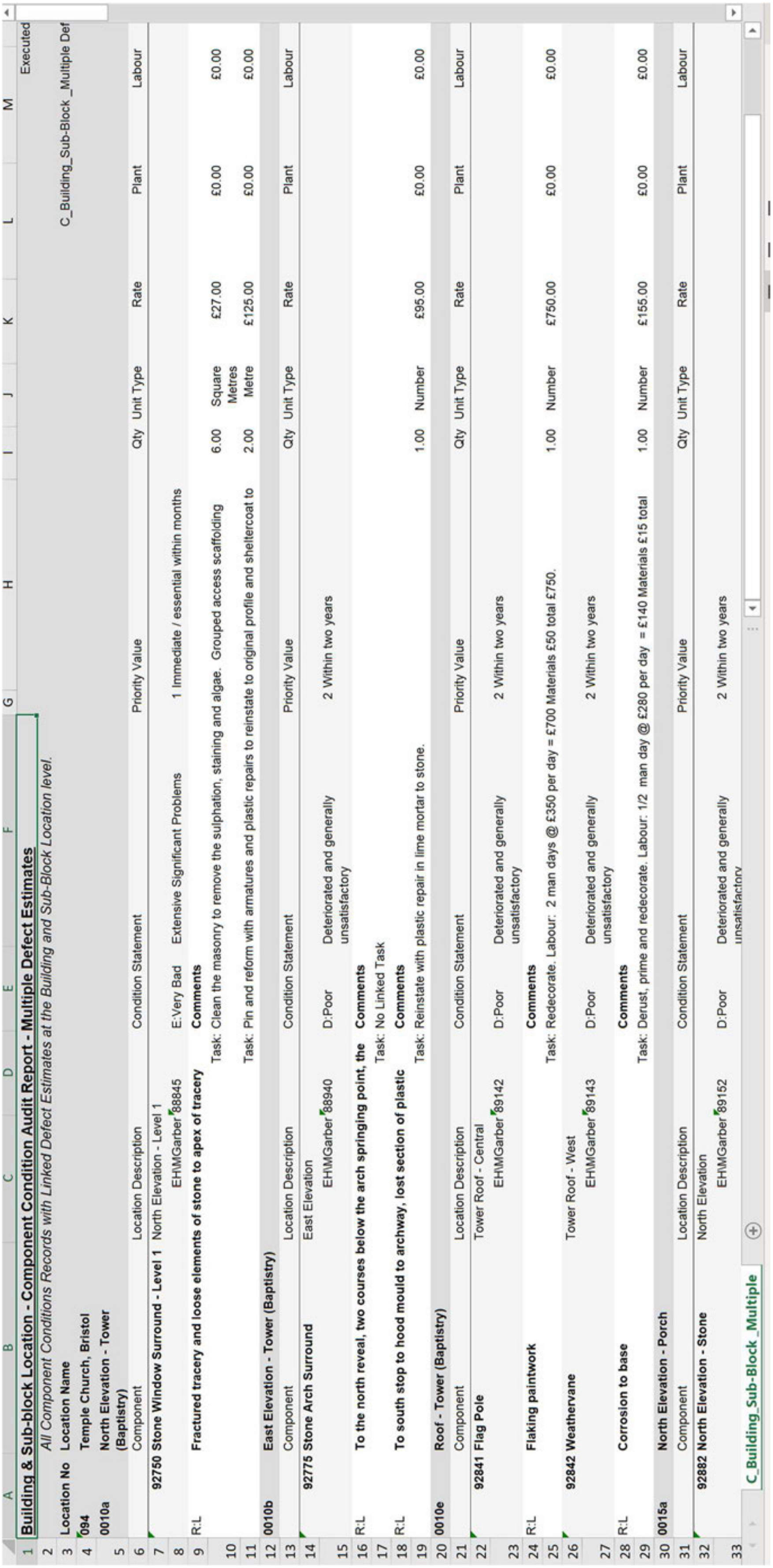
With an established heritage asset management process, and developed asset management database, it was possible to review at high level how collected survey data is analysed for the planning of English Heritage CRM programmes. In Chapter 5 the English Heritage Asset Management Plan 2011-2015 and Sustainable Conservation Strategy and Asset Management Plan 2019-2023 are introduced and in Chapter 6 are described as useful documents in identifying critical information requirements for CRM planning. Demonstrated in the previous section, the identification of critical information requirements is a vital solution for the observed information management issues.

English Heritage use condition survey programmes, estimated value of maintenance backlog (Evdorides *et al.,* 2012)and prioritisation of funding for CRM planning. To do this they use significance, vulnerability and condition assessments resulting in an asset matrix scoring in the planning process. Following building surveys, defects are listed in K2 against building components, along with significance and prioritisation data.

The effectiveness and efficiency of this task relies on the use of Actor 10 for the structure and standardisation of data. As observed, this does not always happen. The use of different formats, and procurement by different Actors means that information may not be uploaded into K2, resulting in inaccurate condition/defect data. Further, where data is provided in a different format, there is an element of duplication and rework required to enter the data into K2.

The report viewer module in K2 is used to produce Prioritisation Reports and these are used by the senior management team in the planning of CRM projects. As data within K2 is live it needs to be managed and part of this process is to close down defects once the works are complete, in effect, updating the condition rating of the building components so that they do not keep appearing on reports as requiring attention. Participant observation and interview provided observations that suggest this does not always happen.

Once the senior management team have used the prioritisation reports to develop a programme of CRM projects, the Territory Project Managers will be given a number of projects to deliver. At the outset of any project they will download the defect information from K2 in a 'C Set Report'. This details all defects identified through condition survey, with proposed remedial action and costs and is used by the Project Manager to develop a scope of works for the project. A screen shot is provided overleaf.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Building & Sub-block Location - Component Condition Audit Report - Multiple Defect Estimates												Executed
2		*All Component Conditions Records with Linked Defect Estimates at the Building and Sub-Block Location level.*											
3	**Location No**	**Location Name**											C_Building_Sub-Block _Multiple Def
4	**094**	**Temple Church, Bristol**											
5	**0010a**	**North Elevation - Tower (Baptistry)**											
6		Component	Location Description		Condition Statement		Priority Value		Qty	Unit Type	Rate	Plant	Labour
7	**92750**	**Stone Window Surround - Level 1**	North Elevation - Level 1										
8			EH\MGarber	88845	E:Very Bad	Extensive Significant Problems	1 Immediate / essential within months						
9	R:L	**Fractured tracery and loose elements of stone to apex of tracery**			**Comments**								
10				Task:	Clean the masonry to remove the sulphation, staining and algae. Grouped access scaffolding				6.00	Square Metres	£27.00	£0.00	£0.00
11				Task:	Pin and reform with armatures and plastic repairs to reinstate to original profile and sheltercoat to				2.00	Metre	£125.00	£0.00	£0.00
12	**0010b**	**East Elevation - Tower (Baptistry)**											
13		Component	Location Description		Condition Statement		Priority Value		Qty	Unit Type	Rate	Plant	Labour
14	**92775**	**Stone Arch Surround**	East Elevation										
15			EH\MGarber	88940	D:Poor	Deteriorated and generally unsatisfactory	2 Within two years						
16	R:L	**To the north reveal, two courses below the arch springing point, the**			**Comments**								
17				Task:	No Linked Task								
18	R:L	**To south stop to hood mould to archway, lost section of plastic**			**Comments**								
19				Task:	Reinstate with plastic repair in lime mortar to stone.				1.00	Number	£95.00	£0.00	£0.00
20	**0010e**	**Roof - Tower (Baptistry)**											
21		Component	Location Description		Condition Statement		Priority Value		Qty	Unit Type	Rate	Plant	Labour
22	**92841**	**Flag Pole**	Tower Roof - Central										
23			EH\MGarber	89142	D:Poor	Deteriorated and generally unsatisfactory	2 Within two years						
24	R:L	**Flaking paintwork**			**Comments**								
25				Task:	Redecorate. Labour: 2 man days @ £350 per day = £700 Materials £50 total £750.				1.00	Number	£750.00	£0.00	£0.00
26	**92842**	**Weathervane**	Tower Roof - West										
27			EH\MGarber	89143	D:Poor	Deteriorated and generally unsatisfactory	2 Within two years						
28	R:L	**Corrosion to base**			**Comments**								
29				Task:	Derust, prime and redecorate. Labour: 1/2 man day @ £280 per day = £140 Materials £15 total				1.00	Number	£155.00	£0.00	£0.00
30	**0015a**	**North Elevation - Porch**											
31		Component	Location Description		Condition Statement		Priority Value		Qty	Unit Type	Rate	Plant	Labour
32	**92882**	**North Elevation - Stone**	North Elevation										
33			EH\MGarber	89152	D:Poor	Deteriorated and generally unsatisfactory	2 Within two years						

C_Building_Sub-Block _Multiple

Figure 7.17 C Set Defect Audit Report – (screenshot) (Source: English Heritage)

Considering this data analysis step, a further two actors are introduced to the overall CRM planning actor network. Rather than show this here, these will be added to an overall network diagram provided at the end of section 7.5.4.

7.5.4 Data use – Scoping CRM Projects

Unlike the UKAHT example, English Heritage do not deliver CRM projects with their own staff, instead employing conservation specialists. This led to a limitation in the observation of data use for delivering CRM and making decisions about CRM projects. Instead, a review of data use for project scoping is presented, and network actors in this process are identified.

Conservation projects delivered by English Heritage are prioritised based on reducing the financial value of the deficit. However over an 18 month period from March 2015 English Heritage realised that the scale of this deficit and reducing the financial value was not realistic. Furthermore, they justified that the financial value of the deficit did not need to be reduced in order to deliver good conservation outcomes (Smith, 2005). English Heritage realised that they had costed all defects in the Asset Management Database, adding to the financial value of the deficit, when not all defects necessarily needed addressing.

An example introduced in Chapter 5 referred to a project of masonry repairs at Goodrich Castle. Further to initial review of the defects listed in the Asset Management System (Actor 4) using the K2 C Set Condition Audit Report (Actor 16), and a subsequent site visit, it was established that many of the defects referred to low level masonry and vegetation growth within the moat structure, work that was not considered a priority in terms of masonry repair.

Figure 7.18 Goodrich Castle, English Heritage (Source: English Heritage)

A common approach for the scoping of CRM works is to review historic building information (Actor 14) to understand the significant components, historic repairs and conservation repair philosophy for the heritage asset. English Heritage, unlike UKAHT, do have conservation management plans (Actor 17) available for the properties in their care and these will be reviewed in the process of scoping CRM works. Further, the full scope of works including repair methodology will need to be approved via the scheduled monument consent process (Actor 18).

Certain information is required for this process and so project managers (Actor 8) will need to access information to complete this process. Highlighted in the previous sections, this process depends on the correct capture, management and access to information.

The CRM process actor network diagram shown in Figure 7.19 illustrates all actors identified across all four steps in the CRM process. As before, actors are shown as Person, Technology or Object/Document. The diagram illustrates that despite a single outcome – delivery of consented CRM works to heritage assets – there are a complex network of actors that must be enrolled in the vision if successful mobilisation is to be achieved.

In the next chapter, the lessons learnt here are incorporated into the Heritage Information Management (H-IM) workflow which is aimed at conservation professionals as a proposed solution to improve efficiencies and effectiveness for CRM planning.

Actor 1	Guide Book Manager	**Actor 10**	K2 Condition Survey Template
Actor 2	National Project Manager	**Actor 11**	Drawings
Actor 3	Curatorial Team	**Actor 12**	External Condition Survey
Actor 4	K2 Database	**Actor 13**	Territory Shared Network Folder
Actor 5	Survey Data Manager	**Actor 14**	Heritage Building Information
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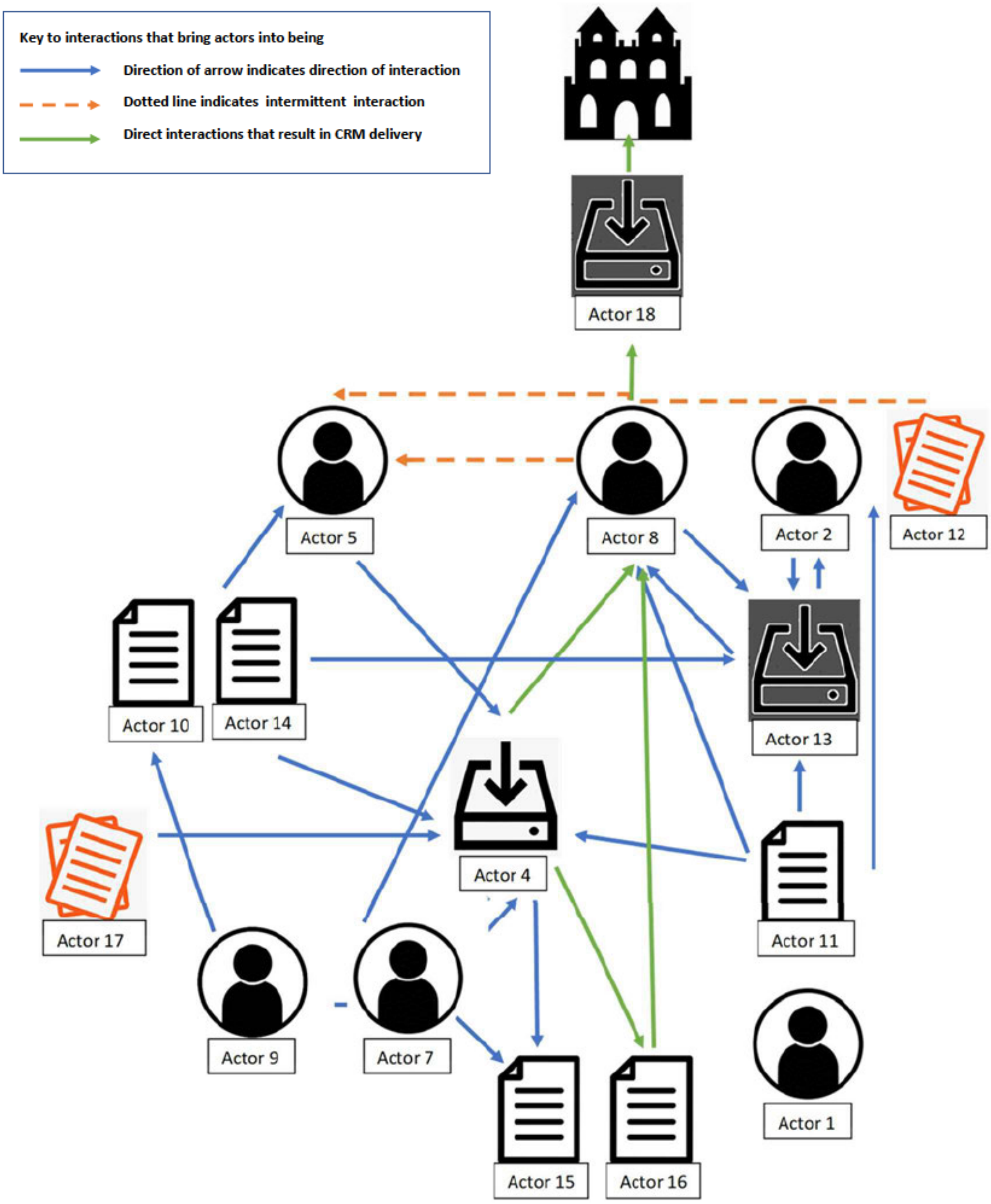


Figure 7.19 English Heritage CRM Process Actor Network Diagram developed by the Author

8. The Heritage Information Management (H-IM) Workflow – Adopting BIM principles for heritage asset management

Chapter 8 is the final chapter in which data collection, analysis and findings are presented. It is slightly different to the other 3 data collection chapters in that it is based on a culmination of the data gathered through earlier chapters, and is specifically aimed at providing a practitioner contribution with the presentation of the proposed Heritage Information Management (H-IM) Workflow.

8.1 Introduction

Digitisation is expected to have one of the biggest impacts on the Construction industry in the coming years, improving efficiency and effectiveness across the entire lifecycle of built assets, including design, construction and operation (Berger, 2017). Introduced in section 2.5 of the literature review, it is suggested in theory that the use of building information modelling (BIM) or, BIM principles, could improve efficiencies in the O&M phase for facilities and asset management activities with value coming from efficiencies in digital processes, improved accuracy of data and better access to data (Kassem *et al.,* 2014). A review of literature focused on BIM enabled asset and facilities management (FM) in the operation and maintenance (O&M) phase e.g. (Cavka *et al.*, 2017; Gao & Pishdad-Bozorgi, 2019) provided further overview of the perceived benefits. These could be categorised into 4 main functionalities:

- Improved Client and Owner understanding of critical information for O&M
- Improved handover of O&M information
- Improved management and access to information used in the O&M phase
- Improved accuracy of O&M information

Despite such benefits, the literature illustrates that adoption of innovation in the sector is slow, with barriers to implementation identified in lack of R&D funding (Dulaimi *et al.*, 2002), lack of strategic implementation (Benmansour & Hogg, 2002), and factors such as silo working and the fragmented nature of the AEC industry.

Challenges affecting the slow adoption of BIM more specifically for asset and facilities management have been identified through literature review. Such barriers as listed below have been proven through this research to be common in both heritage and non-heritage contexts (Kassem *et al*., 2014; Burak Cavka *et al*., 2017) as discussed in earlier chapters:

- Sources of information are spread across a range of systems. In order to integrate these, interoperability between systems requires further development.
- Information requirements (IR) for O&M are not well defined at the beginning of a project and require more input from FM/asset management professionals at an early stage.
- Methodologies and defined information management processes with practical guidance are lacking (McArthur, 2015; Maxwell, 2017).
- There is limited knowledge and a shortage of digital / BIM skills in both Heritage and O&M fields.

Notwithstanding the identified challenges, BIM is considered a necessary digitisation strategy to improve collaboration and efficiency in the AEC sector due to the potential benefits across all phases of the building lifecycle and so, research has sought to fully understand the barriers and propose solutions to improve uptake.

Having considered issues of data fragmentation in the heritage sector and with significance based CRM relying on informed decision making (section 3.2 and Chapter 5), opportunities in improved management, access, and accuracy of O&M information could also be hugely beneficial for heritage asset management, facilitating the management of heterogeneous sets of data that are required for CRM planning. Despite the theoretical benefits, the reality is not yet well demonstrated. There are still a lack of BIM for FM or asset management case studies required to test the theory. Furthermore, the majority of case studies that do consider these benefits are from a new build perspective, as an output following a design and construction process, with very little research that considers this potential for built heritage assets. If a BIM methodology is to support a standardised approach for heritage asset management and CRM planning, identified barriers must be addressed and more case study exemplars are required.

BIM guidance has been purposefully designed in a generic manner and does not address specific organisational needs, particularly for heritage organisations. Furthermore, heritage Clients need to become better educated with regards to BIM processes and information requirements if they are to get the most benefit. Simply stating in a project brief that BIM or, BIM level 2 is required is not enough. The Client needs to take control of the process, define their requirements and state the expected deliverables (Mayo and Issa, 2014; Mcarthur, 2015).

In the case of existing buildings or heritage assets, critical information for CRM planning may already exist rather than being produced during a design and construction phase or, is produced throughout the operations phase as building repair and maintenance is completed. Identifying where legacy data can be found within the varied and fragmented building information can be a tricky task. 'Retrospective compilation' presents a major challenge if organisations wish to develop central asset information models ahead of implementing digital, formalised information management processes, as demonstrated in previous chapters. Furthermore, identifying gaps in the data and bringing this up to date through survey work can be a lengthy process. It was demonstrated with the UKAHT case study that survey and data capture is ongoing, and with limited formal process still presents challenges.

A focus on the BIM *information management process* and expanding the 'Back to BIM basics' agenda into the heritage industry is required if benefits for asset management are to be seen. An increased number of BIM guidance and implementation plans produced by individual organisations, Universities and Government bodies such as the Houses of Parliament and the Ministry of Justice shows a desire to adopt BIM, not only for design and construction but also for lifecycle BIM and the lifecycle management of building information. This development should be built upon to assist heritage asset owners in determining specific information requirements and implementing their own BIM *information management process* to support heritage asset management.

8.1.1 Chapter Objectives

In response to the research question; *'What are the challenges of heritage asset management and how might digital, formalised processes, such as BIM, support conservation professionals?'* the BIM research framework (Succar, 2009) has been applied throughout this research to consider the BIM *process* (information management) field in relation to BIM *Stage 2* (model based collaboration), with the particular BIM *lens* of CRM planning for heritage asset management.

The thesis has been divided into chapters that look at specific themes in relation to the research question. Building Information Modelling has been identified as a critical innovation to improve efficiency in the AEC industry however uptake is still low suggesting there are still people and process issues to be considered. The literature review looked in detail at digital innovation in the AEC industry and more specifically stakeholders, and skills and attitude towards digitisation within the heritage sector. This was then investigated further in Chapter 7, where it was considered why people do not always follow formal processes.

BIM could offer a potential opportunity to support conservation professionals with heritage asset management, yet despite attempts to develop guidance, process and protocol for Heritage BIM, a single protocol for heritage asset management has not been developed and critically, none of the examples have reported on how people engage with the developed processes. This element is critical when considering the adoption and uptake of new digital, formalised processes such as BIM-enabled heritage asset management.

The heritage sector has made steps to understand the benefits of BIM at industry level e.g. (Historic England, 2017; Hull & Bryan, 2019) and there is significant academic research into the use of BIM in a heritage context. While much focus has been placed on 3D data capture and subsequent parametric modelling of historic architectural components, with uses such as visualisation, monitoring and digital documentation, the literature review identified considerable issues in both the wider AEC industry, and heritage sector specifically, with building information management and use in the O&M phase, particularly for facilities, maintenance and asset management. It was reported that the heritage sector lacked best practice maintenance systems, industry guidance and common structured processes for conservation repair and maintenance e.g. (Dann and Wood, 2004), with information management one of the key issues. Furthermore when processes were implemented, success is considered variable (Forster & Kayan, 2009). Factors affecting successful implementation of conservation maintenance strategies were further considered in Chapter 7 where it was illustrated that the way people work, or how they will interpret or perform a process cannot be assumed and thus success is not guaranteed. Moreover, it was illustrated that CRM processes are critically affected by a vast range of socio-technical challenges and surprises. Despite these findings, academic research that considers a BIM methodology to support information management for conservation repair and maintenance, identified as the principal task associated with heritage asset management, represents a considerable gap in the research.

Having considered existing heritage asset management processes, critical information requirements for CRM and the way people engage with both analogue and digital formal process, this chapter is explicitly different from the data collection chapters.

Existing and proposed workflows, protocols and case studies for Heritage BIM are discussed in section 8.3, with a review against the BIM research framework (Succar, 2009) to allow comparisons to be drawn and to position this research and the subsequently proposed workflow as an original piece of work that offers significant contribution to the heritage sector and specifically CRM planning. A continued focus on 3D parametric modelling in the BIM field and confusion in BIM terminology, particularly the Asset Information Model (AIM) is addressed.

Next common functions of the existing heritage and non-heritage asset systems studied as part of this research are reviewed, and data is further analysed to make comparisons with BIM system functions.

Information gathered from these two sets of data is used to produce a list of requirements for a Heritage BIM workflow that can be used to support CRM planning. The aim is a workflow that is more accessible to the range of heritage stakeholders, and suited to the range of skills and funding available within the industry e.g. (Duff *et al.*, 2009; Watrall, 2019). This approach is in the spirit of the 'Back to BIM Basics' agenda (UK BIM Alliance) which considers BIM at its simplest – in particular a *process of information management* rather than a focus on 3D parametric modelling. An emphasis on making small steps towards a BIM process is a step in the direction of moving from analogue to digital. Aligning the H-IM workflow with the ISO BIM information delivery cycle/management process is intended to offer a clearer read across from BIM information management processes.

As a research output, there are several objectives to this chapter:

- Identify common functions of asset management systems and compare these to BIM functions.

- Define the features required for a digital, formal process such as BIM to support heritage asset management.

- Address existing confusion in BIM terminology – particularly the definition of the Asset Information Model (AIM).

- Present a digital, formal process to support conservation professionals with information management for CRM planning.

While other chapters contribute to the academic contribution of knowledge, this chapter is specifically aimed at providing a practitioner contribution. The chapter is based on a culmination of the data gathered through earlier chapters and work carried out during the placement at Historic England which resulted in the publication of BIM for Heritage: Developing the Asset Information Model (Hull and Bryan, 2019).

A proliferation of acronyms within the BIM field is common which can cause confusion, particularly to those not au fait with BIM terminology . As this chapter focuses more heavily on BIM process and terminology a short reference guide is provided in Table 8.1 to help guide the reader through the following sections where acronyms are used more frequently. New terms developed as part of this research are also included. The terms are listed in order of where they appear within the BIM information delivery cycle.

Table 8.1 BIM terminology reference guide

BIM acronym	BIM term in full
EIR	Exchange Information Requirements
BIM	Building Information Modelling
BEP	BIM Execution Plan
MIDP	Master Information Delivery Plan
IMP	Information Management Process
PIM	Project Information Model
CDE	Common Data Environment
AIM	Asset Information Model
OIR	Organisational Information Requirements
AIR	Asset Information Requirements

HBIM	Heritage BIM
H-IM	Heritage Information Management
H-IMP	Heritage Information Management Process
H-AIM	Heritage Asset Information Model
HIR	Heritage Information Requirements

8.2 Existing BIM Guidance

There are a number of documents that aim to offer practical guidance for the application of BIM The most prominent of these are summarised in this section.

The BIM Level 2 suite of documents was produced to help the construction industry adopt BIM and includes the following British Standards (BS) and PAS (Publically Available Specifications):

BS EN ISO 19650-1:2018: *Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling - Information Management using Building Information Modelling: Concepts and Principles* (BSI 2019a)

BS EN ISO 19650-2:2018: *Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling - Information Management using Building Information Modelling: Delivery Phase of the Assets* (BSI 2019b)

PAS 1192-3:2014: *Specification for Information Management for the Operational Phase of Assets using Building Information Modelling (BIM)* (BSI 2014)

(BS 1192:2007 + A2:2016 and PAS 1192-2 are superseded by BS EN ISO 19650.)

PAS 1192-3:2014 (BSI 2014) provides guidance for asset managers on how to integrate the management of information across the longer term activity of asset management with the shorter term activity of asset construction for a portfolio of assets. PAS 1192-3:2014 is the principal document that should be used in asset management.

PAS 1192-3:2014 will eventually be replaced by BS EN ISO 19650-3 *Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM) — Information Management using Building Information Modelling: Operational Phase of the Asset*.

The International Organization for Standardization (ISO) international standards have been developed based on the UK's standards for information management using BIM.

The Construction Industry Council (CIC) BIM Task Group support and help deliver the objectives of the Government Construction Strategy for BIM implementation. They hypothesise that 'significant improvement in cost, value and carbon performance can be achieved through the use of open sharable asset information'. Their aim is to raise awareness of the BIM programme and requirements and ensure that a consistent message is delivered to the supply chain, share best practice and allow a feedback route back to the Task Group. CIC are responsible for the publication of the CIC BIM Protocol – a standard protocol for use in projects using Building Information Models. The Protocol is intended for use with all common construction contracts, putting into place specific contractual obligations on the Employer and the Project Team Member, identifies the information which members of the Project Team are required to produce, can require compliance with security standards and processes. It is suggested that the Protocol is flexible and suitable for use on all Level 2 BIM projects. The Protocol is an effective way to introduce a standardised approach to the contractual use of BIM in construction projects.

It is clear from the BIM guidance noted above that to date it has principally focused on new build construction, meaning that adoption of BIM for existing buildings, including heritage, is limited and unclear. Historic England (English Heritage at the time) started consideration of BIM in 2013 through inclusion within its Heritage Science strategy and establishing its own internal BIM Special Interest Group (BIMSIG) that considered the relevance and potential adoption of BIM across its own historic estate and the impact BIM might have on its external advice.

'Following the COTAC Digital Future for Traditional Buildings Conference in November 2013, the Council on Training in Architectural Conservation (COTAC) produced a report entitled: Integrating Digital Technologies in Support of Historic Building Information Modelling. The report concluded that there had been no serious work initiated to date in determining how BIM might be applied to the diverse conservation, repair and maintenance (CRM) work activities in the Conservation Sector of the UK's construction industry' (Maxwell, 2016a).

In September 2017 a special interest group, BIM4Heritage, was set up within BIM4Communities to champion BIM within the historic environment and provide a forum for organisations and industry professionals to share knowledge and lessons learnt on the application of BIM in a heritage context. Historic England form part of this committee.

In 2017 the BIM4Heritage group held their inaugural conference which was followed by the publication of the BIM4Heritage Conference Report 2017 (COTAC). This report identified a range of needs that would be required to encourage a greater degree of BIM uptake in the heritage sector:

- Provide BIM guidance for Owners and Clients including workflows and templates
- Understand roles and responsibilities as indicated in PAS documents
- Guidance to be simple & relevant
- Migrate easily from existing workflow patterns
- Ensure competence at Level 1 first
- Reduce confusion surrounding the 3D modelling aspect of BIM

In 2017 Historic England published *BIM for Heritage – Developing a historic building information model.* This guidance offered the heritage industry an introduction to building information modelling and application in a heritage context with a number of case study examples.

In 2018, Historic England publish *BIM for Heritage – Developing the asset information model.* This guidance focuses on heritage asset management, in particular CRM planning, and suggests that the first task when adopting a BIM information management approach in a heritage context is to develop an asset information model. The guidance is aimed at helping conservation professionals think about the information they need for CRM and how they might develop asset information models with associated information management processes to support heritage asset management.

As ISO standards are not specifically related to heritage or existing buildings, to the heritage industry BIM may be considered a specialist subject or approach that is too costly or time consuming. Guidance produced by leading heritage organisations such as Historic England is vital to break down these barriers but the message needs to be clear. The first Historic England publication, like much of the research and Heritage BIM case studies, focused on the parametric modelling aspect of BIM. The second publication however, produced as a result of this research, has focused on the information management aspects of BIM, particularly for the activity of asset management. Despite the publication being one of the organisations most downloaded technical guides, there has been no progress in the standardisation of information management for heritage asset management and so, further guidance, training and an outlined workflow designed on the acknowledged socio-technical factors that impact implementation is required.

8.3 Proposed Heritage BIM workflows, protocols and case studies

The Council on training in Architectural Conservation (COTAC) (Maxwell, 2016a) acknowledged in 2016 that BIM guidance, including workflows and templates, is required to support BIM uptake in the heritage sector. It is therefore important to understand the protocols and frameworks for heritage BIM (HBIM) that have been developed to date. As an overview, those found in academic literature to date lean towards heritage intervention and historic preservation and management, rather than heritage asset management or CRM planning more specifically. This research is not about decision making around heritage interventions – adaption, reuse, or development. It is about the operation and maintenance of historic buildings – the planning of preventative maintenance based on conservation data parameters such as condition, significance and priority. Minimal loss of historic fabric and preservation for future generations is the goal. However, with a lack of more related research, these proposals offer the only options for review and analysis.

A particular case study focused on Durham Cathedral does however specifically consider the implementation of a BIM information management plan and the development of an asset information model and so is included in this discussion. While it is acknowledged that there are a number of HBIM case studies that could be considered for analysis within this research (Ewart and Zuecco, 2019), the Durham Cathedral case studies have been selected as they offer the best example using the facilities management (FM) process lens and importantly, include the development of an *asset information model.* Proposals based on software solutions that include 3D models, desktop, and mobile applications e.g. (Piaia *et al.*, 2021), to leverage existing data in BIM, and support optimised CRM planning and onsite condition assessment are ignored in favour of information management processes that offer a more accessible option to heritage stakeholders in line with the 'Back to BIM basics' initiative. Similarly, those workflows that rely on multiple digital technologies (McGibbon *et al.*, 2018) are excluded.

While the research discussed below is all positioned within both the BIM 'process' field, and BIM stage 2, the BIM lens' show some variances. While all are positioned within a heritage context, this might not be in relation to CRM planning for heritage asset management as in this research. This will be considered throughout the discussion and for ease is summarised in Table 8.2. Of the 3 workflows, or protocols, described, all are positioned within the lens of heritage building interventions, but these covered the full conservation/building lifecycle rather than the O&M phase specifically. Each referred to the development of an HBIM model, which in all cases involved the development of a 3D BIM/parametric model as the central source of data to be used in the planning and delivery of heritage building interventions. On the other hand, the two Durham Cathedral case studies used the lens of FM processes for heritage sites. This is more akin to heritage asset management, or CRM planning, albeit there is some confusion in the terminology used within the second case study, both still focused on the development of a 3D parametric model.

Table 8.2 Review of proposed workflows/protocols/case studies for HBIM

HBIM Workflow/Protocol/Case Study	BIM Lens	Theoretical / Practical	Key Themes	Benefits	Limitations
HBIM Theoretical Framework	Heritage building intervention	Theoretical	Information requirements and exchange between stakeholders. Relationships between people, process, policy and technology. Central data model.	A theoretical framework as a basis for future research.	No conclusive implementation approach.
HBIM Framework Evaluation Criteria	Heritage building intervention	Theoretical	Key activities in the planning and delivery of conservation interventions. Key conservation influences in the planning and delivery of conservation interventions. Central data model.	Centralised, single source of information across a conservation intervention process.	BIM principles or methodology are unclear. Does not include a cost/benefit analysis.
BIMLegacy	Heritage building intervention	Practical	Key activities in the planning and delivery of conservation interventions. The process of linking historical documentation to HBIM models. Central data model.	Centralised, single source of information across a conservation intervention process. Proposes a common data environment using an easily accessible online portal.	Does not include a cost/benefit analysis.
Durham Cathedral Chapter House - Case Study 1	FM processes for heritage sites	Practical	Conservation data parameters for maintenance planning. Creation of maintenance schedules directly from HBIM model. Central data model.	Centralised, single source of information across a conservation intervention process. Visualisation for maintenance planning. Quick access to information for maintenance planning.	Does not state what the conservation parameters should be.
Durham Cathedral Chapter House - Case Study 2	FM processes for heritage sites	Practical	Development of an Asset Information Model. Identify heritage information requirements.	Centralised, single source of information across a conservation intervention process. Visualisation for maintenance planning. Quick access to information for maintenance planning.	Does not state what the heritage information requirements should be. Definition of the AIM is confused with a parametric model.

Following a review of HBIM application within the heritage sector, research by Megahed (2015) proposes an HBIM theoretical framework that defines the information requirements and exchanges needed for historic preservation. ' The proposed framework illustrates how people, technology, process, and policy interact to support historic buildings throughout their lifecycle' (Megahed, p142, 2015) and is depicted in the visualisation of the theoretical

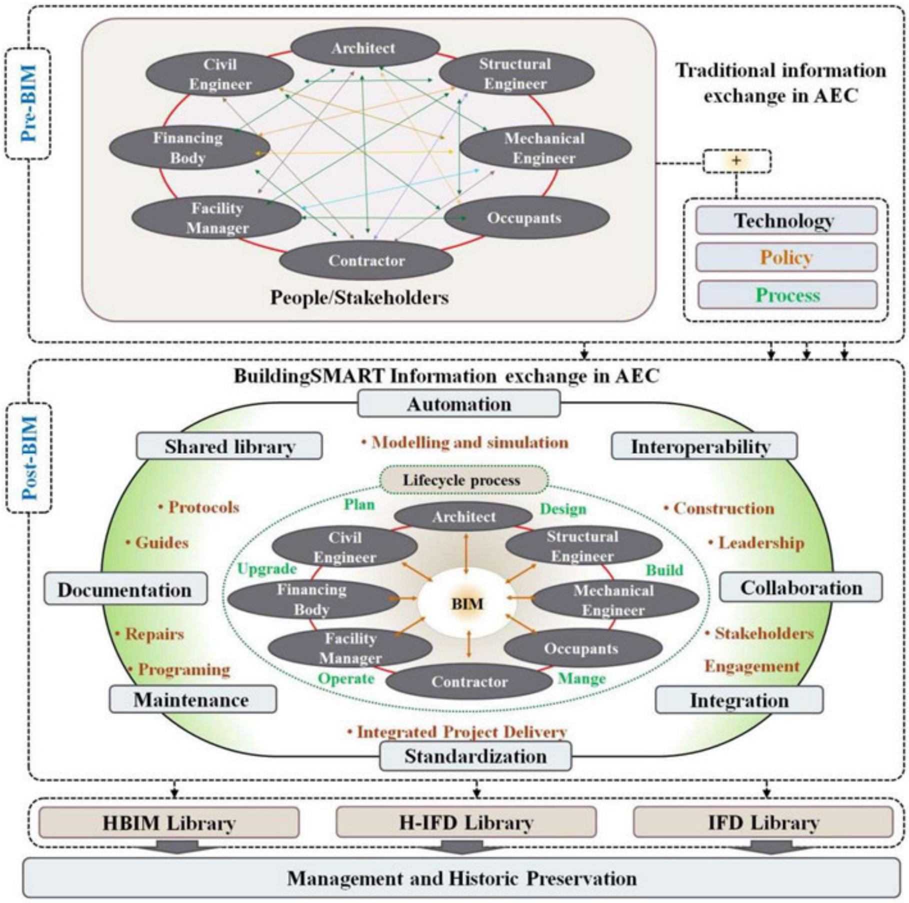


*Figure 8.1 HBIM Theoretical Framework Diagram (*Megahed, p143, 2015*)*

The visualisation of the theoretical framework illustrates that without BIM people, technology, process, and policy often work separately when dealing with information exchange, wasting time, resulting in increased costs, and reduced management. This situation within the heritage sector has been demonstrated through this research, and in particular, the relationships between people, technology, process and policy. It is illustrated that BIM could significantly improve collaboration between actors, however it is suggested that for this to be successful, a clear understanding of information requirements and how to structure this within the centralised platform is required.

The research focuses widely on the whole heritage conservation lifecycle and the various BIM challenges that were discussed in the literature review, including 3D data acquisition, modelling of historic architecture and historical BIM libraries thus providing a more general review of HBIM research to date, and offering the theoretical framework to bridge the gap between various theoretical discussions and demonstration of practical application. It is acknowledged that the paper does not provide a conclusive implementation approach, instead offering a theoretical framework to be used as a starting point for further research.

In response to a lack of serious research that considered how BIM might be applied to the range of CRM activities, the Council on Training in Architectural Conservation (COTAC) developed the HBIM Framework (Maxwell, 2016; Maxwell, 2016b). Taking the Construction Industry Council (CIC) BIM Cyclical Diagram as a base point, COTAC have attempted to identify the range of conservation themes and process steps that will need to be considered if applying BIM in a heritage context. This results in a series of workflow diagrams that are illustrated here.

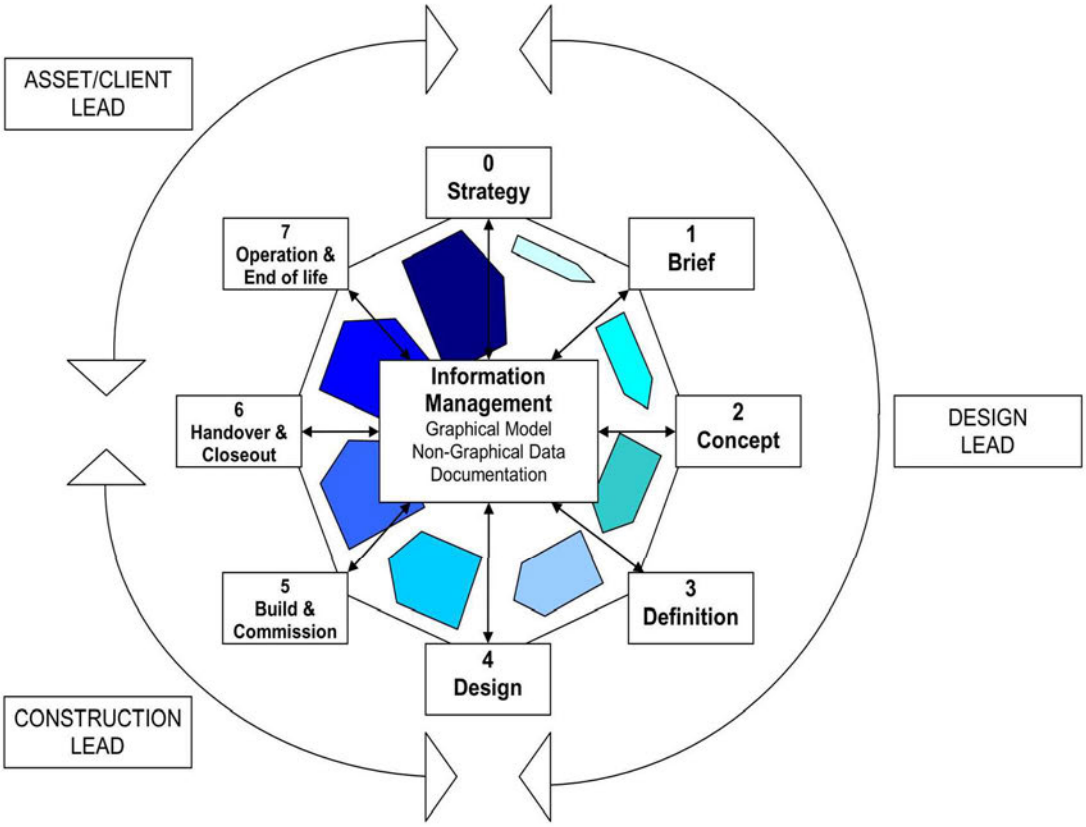


*Figure 8.2 Construction Industry Council BIM Cyclical Diagra*m (Maxwell, p5, 2016a)

A change in emphasis from design and construction to conservation philosophy and developing an asset management strategy is noted as key to the HBIM process and aligns with the findings of Chapter 5, where asset management in a heritage context is illustrated to differ from traditional asset management due to the emphasis on conservation philosophy and significance based prioritisation. Maintaining a read across to the CIC BIM Cyclical Diagram, COTAC presented the HBIM Framework Diagram:

*Figure 8.3 COTAC HBIM Framework Diagram (*Maxwell, p7, 2016a)

Further, the COTAC report identified that a full range of conservation influences must be integrated within the BIM process to understand the full HBIM requirements at each of the 8 steps. These included, but were not limited to:

- Application of ICOMOS education and training guidelines
- Application of BS7913: 2013 Guide to the conservation of historic buildings
- Application of Historic England Conservation Principles Policies and Guidance: April 2008
- Application of the COTAC Annual Conference 2014 Report findings
- Application of the UNESCO Disaster Risk Management Cycle

It was suggested that these, and other, conservation influences should be overlaid to the base diagram 'to create a more in-depth process of what, collectively, needs to be and should be incorporated. As historical and traditional buildings already exist a full understanding of their needs must be fundamentally informed by a detailed survey and analysis of what is currently there, together with an awareness of their significance and value, and the risks they face' (Maxwell, 2016a).

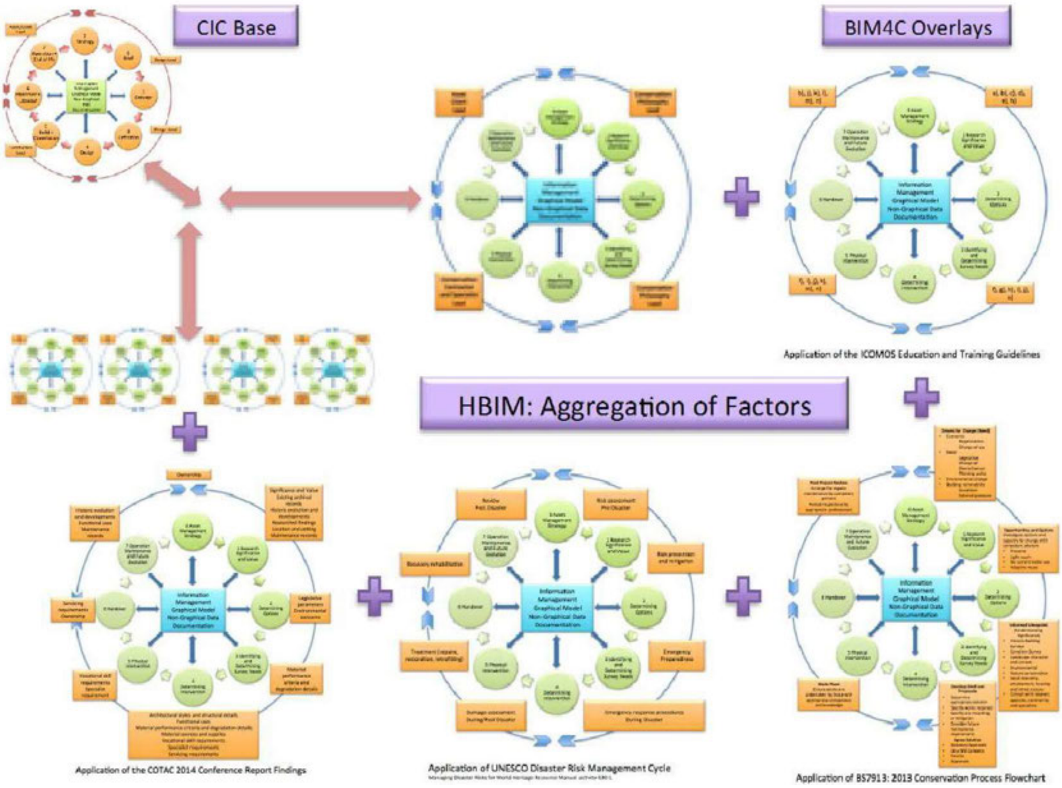


Figure 8.4 COTAC HBIM Framework Diagrams including conservation influences (Maxwell, p24, 2016a)

While the COTAC HBIM Framework Diagram is useful in considering the range of information that will be required at each stage in the conservation intervention cycle, and thus, the information to be collated and shared as part of an HBIM process, it does not address the need for knowledge and guidance in the identification of information requirements, implementing a BIM information management plan for historic assets or, how bespoke conservation data parameters may be used for BIM enabled heritage asset management. It does not specifically look at BIM principles, instead focusing on the project/conservation cycle information requirements. Further, the read across from a project process to an asset management process causes some confusion.

In Part 2 of the COTAC BIM4C Integrating HBIM Framework Report (Maxwell, 2016b), rather than trying to understand the differences between heritage and non-heritage contexts across the cyclical project or asset management process, and the different information requirements, emphasis is given to CRM and physical work programmes. The various steps that should be considered at different stages of the cycle are defined and mapped against the HBIM framework diagram to produce the HBIM Framework Evaluation Criteria (FEC).

The four key steps identified are as follows:

1	Definition
2	Data Collection, Diagnosis and Evaluation
2a	Conservation Intervention: Site specific
3	Intervention Strategy

Within each step a number of activities are identified.

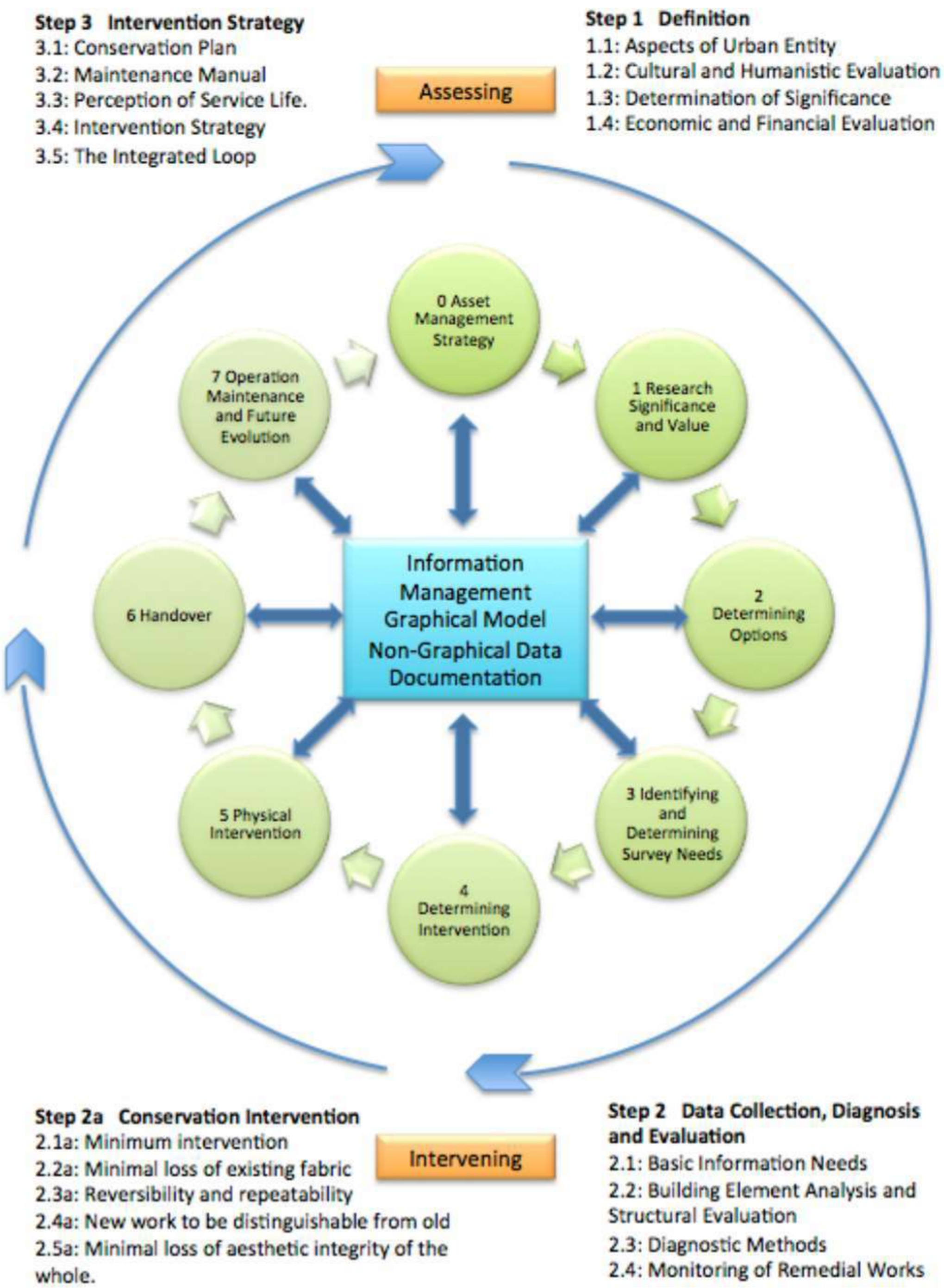


*Figure 8.5 COTAC HBIM Framework Evaluation Criteria Diagram (*Maxwell, p8, 2016b)

While the HBIM Framework Diagram specifically refers to asset management strategy, and looking back to chapters 5 and 6, steps 1.3, 2.1 and 2.2 closely align with those identified for CRM planning, the framework is aimed at the full conservation intervention process.

Despite the root of the HBIM Framework Diagram and the HBIM Framework Evaluation Criteria being the CIC BIM Cyclical diagram, it is difficult to understand the BIM relationship in these reports. Both diagrams consider various steps required for CRM across a project cycle, and thus the information that might be required when developing a BIM model. This is not made explicit in the research however and has been assumed based on the diagram which illustrates the information management graphical model at the centre of the cyclical process.

Similar research involved the development of 'BIMLegacy', the objective of which was to provide a protocol for managing heritage building interventions using BIM (Jordan-Palomar *et al.*, 2018). Similar to the HBIM Framework Diagram, the protocol focuses on an 8 phase HBIM process for the delivery of conservation projects or interventions that begins at the traditional 'CAPEX' entry point and was also developed on the basis of the CIC BIM Cyclical Diagram. Further similarities including the correct identification and sharing of information to ensure correct CRM methodologies and techniques are used and, to control changes during the project. The BIMLegacy protocol also seeks to improve the upfront accuracy of project costs. Objectives of the research were noted to include:

- study the stakeholders needs in heritage interventions and the real issues of HBIM application
- design a protocol for managing the interventions in historical buildings with HBIM
- evaluate and validate the designed protocol with interdisciplinary professionals in a workshop and in a focus group

(Jordan-palomar *et al.,* 2018)

Comparable to the HBIM Framework Evaluation Criteria, the BIMLegacy protocol has gone through a process of design and evaluation in order to produce the final BIMLegacy 3 protocol. Like the COTAC HBIM Framework Diagrams, there are several layers of data suggested in BIMLegacy. Layer A is a high level diagram identifying the key steps while Layer B provides the detailed activities within each step. Layer C was an area for future research and would include a modelling protocol. However, in contrast the research does acknowledge BIM information management concepts such as the need to define the purpose of adopting Heritage BIM (such as developing Organisational Information Requirements), the development of a precontract historical BIM execution plan (BEP) and, establishing a common data environment (CDE) at the outset in which to manage project documentation and improve stakeholder collaboration. Additionally, effort is given in identifying the variety of stakeholders involved in the process of heritage building intervention, linking traditional heritage management processes with BIM processes, and considering practical BIM implementation.

Emphasis is however generally based on the design and construction phases, with just some reference to maintenance in Phase 7. The various phases in the intervention process and the information requirements are intended to be built into a 3D 'BIM' model. While it was not explicitly stated in the COTAC HBIM Framework Evaluation Criteria case, it is believed that the intent was the same. It is suggested that the HBIM protocol in both of these cases is based around the creation of an 'as built' 3D model with particular conservation data added which can be used in the planning, decision making and delivery of heritage building interventions and so, are very similar.

Phase 7 of the BIMLegacy protocol acknowledges that maintenance information incorporated in the HBIM 'as built' model should be linked to organisation management systems, but it does not suggest what this information is, the format it should be in or, how it should be structured. The research does however identify that for the information to be useful to maintenance managers it must be simple.

A key benefit suggested by the research is the use of the innovative BIMLegacy online platform as a common data environment that offers users easy access to information, particularly in a field that is less skilled and knowledgeable with regards to BIM. It was however noted that over loading the model with information could be counterproductive. It is suggested in this research that the wide spectrum of historical documentation suggested across the building lifecycle and, to inform the wider historic building information process, could be too resource heavy for the resultant benefits. Centralising documentation to improve collaboration is clearly a huge benefit but, the complications of attaching this to 3D models and developing online platforms, along with the ongoing maintenance and upkeep of the information needs to be carefully considered to understand if the cost and resource outweighs the benefits. The paper describing the BIMLegacy solutions suggests that while this is an initially costly exercise, 'the standardisation of the work processes proposed in BIMlegacy supports the organisation of data and processes by heritage teams, which should provide economic benefits in the long term' (Jordan-palomar *et al.,* p14, 2018). This requires further demonstration.

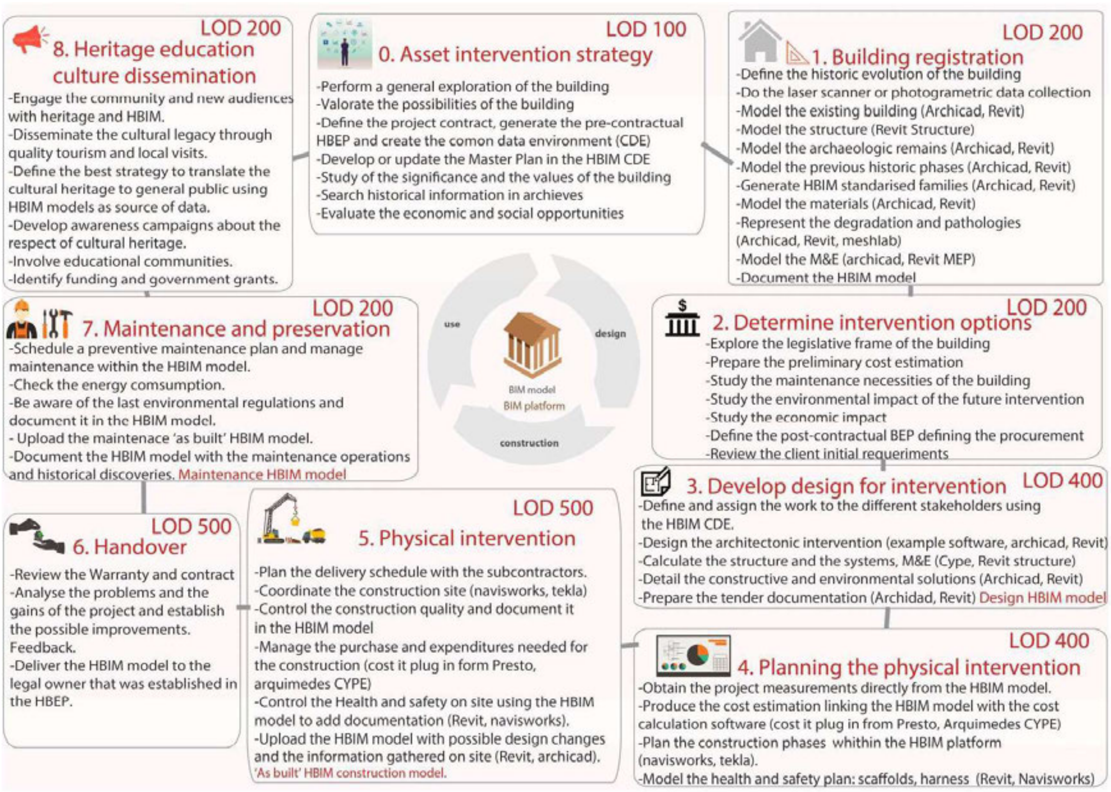


Figure 8.6 BIMLegacy Protocol (Jordan-Palomar *et al.,* p10, 2018)

While the protocols above consider the use of BIM models as a central source of information to support heritage building interventions, a case study using the Chapter House at Durham Cathedral (Tapponi *et al*., 2015) touches on parametric, component based BIM approaches which are identified as beneficial for facilities management (or, heritage asset management) processes.

The general theme of the case study is to illustrate how a central, data rich BIM model can be created and used in the planning and delivery of heritage building intervention, akin to the protocols described before, but further describes how BIM may be used to support the decision making of daily FM operation. Similar to the research data provided in Chapter 6, and the pilot study which identified an area for future research, the case study describes the addition of bespoke conservation parameters or data attributes to the model, such as element condition, significance and urgency of repair/maintenance. These can be used as a visual planning tool within the model and could be particularly useful for heritage asset management.

In addition to an HBIM model that provides wider historical documentation required across the whole conservation and heritage building intervention cycle, the research identifies a number of benefits of the HBIM approach that could benefit the heritage maintenance phase more specifically:

- Provide a single source of accurate information on the current state and condition of the building.
- Added bespoke parameters including the condition of elements interlinked with the BIModel with a set colour for each parameter value denoting the severity of the condition and the urgency of repair work could be used as a planning tool and as a visual aid tool for locating objects.
- Enables traditional outputs such as sections, floor plans and elevations as well the dimensions and volumes of ceilings and walls to be produced at no additional cost and within seconds.
- Enables the creation of maintenance schedules directly from the BIModel.
- Create detailed room data sheets with a log of past issues and actions.
- Provide accurate stone surveying: high resolution Point Cloud allows to take sections of the building and the survey of their condition thus, minimizing site disruptions and decreasing surveying costs.
- Enables scaffolding simulation for refurbishment planning.

(Tapponi *et al.*, 2015)

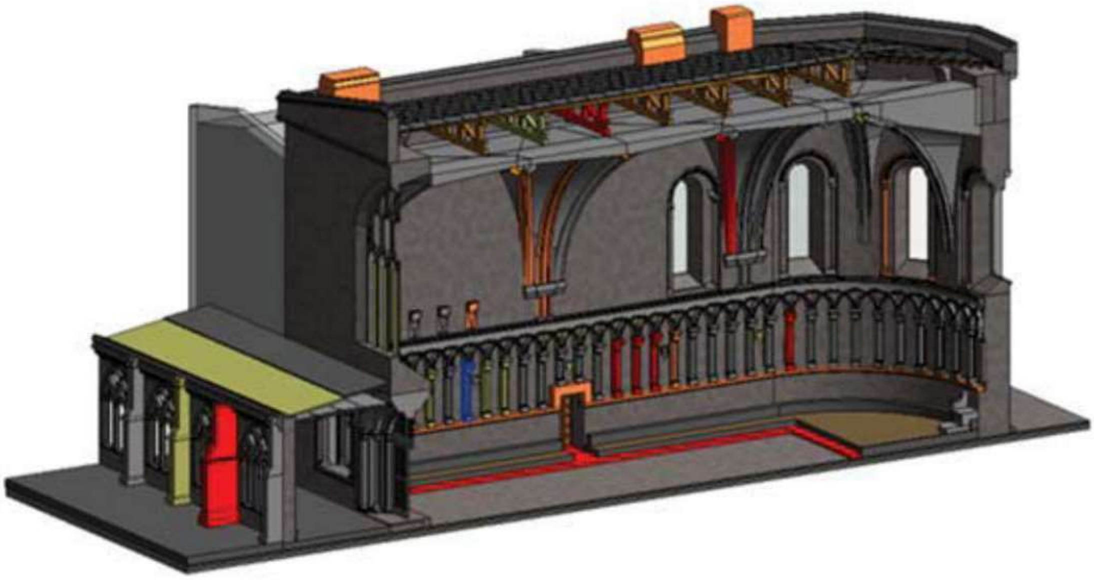


*Figure 8.7 Durham Cathedral BIM Model with colour coded conservation parameters (*Tapponi *et al.*, p712, 2015*)*

Whilst both the case study and this research have identified the use of bespoke parameters as a vital direction for BIM enabled heritage asset management, the case study provides no detail on establishing conservation parameters for building information modelling. This could however be expanded based on the standard set of conservation data parameters proposed in this thesis and the trial application (Chapter 6).

A point of note to take from the case study is that while an HBIM model can provide a new digital toolkit for understanding and managing built heritage more efficiently, a combination of adequate hardware, software and skillset is required to achieve the whole process from laser scanning to producing a BIM model, identifying data parameters, and analysing data for future CRM works (Tapponi *et al*., 2015). Lessons learnt in Chapter 7, and as noted above, highlight that the people, process and technology aspects must be carefully considered when proposing an HBIM protocol for the sector.

Follow up research by Charlton *et al.* (2021) on the Durham Cathedral case study offered initial excitement. Missing from the first case study, the abstract noted a need to identify specific conservation, or heritage, information requirements (HIR) as proposed in guidance published as a result of this research (Hull & Bryan, 2019). Further, in line with industry guidance (Hull & Bryan, 2019), the research suggested a need to develop an asset information model (AIM) for use in the O&M phase and delivery of CRM works. However, despite these progressive proclamations, the focus remained on 3D parametric modelling. The case study referred to 3D data acquisition, challenges in modelling historic architecture and the required level of detail, and a need to embed historical building information and documentation into the model.

The development of an AIM is the ultimate goal when applying BIM for the O&M phase, such as FM or asset and maintenance management. The protocols and case studies described thus far echo a statement made in Chapter 2, which suggested the focus of much BIM research in the O&M field is on the 3D modelling aspects of BIM. As can be seen above, each of the proposals refer to a central HBIM model. However, for the O&M phase it can be argued that the AIM is much more critical. Within a common data environment, the AIM provides a digital data model of structured information required for facilities and asset management activities. Creating an AIM supports efficient navigation through documents and individual structured data sets, even in the simplest format such as spreadsheets that are structured using defined conservation data parameters, can be queried to improve asset and facilities management activities. The asset data capture spreadsheet as developed by UKAHT could be considered one of these structured data sets that sits within the AIM. In the case of English Heritage, a similar structured data set sits within the K2 asset management database, which in itself could be considered an AIM. The AIM may be developed alongside a 3D model but, the 3D model is certainly not a requirement.

Therefore, despite initial promise, it appears that the definition of the AIM within the Durham Cathedral case study is confused.

With the challenges identified in the research proving to be significant barriers to adoption and implementation of BIM for heritage management, research for HBIM protocols must be clear on the requirements and benefits of the 3D model, and offer clear guidance on the use of BIM information management processes *without* the use of 3D data capture and parametric modelling. Taking an HBIM approach for the O&M phase that explicitly removes the 3D model, or leaves the addition of 3D models as an 'option' within the process, instead focusing on BIM information management concepts, will remove the persistent barriers:

Level of detail/accuracy – continues to be a significant challenge when modelling historic architectural features.

Access to information – structuring data and embedding it within the model is challenging. Moreover, historic building information is inherently unstructured and so the industry must provide clear guidance on information requirements in order to complete retrospective compilation (Chapter 6).

Technical skills - software and skills shortages continue to be a challenge to heritage professionals who are expected to access information from a parametric model or to manage and maintain data within the model.

Key BIM concepts, such as establishing organisational information requirements (OIR) and asset information requirements (AIR) to support a BIM information management process and the development of an AIM (Chapter 2, section 2.5), and exchange information requirements (EIR) where required are noted in the second Durham Cathedral case study but there is no attempt to define what these information requirements are. The paper concludes that 'further research is required to understand the need, potential and structure of [specific] heritage information requirements (HIR), and to deliver a template that heritage organisations can implement as part of a coherent and relevant HBIM approach'.

This has been developed as part of this PhD and an initial introduction to HIR, along with template documents to support heritage organisations with identification of HIR and the development of an AIM were published by Historic England in 2019 (Hull & Bryan, 2019). These, along with lessons learnt from this review of proposed HBIM workflows, will be incorporated in the proposed Heritage Information Management (H-IM) workflow in section 8. 6.

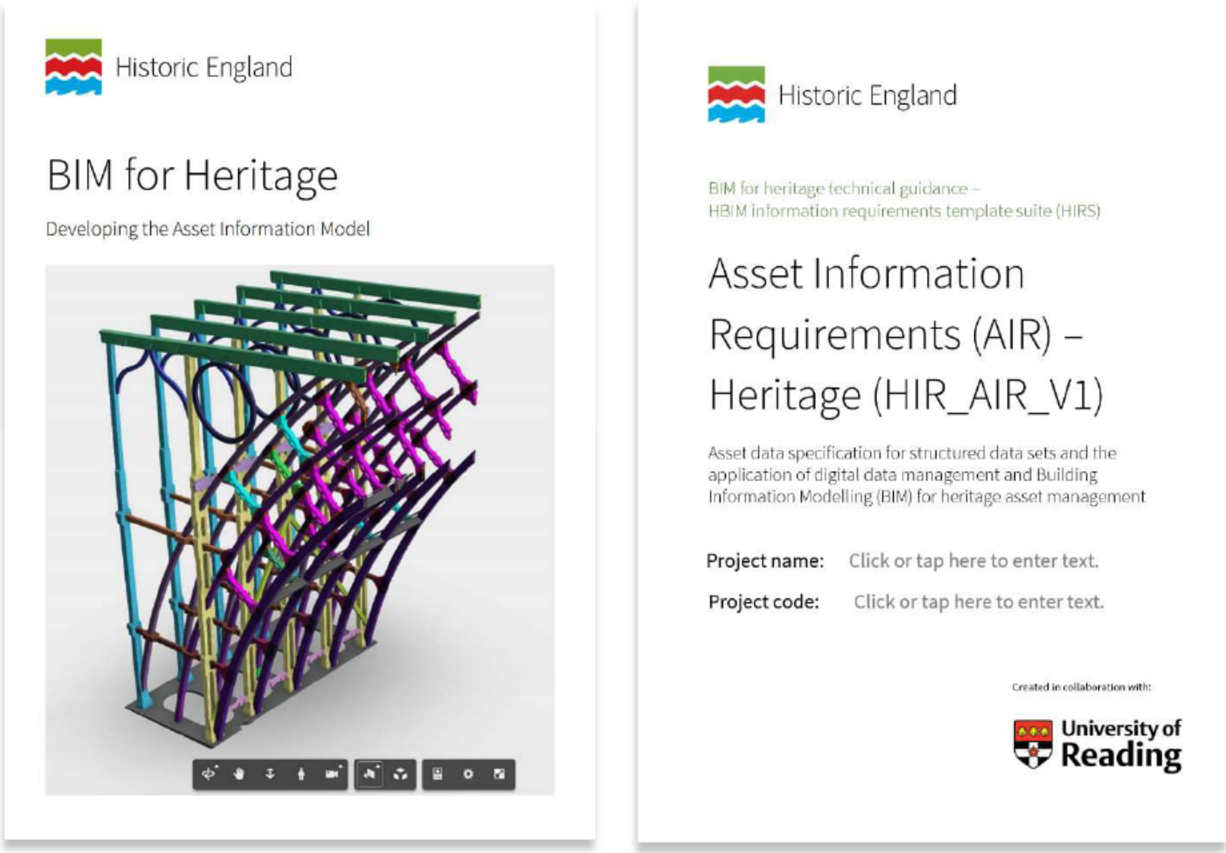


Figure 8.8 BIM for Heritage Publications – (Source: Historic England (Hull and Bryan, 2019)*)*

8.4 Common factors between existing asset management and BIM systems

As noted above, new technological innovations such as BIM are a socio-technical network that cannot be considered from a single social or technical perspective. Further, existing and entrenched ways of working (Harty, 2005) act as a barrier to implementation of new innovation in the construction industry and, the same can be said in a heritage conservation context.

Ethnographic research methods were employed to study the UK Antarctic Heritage Trust' s attempts at developing their information management process for the UKAHT Heritage Management Programme. Observation of people, process and other non-human actors has identified that even when formalised processes are implemented, they will not always be followed as expected. Process and system design therefore needs to take these factors into consideration. As the existing research suggests, and as observed, individuals are more comfortable with existing ways of working and so, commonality with existing process may improve the potential success of any new ones. In Chapter 5 three organisations were studied to compare asset management processes in heritage and non-heritage contexts. While different contexts, each organisation is responsible for the asset management of existing buildings, both historic and more modern, using standard FM practices. An element of these studies was to consider how each organisation managed their building information. Here, this data can be further analysed, considering common functions of the technology, information management processes, and roles and responsibilities to consider similarities and differences between them. When considering the potential of BIM to support conservation professionals in the heritage asset management process we can look to the existing systems and process to look for common factors, and to see how these compare to BIM processes.

Data gathered through the mixed methods approach has been reviewed and analysed to identify the various system functions used by the three key organisations. These are illustrated in Table 8.3 alongside BIM system functions. All BIM system functions have been listed to set the benchmark against which the existing asset management system functions could be compared. There are two additional system functions that were identified in the UKAHT processes and so are added to the list in the table above. These are:

- 3D CAD model
- 3D data capture (Point Cloud)

The 3D CAD model has been noted as there is a significant difference between 3D CAD and parametric modelling. 3D data capture has also been noted as while this might be a tool used when adopting a BIM methodology, in its own right does not form part of the information management process. It is however considered a digital record which might be considered a critical information requirement for some organisations.

Table 8.3 Comparison of asset management and BIM system functions

System Function	UKAHT	English Heritage	Org. A	BIM
Central data hub / Common data environment	X	X	X	X
Component based data management	X	X		X
Base set of measured drawings	X		X	X
3D CAD model	X			
3D Parametric model				X
Digital documentation - 3D data capture/point cloud	X			
Visualisation (CRM planning)				X
Integration / Interoperability				X
Naming standards / conventions	X	X		X
Information management processes *				X
Roles and Responsibilities for Information Management **		X		X
Information Management Processes *	**UKAHT**	**English Heritage**	**Org. A**	**BIM**
Asset management strategy / policy		X		X
Information management strategy				X
Defined information requirements				X
Defined naming conventions	X	X		X
Formalised information management process				X
Roles and Responsibilities for Information Management **	**UKAHT**	**English Heritage**	**Org. A**	**BIM**
Document or Information Manager				X
Information Management Team		X	X	
Lines of communication established				X
Information management responsibilities identified in job spec				X

Despite suggestions in the literature that heritage maintenance management processes are lagging behind the wider construction sector (Dann & Wood, 2004; Forsyth, 2007), it is interesting to note that the two heritage organisations have more system functions aligned to a BIM methodology than Organisation A, the non-heritage organisation. However, English Heritage is the UK's leading heritage organisation and, UKAHT have made specific efforts at introducing an information management process to support their Heritage Management Programme and so, in that sense, might not be considered typical.

The creation of a central environment for storing building information is common in each of the organisations. As described in the previous section, the common data environment is referred to as the asset information model (AIM) and will include a variety of structured data sets. These may include spreadsheets or databases of structured data (such as component based data), geometric data (such as 3D parametric models) and documentation. In each example attempts to structure data have been made, giving some thought to the relevant pieces of data that are useful for CRM planning rather than overloading the system with every piece of information available, however it was noted in all cases that some unnecessary information is stored and, the analogue nature of the data is inefficient for analysis and planning. Legacy data from various locations has been added to the systems in all cases, being digitised where this had only existed in paper form. This process of 'retrospective compilation' was found to be one of the biggest issues affecting organisations responsible for the management of an existing estate, whether a heritage or non-heritage context. While the 3D parametric model is one function of a BIM system, it does not appear in any of the other systems.

In the case of English Heritage, naming conventions are used but this is not a consistent approach and rather than an intentional strategy, often a consequence of using an asset management database. In both UKAHT and Organisation A attempts at implementing naming conventions had been made but were not well embedded in formal processes. UKAHT had however specifically defined the naming convention, so it is included as part of their system. The use of the naming conventions had been trialled but in general was not overly successful. Heritage data management undertaken by English Heritage was in part, informed by their Asset Management Plan. The use of the K2 asset management database had been defined as part of the asset management strategy and certain information management processes were developed in response to the use of the K2 software. These included the K2 Basic User Guide and Naming Standards. UKAHT had developed a data capture programme as part of their overarching heritage management programme but there were no formalised processes for this. Similarly, Organisation A do not have an overarching plan to inform the way they manage data for asset management.

Finally, with regards to roles and responsibilities, organisational structures can be further reviewed. English Heritage's Survey and Data team represents an information management team. Similarly, Organisation A's Technical Library and Document Control staff represents a level of information management. However, in both cases, with no formalised information management processes, these are failing. UKAHT are a much smaller organisation that does not have specific information manager roles within the department.

Where much focus to date has been on parametric modelling for Heritage BIM application, this research has shown that the BIM concepts that should be given greater attention to see increased adoption are information management, and roles and responsibilities. It is also important to remind the reader of the BIM lens adopted for this research. Where existing workflows and protocols have been aimed at heritage building interventions more widely, including the design and delivery of such interventions, the focus of this research is to consider the adoption of BIM in the O&M phase and for CRM planning more specifically. This BIM lens mirrors the case studies that were studied above. From the data analysed in the previous sections of this chapter, and the table above, the list of criteria illustrated in Table 8.4 is established as key in the development of BIM protocols for heritage asset management and CRM planning.

Table 8.4 Key requirements for HBIM workflows that support CRM planning

Key requirements for HBIM workflows that support CRM planning
Asset management strategy
Information management strategy
Asset information model / Common data environment
Component based data management
Heritage Information Requirements for CRM planning
Conservation data parameters
Naming conventions
Formal information management process
Information management roles and responsibilities

8.5 Developing the Heritage Information Management (H-IM) Workflow

It has been demonstrated that there is a lack of heritage specific guidance, and no standardised approach for the adoption of BIM specifically for information management across a building lifecycle, and particularly specific phases such as O&M.

The Heritage Information Management (H-IM) workflow has been developed to provide the guidance required to see increased adoption and implementation of BIM to support conservation professionals with the process of heritage asset management – specifically the planning of CRM programmes. The proposal is offered as a solution to issues with data fragmentation and lack of structured process demonstrated through the research case studies and is intended to offer a significant contribution to the field.

The H-IM workflow offers a process based on existing industry practice and aligned with BIM principles to offer a formal, digital process to which heritage organisations can conform. While existing workflows described in section 8.3 are based on the CIC BIM Cyclical Diagram for information management across the building lifecycle, the H-IM workflow has been developed based on the principles of the BIM information delivery cycle (BS EN ISO 19650-1:2018).

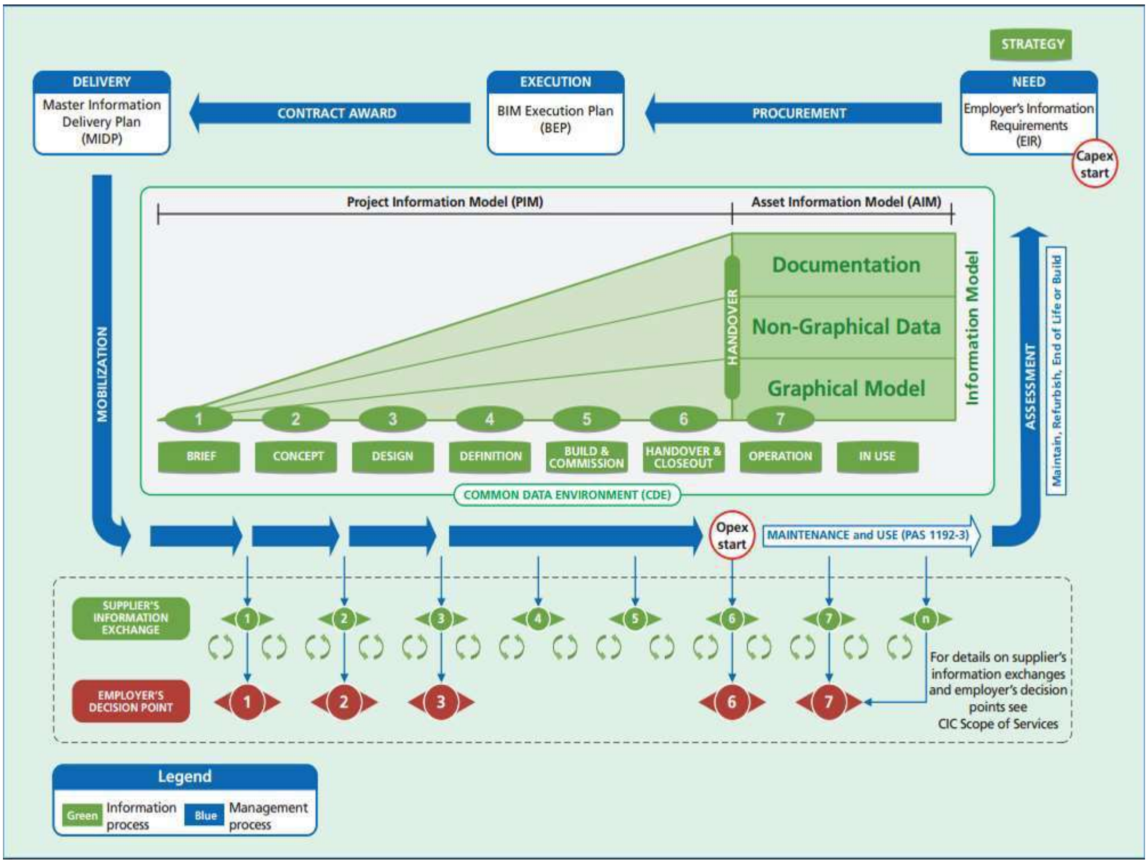


Figure 8.9 BIM Information Delivery Cycle (BS EN ISO 19650-1:2018)

BIM information management processes for heritage asset management take place in the maintenance and use phase of the building lifecycle, commencing at the ‘Opex start’. It is therefore the right hand side of the BIM information delivery cycle that has the most relevance to heritage asset management, illustrated by the grey overlay to the ISO diagram depicted in Figure 8.10. This part of the information delivery cycle has been developed to create the H-IM Workflow.

Using the BIM information delivery cycle as a basis for the development of the H-IM Workflow offers a clear read across from a conventional BIM information management process. This has not existed in other HBIM workflows researched and therefore offers an original and significant contribution to the research field.

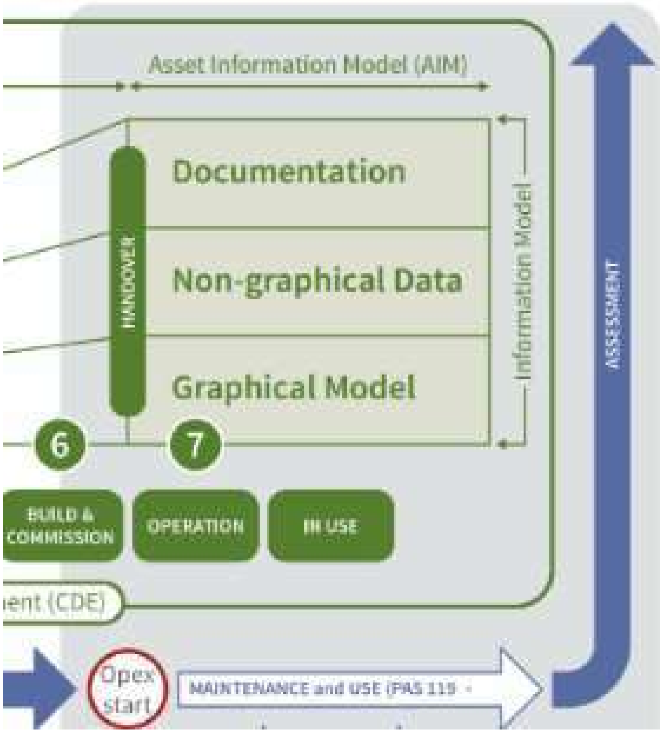


Figure 8.10 BIM information delivery cycle in a heritage context (Historic England, 2019)

The H-IM Workflow illustrated below illustrates the development of a heritage asset information model (H-AIM) within a common data environment. The information model is similar to a standard asset information model, comprising documentation, graphical, and non-graphical data. It is noted that the H-AIM should include component based data and the use of conservation data parameters. It is further noted that geometric data may be 2D *or* 3D.

Rather than the H-AIM being developed at project handover, it is illustrated that instead the information model is initially developed as a result of ‘retrospective compilation’ of legacy data.

The H-IM workflow introduces 4 new steps into the BIM information delivery cycle that replace step 7. Numbers re-commence at number 1 as they are considered separate to the full BIM information delivery cycle and will generally be considered in isolation to the wider cycle.

The 4 steps of the H-IM workflow are required to inform and manage the ‘retrospective compilation’ of legacy data to develop the H-AIM, and to define the ongoing heritage information management process (H-IMP) in order to maintain the H-AIM. Data from the H-AIM can be used for improved CRM planning (as an equivalent to *assessment for maintenance, refurbishment, end of life, or build* in a traditional BIM information delivery cycle).

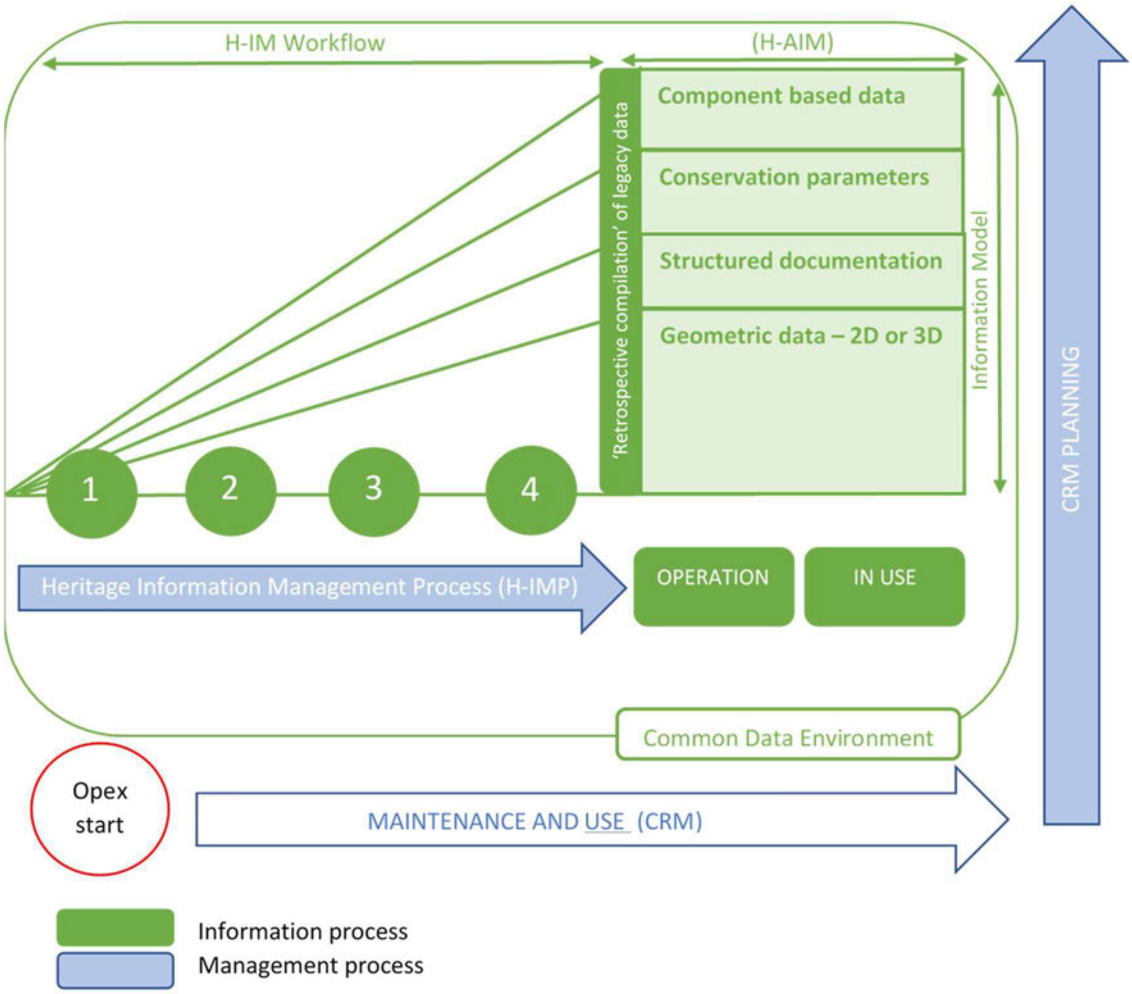


Figure 8.11 The Heritage Information Management (H-IM) Workflow developed by the Author

8.6 The Heritage Information Management (H-IM) Workflow

The Heritage Information Management (H-IM) workflow starts in the maintenance and use phase and can be adopted at any time. It consists of 4 steps, all of which include retrospective compilation of legacy data, and contribute to the development and management of the H-AIM. Defined HIR, structured data sets and the use of conservation data parameters within the H-AIM are proposed to support conservation professionals, offering improvements and efficiencies in heritage asset management, and CRM planning more specifically.

Each step is described in the following sections, and where appropriate, additional guidance to support certain steps is provided. Template documents are included within the guidance to provide the required tools to see improved BIM adoption in the heritage sector, as called for by COTAC (Maxwell, 2016a).

1 Step 1 – Develop the heritage information management strategy

2 Step 2 – Define heritage information requirements (HIR)

3 Step 3 – Define the heritage information management process (H-IMP)

4 Step 4 – Implementation and Management of the H-AIM

8.6.1 Step 1 – Develop the heritage information management strategy

BIM concepts are, at their core, about frameworks and processes for the collaborative production, management and delivery of information in relation to a building's lifecycle. One of the key tasks when adopting a BIM approach for the management of information about an asset or estate (whether new or existing) is to establish the overarching strategy to support implementation. The strategy should be a high level organisational document that states the key steps in the H-IM workflow and how the organisation plans to meet them. Organisations can use any format to document the information management strategy although it is acknowledged here that a standard template for the industry would encourage adoption and aide standardisation.

The information management strategy should include the following information:

- The format of the H-AIM (heritage asset information model)
- How heritage information requirements (HIR) for the H-AIM will be established
- The structured data sets and documentation that are to be included in the H-AIM
- Reference to the heritage information management process (H-IMP)

8.6.2 Step 2a – Define heritage information requirements (HIR) – Organisational information requirements

Understanding information requirements is key to a BIM process and in case studies that have sought to develop an AIM to be used by heritage managers in the planning of CRM it is noted that heritage specific information requirements must be established if BIM adoption is to be successful (Charlton *et al.*, 2021). While it has been acknowledged that HIR should be established, literature has shown that identifying and defining IR is a common challenge e.g. (Ahn & Cha, 2014).

Defining HIR is considered critical to the H-IM workflow and so guidance is provided to accompany this step. This guidance has been published as part of this research by Historic England (Hull & Bryan, 2019).

Organisational Information Requirements - Guidance

An organisation should begin by developing an overarching organisational information requirements (OIR) document that defines the information required to meet the needs of the asset management system and other organisational functions. The OIR is a high level, organisation wide, document that helps the organisation and project team focus on the overall information requirements rather than the finer details of how this information is to be managed, such as data format, function and responsibilities and delivery programmes. This level of detail is defined in the AIR and EIR. Where organisations have an asset management strategy/policy and asset management plan in place, these should be used to help inform the development of the OIR. Each organisation may have different information requirements, so it is important to begin this process early and communicate with all the departments or stakeholders who have a responsibility for strategic decision making concerning the asset or estate. BIM processes promote collaborative working practices and the development of an OIR provides an opportunity to collaborate and is intended to integrate information requirements at an organisation wide level (Maxwell, 2017; BIM Level 2 Guidance from Scottish Futures Trust n.d.).

The people involved in establishing the OIR will vary according to individual projects and organisations. In order to establish who should be involved, it is important to understand what the asset management activities are and who is involved in the decision making processes. Early discussions should take place to bring a project team together. While high level discussions might take place between directors and departmental leads, it is also important to undertake detailed discussions with all information users. The range of stakeholders, while broad across the AEC sector in general, comprise a different network of individuals in the heritage context yet, it is the local level stakeholders that are directly involved in the heritage asset management process (Chapagain, 2008) that should be involved in identifying the information needs.

It can be difficult to think of all the data and information that are used day to day to perform tasks and complete activities, therefore it is important to work closely with information users to gain a full understanding of the requirements. UKAHT had made attempts to work closely with information users, particularly the conservation teams, to establish information requirements but this was not formalised in a written strategy and there were further issues with how this was structured and managed. It is noted that while English Heritage had created an information structure within their asset management database, nobody could explain how the information categories and requirements had been established. Furthermore, it was identified that while English Heritage had developed a central repository of information, information contained within it was not always useful, was duplicated or, on the other hand, critical information was missing or could not be found due to the structure or lack of data management. This was an issue highlighted in the literature review where it was suggested that too much information, or information not critical to the task can make it difficult to manage (Cavka *et al.*, 2017).

In the case of heritage organisations the following people may all contribute to the development of OIR:

- directors
- heads of departments
- property steering groups/project boards
- project lead/senior responsible officer (SRO)
- project and facilities managers
- estate, historic building surveyors and geospatial surveyors
- conservation architects
- architectural technologists
- property curators
- survey coordinators
- data managers/asset data managers
- site/building managers and users
- consultants
- user panels
- champions
- ‘friends of’ groups

While PAS 1192-3:2014 (BSI 2014) provides guidance in the development of OIR, it does not define the content of an OIR. Typical content headings that might be found within an OIR are provided in PAS 1192-3:2014 Annex A.2, but these are aimed at new build assets and do not take heritage specific information requirements into consideration. Asset information may be used within an organisation by a range of different departments.

This research has helped to identify the questions that should be asked to consider some of the activities undertaken and the information required.

Before I can carry out conservation intervention, what information will I need?

What is the historical significance of this space, or this building fabric, and how does this affect what I do?

To put together consent applications for conservation intervention, what information will I need?

What information do I need to understand and manage planned and preventative maintenance tasks?

What equipment and plant do we have, and what information do we need to maintain it?

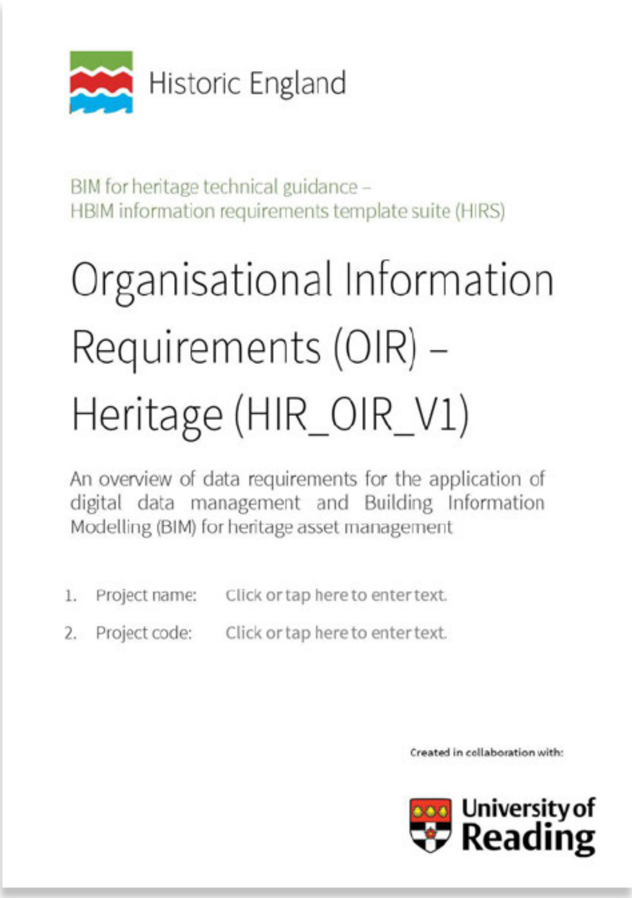
What are the presentation requirements of this space?

The study of 3 organisations, both heritage and non-heritage, has helped to understand existing asset management processes and the information that might be required. Estates departments at a strategic management level will require information regarding the condition of the assets, anticipated future needs and the value of defect liabilities, to enable budget planning and programming of CRM activities. In addition, information regarding significance, heritage values and risk to significance is required to facilitate the prioritisation of CRM activities. Conservation maintenance and facilities management teams will also require information regarding the condition of assets, but this information might be more specific to particular defects, historic building material specifications, historic building components or equipment, and life expectancy, inspection and certification details. Curatorial or interpretation teams might require information relating to space planning with regard to space categories and use, space size and access routes. Health and safety teams will require information regarding the inspection of historic sites and related risks and mitigation measures, in order to meet statutory and regulatory obligations. This is not a complete list, and there might be many more information requirements within an organisation, but these suggestions will help organisations think about the range of activities that take place, and therefore the range of information that is required.

However, it is always worth considering the following:

- Why am I collecting this information, what use is it and is it required?
- What else can this information be used for, who else will it assist?

As an output of the research, and in support of Step 2a of the H-IM workflow, a list of suggested content headings to meet heritage information requirements is provided in the OIR template document HIR_OIR_V1 (Historic England, 2019a). This document should be used to develop specific OIR for individual organisations.



Historic England

BIM for heritage technical guidance –
HBIM information requirements template suite (HIRS)

Organisational Information Requirements (OIR) – Heritage (HIR_OIR_V1)

An overview of data requirements for the application of digital data management and Building Information Modelling (BIM) for heritage asset management

1. Project name: Click or tap here to enter text.
2. Project code: Click or tap here to enter text.

Created in collaboration with:

University of Reading

Figure 8.12 Organisations Information Requirements - Heritage (HIR template) (https://historicengland.org.uk/images-books/publications/bim-for-heritage-aim/)

8.6.3 Step 2b – Define heritage information requirements (HIR) – Asset information requirements

Asset Information Requirements - Guidance

The development of a detailed AIR document is the second stage to Step 2 (2b) in the H-IM workflow, and therefore in the successful implementation of BIM in a heritage context to support heritage asset management. AIR define the data and information that are required in an AIM to support specific asset management activities. They should be informed by the defined OIR. Development of AIR is a considerable task that requires time and effort to complete (BIM Level 2 Guidance from Scottish Futures Trust n.d.). Taking sufficient time to develop robust AIR will significantly improve the process of developing an AIM for a historic asset, and initially will require significant review of legacy data. This is the key area that distinguishes a H-IM workflow from a traditional BIM information cycle. As described above, due to the nature of heritage buildings being 'existing', conservation professionals are dealing with legacy data (Gu *et al.,* 2014) rather than new information that has been produced during the design and construction phase. The process of 'retrospective compilation' of the legacy data is identified throughout this research as one of the biggest challenges and thus adoption of the H-IM workflow, and a specified set of AIR has been considered a solution to support this challenge. Defining critical information requirements for O&M or CRM planning could significantly improve retrospective compilation and data management processes and so, Chapter 6 focused on 2 layers of data collection designed to identify critical information requirements for CRM planning, and to develop a framework of standardised conservation data parameters (conservation AIR) that could be used as a baseline in the H-IM workflow. These are noted in Table 8.5.

Table 8.5 Final set of conservation data parameters for CRM planning

Final set of conservation data parameters for CRM planning	
1	Monument Number / Unique Identifying Number
2	Building / Asset Elements or Components
3	Statement of Significance
4	Condition Rating
5	Minimum standard of repair / presentation
6	Defect
7	Risk
8	Priority
9	Material

Further asset information requirements have been prepared to provide guidance for individuals or organisations that are developing their own AIR for heritage assets. Parameters (IR) may be set at site, facility, room or element level depending on the organisation's requirements. Those identified as critical to CRM planning are element level conservation data parameters, but further parameters that support the organisation's wider activities should be considered. Suggestions are included in the asset information requirements template that has been produced as an output of this research in support of Step 2b of the H-IM workflow, but the research was limited to identifying those critical for CRM planning specifically. HIR_AIR_V1 (Historic England, 2019a) should be used to develop specific AIR for individual organisations. The AIR document will set out the asset information requirements in the form of data, documents and geometry required in the development

of an asset information model (AIM) to enable facility and asset management teams to operate and maintain specific assets effectively.


Historic England

BIM for heritage technical guidance –
HBIM information requirements template suite (HIRS)

Asset Information Requirements (AIR) – Heritage (HIR_AIR_V1)

Asset data specification for structured data sets and the application of digital data management and Building Information Modelling (BIM) for heritage asset management

Project name: Click or tap here to enter text.

Project code: Click or tap here to enter text.

Created in collaboration with:

University of Reading

Figure 8.13 Asset Information Requirement - Heritage (HIR Template) (https://historicengland.org.uk/images-books/publications/bim-for-heritage-aim/)

Element Parameters
Unique Identifier (UID)
Historic / Common Name (historic/architectural features)
Year of Construction / Historical Construction Phase
Installation Date
Life Expectancy
Original / Historic Fabric (Y/N)
Level of Significance (value)
Material - high level (Stone, Timber etc)
Material specification (link to stone matching report/petrographic analysis etc)
Colour
Finish / Mix / Ratio (link to mortar analysis etc)
Material Source / Supplier
Sustainable Material (Y/N) / Sustainability Note
Asbestos (Y/N)
Condition - Good, Fair, Poor etc
Priority - Urgent, within 12mths, within 24mths etc
Defect Description
Current Defect (Y/N)
Repair / Task
Reversible Repair (Y/N)
Cost / Defect Liability
PPM Task / Cyclical Maintenance Task (planned and preventative maintenance)
Ecology Issues (Y/N) - Bats, Bees, Birds, Newts etc
Environmental Monitoring (Y/N) - (link to doc/reading)
Existing Drawings (Y/N) - (link to drawings)
Archaeological record (Y/N) - (link to document)
Other Specialist Reports (Y/N) - (link to document)

Facility Parameters
Asset Number / Unique Identifier
Occupier
Owner
Responsible Authority/Trust/Manager etc
Building / Monument Name
Building / Monument Address
Conservation Designation (Grading)
Scheduled Monument Number / List Entry Number (link to listing description)
National Grid Reference
Conservation Area (Yes/No)
Property Type (Heritage Estate - Roofed, Un-roofed, Ruin etc)
Current Status / Use
Original building date
Statement of Significance / Heritage Assessment (link to document)
Conservation Management Plan (link to document)
Existing Drawings (link to documents)
Existing Condition Survey (link to document)
Asbestos (Y/N) - (link to asbestos register/management plan)
Structural Integrity (Y/N) - (link to structural survey)
Project Files (archived - link to document)
O&M Manual (link to document)
Ecology Issues (Y/N) - (link to ecology survey)
Photograph - current / historic (link to documents)
Archive Records - (link to list of archive references)
Insurance (Y/N) (Link to document)

Figure 8.14 AIR – Example parameters to support heritage asset management (https://historicengland.org.uk/images-books/publications/bim-for-heritage-aim/)

8.6.4 Step 3 – Define the heritage information management process (H-IMP)

An information management process (IMP) that defines the way in which data and information are collated, managed and transferred to and from the H-AIM should be developed. Chapter 5 summarised that despite heritage organisations trying their best to manage historic building information for CRM, evidence demonstrates that organisations in both a heritage and non-heritage struggle to manage this information due to the inherent fragmentation e.g. (Gardner & Whitehead, 2003; Pärn et al. 2017). It was suggested that often the strategy behind information management processes, along with the process itself, appeared to be based on knowledge and experience and were not formally documented. Furthermore, it was demonstrated through the UKAHT case study that when formal processes are implemented, they are not always followed and that collecting, structuring and managing data in a heritage context might be affected by a wide range of unknowns. It was identified that implementation of the designed data management process identified a range of socio-technical challenges and surprises, including difference in working practice, the analogue nature of conservation craftspeople and building surveying practice, and the impact of external factors on technology that cannot always be predicted. Acknowledgement of this has been drawn into this developed H-IM workflow where a formal process with defined roles and responsibilities is proposed as a solution to mitigate these challenges.

As CRM works are carried out, new information will need to be added to the AIM, and out of date information will need to be archived. Surveys and information on the condition of a building should be updated and new findings of cultural significance should be added. The processes for managing these tasks should be defined in the H-IMP and should be developed by considering the following items.

- Data collection, format and structure
- *How will information be collated?*
- *What format should the data be in?*
- *How will you classify and structure your data?*

- Functions and responsibilities for information management
- *Who will manage the information?*
- *Has an information manager been appointed?*

- Process, procedures and activities for information management
- *What is the validation/sign off process?*
- *How will version control be managed?*
- *How frequently should information be updated?*
- *What is the process for monitoring and improving the data to ensure it constantly meets organisational requirements?*
- *What are the processes for retrieval, distribution and availability of data?*

- Risks to information management
- *What are the quality control procedures?*
- *How will data be checked for accuracy and validated against the AIR requirements?*
- *How will unwanted or incorrect data be archived?*
- *What access rights and security procedures are in place, is data confidential, do external stakeholders need access to information, and are restricted access rights required?*
- *What back up strategy and disaster recovery procedures are in place?*

8.6.5 Step 4 – Implementation and Management of the H-AIM

The goal of the H-IM Workflow is the development, implementation and management of a H-AIM to support heritage asset management through digitisation.

There is some confusion surrounding the asset information model, not least in the heritage sector. Asset information models are often thought of as the same thing as a 3D parametric model (Charlton et al. 2021), introducing barriers to implementation, particularly in the heritage sector where the skills and resource to accommodate such processes are lacking.

Simply put, the AIM could be defined using the following statements;

- a set of structured and unstructured information containers
- a digital data 'model' or 'repository' of building information
- a digital version of traditional (paper based) building and project files and archives

It could be thought of as a document management system or file storage system that contains validated data and information relating to an asset or portfolio of assets. It should be collated from a range of sources to include information about the history of the building, building components and materials, and the information required to support decision making and asset management activities. It will comprise geometrical (3D models and/or 2D drawings, photographs) and non-geometrical components (structured building data, databases) and documentation (conservation management plans, historic building reports, operation and maintenance manuals, surveys, contracts), and will be managed within a common data environment (CDE), i.e. a digital workspace.

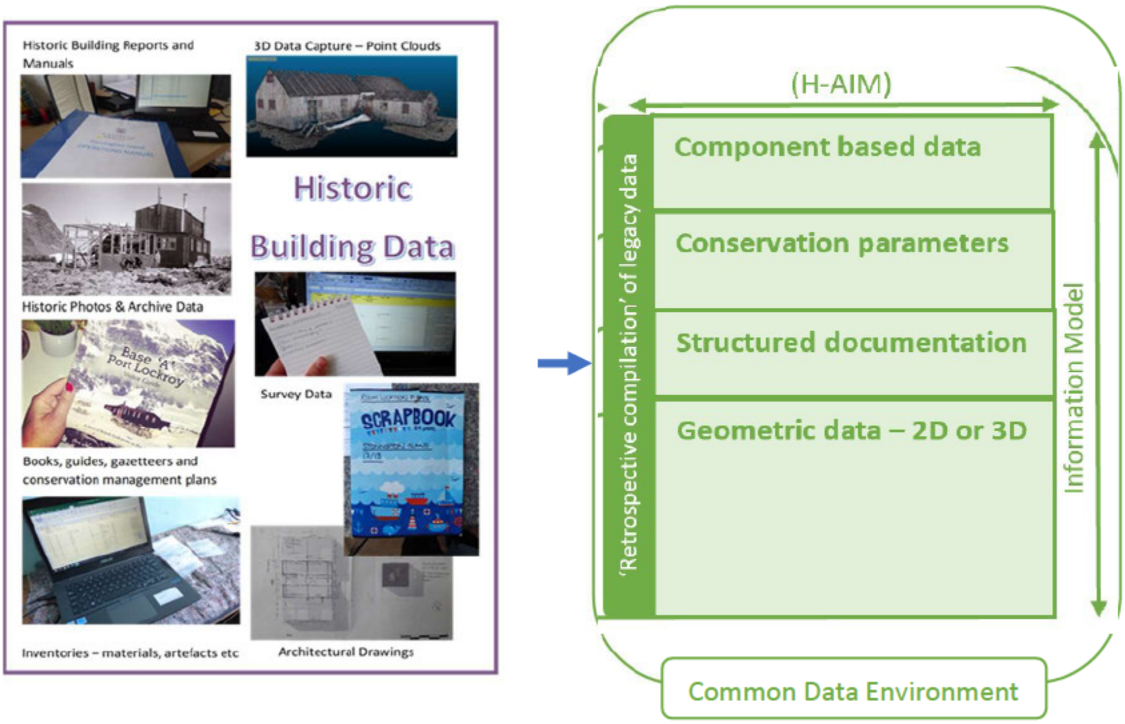


Figure 8.15 Illustrating the Heritage Asset Information Model developed by the Author

The CDE may take any form as decided by an organisation or project team, but it is generally a type of file based retrieval system or electronic document management system. There are specific BIM CDE software systems available, but in its simplest format the CDE may be a project server or SharePoint. Establishing the CDE should be a main priority. English Heritage have developed a central repository that could be considered an AIM, using bespoke asset management software, K2. On the other hand, both UKAHT and Organisation A were developing a repository using SharePoint.

While 'retrospective compilation' of legacy data has been noted as key to the initial development of the H-AIM, this may alternatively be achieved by any of the following activities, all of which are relevant to heritage asset management.

- Transfer of information and data from existing organisational systems, such as existing property management systems, data management systems (sharepoints or network drives), archive systems, etc.
- Recognising or relabelling an existing data and information store as part of the AIM, such as an existing asset management database, GIS or similar.
- Collection of new or updated information and data from surveys of the physical asset, including digital survey data and structured survey data.

The information required in an AIM is unique to each organisation. Furthermore, the range of data and information required for the management of heritage assets is complex, requiring thought and attention. Establishing an AIM for a historic building is potentially a large, resource heavy undertaking but, should be considered where there is a suitable business case. In the case of large heritage organisations that are responsible for the conservation of historic estates, such a business case will exist.

An AIM may be developed progressively over the life of a building or built estate, and enhanced as a phase of prioritised and programmed activities in line with the OIR. When first developed it may be at quite a simple level, using only 2D geometrical components and some structured data in spreadsheets and simple databases. Over time an organisation may choose to make developments to the AIM, adding 3D models and transferring model data into structured databases or CAFM systems, for example. Phased development of an AIM might be a particularly useful approach for heritage organisations.

All three of the organisations studied had made attempts, consciously or unconsciously, to develop an asset information model. However, comparisons of existing data management processes and systems discussed in section 8.4 identify that all organisations were missing a written strategy for information management which resulted in issues with management of data and effective implementation.

9. Discussion and Conclusion

This chapter offers a detailed discussion of each chapter and the key findings. Accepted wisdom from the literature review is re-presented to support the findings and close the research circle, reflecting on what the findings mean for heritage practice, and how they are positioned within information management practice and associated issues. A presentation of the completed research and final research outputs is also provided.

A personal reflection on the research aims and objectives, the data that has been used to address these and the overall success in answering the research question is then given, followed by a further reflection on the research approach, limitations and the contribution to the body of knowledge. The academic contribution to the research body of knowledge, along with the practitioner contribution offered in the Heritage Information Management (H-IM) Workflow is discussed. The significant contributions of the research are also reflected upon, noting benefits to several literature themes:

- Conservation of Historic Buildings
- Heritage information management
- Heritage asset management
- Heritage BIM
- BIM for O&M
- BIM for FM

Areas for future research that have been identified are described, with thoughts on how these may benefit the heritage sector and CRM planning more specifically. Further, thoughts and considerations are given to the possible limitations, or significant impact that this future research could have.

9.1 Discussion and key findings

In the following section the data collection chapters (5, 6, 7 & 8) are discussed to synthesize and reassert key findings of the research. Sub-headings help to structure the discussion, discern the key findings and describe the importance of the findings, demonstrating how these are positioned against the existing wisdom.

Standardised approaches to asset management are lacking in both heritage and non-heritage contexts

In Chapter 5, three different organisations responsible for the management of a collection or estate of assets and thus, responsible for asset management were reviewed. Two heritage organisations were chosen that presented as 'typical', therefore offering lessons that can be applied to the wider heritage sector. A further non-heritage organisation, with similar 'typical' characteristics, was chosen allowing fair comparison of asset management practice and to draw conclusions about differences and similarities in process. The aim of the chapter was to consider the following questions:

Is asset management different in heritage and non-heritage settings?

Do different heritage organisations carry out asset management in the same way?

What challenges do heritage organisations face when implementing asset management programmes?

What information is used, and how is it used, in heritage and non-heritage settings?

Each case study followed a structure that picked out themes from the literature review that required analysis:

Type and range of assets

Organisational structure and resource

CRM and/or asset management process

Data fragmentation & challenges

The type and range of assets within each of the organisations varies quite considerably. The number of assets managed by UKAHT is much lower than the other two organisations.
Further, the assets are all fairly similar. Historic research sites comprising huts of similar construction and related assets such as dog pens, generator sheds and radio masts. The huts all share a similar significance – a reminder of British presence and research in Antarctica. It could be said that the range of buildings cared for my English Heritage is the broadest. CRM is based purely on preservation. While initially one might notice the more typical heritage assets, castles, abbeys etc, the trust are also responsible for earthworks, bridges, and historic houses. Further, the trust manage and maintain operational and functional buildings such as shops, tea rooms and holiday cottages. The values applied to these buildings ranges from historical value and cultural significance, to operational value for income generation. This broader range of value results in a slightly more complex approach to asset management within English Heritage. It could be considered that this would be typical to any heritage trust that manage a national collection or a trust that relies on visitors for income generation. It is possible that the more complex approach required, and the competing requirements for preservation and operational function are contributors to a lack of common approach to heritage asset management. The buildings on the Organisation A estate do range in type but common to all is their operational function and thus the clear strategy behind Organisation A's asset management process is to maintain service, ensure availability and to maintain assets to an agreed condition standard.

The main difference identified in organisational structure is that smaller heritage trusts often rely more on passionate individuals who may be volunteers or, work on short term contracts. While UKAHT is not typical in the sense that staff must travel and live away from home for periods of times, volunteering was identified as common to the industry through literature review (Orr, 2006; Chapagain, 2008). The level of skills and qualifications in such groups differs considerably and is unlike the must more structured recruitment found in organisations such as English Heritage or Organisation A where most individuals are construction or conservation professionals with specific technical qualifications and industry memberships. This may play a part in the development of structured and standardised approaches to heritage asset management. It was demonstrated that the asset management process used by UKAHT is first and foremost based on annual maintenance programmes, with instructions provided to non-technical or construction based staff, with strategies for conservation repair and maintenance programmes coming second. While there is a desire to develop structured processes these are still in development. Surprisingly, Organisation A was found to be in a similar position, despite the more structured recruitment and clear focus on technical hard FM. On the other hand, English Heritage have developed a very structured process, based heavily on data analysis and clearing a financial backlog of defects. However, to its detriment, this has resulted in some of the 'personal' and professional judgement necessary in CRM processes to be missing from the process.

The chapter is intended to study process and information, how different organisations undertake asset management, the processes and information used. However, it is acknowledged that people are involved throughout. In relation to process, it is noted that people may or may not be aware of processes, and that they can choose to follow process or not. The skills and qualifications of individuals varies, and the motivation and interests of people vary, impacting how they approach various tasks.

The case studies demonstrated that each organisation has a plan for asset management. While this is formally recorded as an organisational strategy by English Heritage through their written asset management plan, UKAHT had developed a high level phased plan that had been used to communicate their intentions to the Board of Trustees. In both cases, the charity status and organisational structure placed a requirement on the heritage organisations to communicate their plan. In the case of Organisation A, asset management is a key task with a contractual process in place. The process itself is well documented however, the organisation is lacking a written strategy. This finding is surprising. Literature has suggested that asset management best practice is common in traditional contexts but requires development in the field of heritage e.g. (Giglio *et al.*, 2018; McGibbon *et al.*, 2018). However, findings suggest that processes or high level plans, particularly contractual ones, are in place but more formalised frameworks and written strategies are lacking.

It is noted that prioritisation and planning of asset replacement or conservation repair and maintenance differs between organisations. The organisational goals of both UKAHT and English Heritage are for the preservation of heritage for future generations. Both UKAHT and English Heritage state health & safety, and access to be of importance. Conservation action delivered by UKAHT is prioritised on the basis of the historic significance of the site and, the material state of any structure or artefact which will be informed by developed Conservation Management Plans however, UKAHT do not yet have a well established programme of cyclical condition survey to inform this process.

Similarly, the English Heritage Sustainable Conservation and Asset Management Plan uses a matrix of significance, vulnerability and condition as a tool to prioritise conservation works and focus resource efficiently. While missing for UKAHT, English Heritage do carry out cyclical condition surveys to provide the condition data required for this planning. In contrast, prioritisation of asset replacement or repair and maintenance on contract X managed by Organisation A is based on contractual obligations and maximisation of profit. Like English Heritage, the Estates department monitor assets through ongoing surveys, but instead of monitoring condition in terms of risk to historicfabric, surveys are to ascertain life periodicity. Organisation A will programme asset replacement where assets are nearing end of life. Programmes of repair and maintenance will also be programmed to meet contractual requirements ensuring all assets are handed back in a pre-agreed condition at the end of the contract, and that assets are always available to the Client when required. Programmes of work are carefully planned for maximum cost efficiency.Like both UKAHT and English Heritage, health and safety is always a primary consideration in the planning and prioritisation of asset replacement or repair and maintenance.

Fragmentation of building information for asset management is reported in all 3 of the organisations. In both heritage and non-heritage contexts, legacy data contributes to asset management, yet the management of this data is a challenge in all cases. All three organisations had, or were in the process of, establishing a single location for their building information. Whilst both English Heritage and UKAHT had structured their heritage information by building/monument/site, this was not the case in Organisation A and had been identified as one of their challenges. Instead, building information in both the network drive and the department SharePoint was structured by category, such as Surveys, Maintenance Certificates or Drawings. Whilst a similar set of information requirements for each organisation was used, Organisation A had not stored this set of data at building level. The exception was information found in CAFM that due to the nature of the software system, was by default structured by building. This is an interesting point to note. Of the three organisations, only English Heritage had adopted specific asset management software. It was described that the structure of the software itself contributes to how information is structured, and the type of information that is stored. Both UKAHT and Organisation A were using electronic document management systems (SharePoint) that are structured in whatever way the user chooses.

Critical information requirements must be established for successful asset management

A key finding from this research was that while organisations were trying to structure their building information, it was not recorded what the specific building information requirements were, or how it had been decided which information would be collated. This raised the question of 'what are the critical information requirements for successful asset management?'.

Contrary to other reported barriers to implementation of digitisation approaches such as BIM, where the identification of critical information requirements was considered a key challenge e.g. (Mayo & Issa, 2014; Burak Cavka, 2017), establishing the critical information requirements and thus, a framework of conservation data parameters for heritage asset management and CRM planning, is shown in Chapter 6 to be a relatively simple task. This is a positive finding, clearly demonstrating that adoption of a standard set of conservation data parameters will have significant impact for the heritage sector and is therefore critical. If not adopted, the heritage sector will continue to operate in a fragmentary and analogue nature, seeing little in the way of improvement.

It has been demonstrated that conservation data parameters may be applied to data modelling approaches to support the regular maintenance of building information and mitigating digital decay. Furthermore, the use of conservation data parameters allows organisations to achieve standardisation. This combination will result in significant efficiencies in the heritage sector, particularly for CRM planning. It is noted that in the simplest form, conservation data parameters may be used for data modelling within spreadsheets and databases. However, the pilot application of conservation data parameters within a simple model indicates further potential benefits that should be the focus of future research.

The development of the UKAHT asset data capture spreadsheet, or other similar documents used by typical, small heritage trusts, for heritage asset management, could equally benefit from using the standard conservation data parameters to inform the data collected about an asset and to structure the data. This will allow for regular maintenance of the digital assets, minimising digital decay and thus improving the ongoing data analysis for CRM planning. Given the reported issues in a lack of digital skills in the heritage sector (Vileikis *et al*. 2012; Duff *et al*. 2009), simple data modelling using standardisation is likely to see the biggest impact to improved heritage asse management.

The digitisation used by English Heritage in the K2 asset management database is an example of best practice in heritage asset management that applies data parameter principles as discussed above. It ensures information is accessible and structured, therefore reducing the failings reported in the literature (Simeone *et al*. 2018; Jordan-Palomar *et al.* 2018), and allows for regular maintenance. It further demonstrates that simple digitisation could be sufficient within the heritage context, negating the need for 3D parametric models where skills and funding might be a barrier.

Retrospective compilation of building information is a significant challenge

The UKAHT case study does however identify that the 'retrospective compilation' for the structuring of legacy data using defined conservation data parameters provides a significant challenge. This view was mirrored in literature where the production of 'as-is' BIM data for O&M is considered a labour intensive task (Stojanovic *et al.,* 2018), and was further illustrated as a challenge within English Heritage.

To consider why 'retrospective compilation' presents such challenges it is important to review the practical implementation of conservation maintenance strategies. An appreciation of the factors that impact the process will provide an informed approach to the development of heritage information management processes that mitigate identified challenges.

In Chapter 7, two sets of data from different heritage organisations have been presented and analysed to understand how people engage with formal process and guidance and why they do not always follow it. And to identify the specific challenges that conservation professionals face when engagingwith digital, formalised processes.

The BIM research framework 'process field' (Succar, 2009) is used to structure the data for discussion and analysis. Four identified steps in the CRM process were selected and studied to analyse how people engage with them, why the processes are not always followed, and identify specific challenges with digital, formalised processes.

Survey and Data Capture

The survey and data capture process presented surprises, and issues in both cases. The example described in the UKAHT case was based around the survey and data capture of windows in the historic hut, Base E. An initial survey was undertaken to number the windows, making annotations on architectural plans of the building. Character G had expected this to be completed in a particular way, starting in particular place, and moving around the building in a particular way however, no explicit process or format for the window numbering had been provided leading to a surprising way for the windows to be numbered and an unexpected numbering convention. This had an impact on other data that was to be collected and so resulted in some rework to amend the prefixes given to the window numbers.

In a similar fashion, in both survey and drawing procurement processes observed at English Heritage it was found that the processes were not always followed. Although in this case there was a process, it had not been well communicated or formalised. Use of the K2 Condition Survey Template (Actor 10) to ensure standardisation and correct format of data for upload into K2 (Actor 4) was not used in all cases, and information was not always passed to Actor 5 to ensure data was uploaded. The same issue was identified with drawings. Procurement of drawings often resulted in duplication and the capture of drawings to ensure they were uploaded into K2 was not always successful. Again, these situations led to a certain amount of rework to ensure data or documentation was uploaded correctly or, additional work to obtain the information so that it could be uploaded was required and so correlating with findings from the literature regarding inefficiencies and duplication.

Data Management

The study of data management across both organisations presented similar issues. In the UKAHT case processes had been developed for the capture of survey and material sampling data. Template documents and naming conventions had been defined yet it was found that information was rarely entered into the documents from the outset, requiring rework at a later date. Similarly, the naming conventions were generally only used once Character G had been passed the information and processed it to add to the template documents/spreadsheets.

While mobilisation of the survey and data capture process was primarily affected by the actions of human actors, further data analysis demonstrates that it is not just people that impact the data management process. In the UKAHT case it was noted that actors such as the weather, batteries and laptops had an impact on the process. While in some cases it is possible to negotiate with network actors in order to achieve enrolment and mobilisation, there are some factors, such as the weather, that cannot be negotiated with and so displacement or transformation must take place.

In the English Heritage example, data management was focused around the use of a common data environment for storing historic building information that would be used in the CRM planning process. Despite a data manager role being established, lack of mandatory process and collaboration between different departments/stakeholders lead to silo working resulting in a failure in the data management process. This is a common issue in the sector (McGibbon *et al.,* 2018). Information was located in different places, and not necessarily within the common data environment. It was further observed that critical information requirements for CRM planning had not been defined to inform an information management structure. A set of proposed criteria for future processes or workflows was established which should be considered when developing or proposing new digital, formalised processes. These comprise:

Information manager roles
Single location
Agreed structure
Identified critical information requirements
Retrospective data collection
Mandatory process

It was further proposed that training and control could offer significant benefits and opportunities for successful enrolment and mobilisation. While training is a fairly obvious point, control is defined here in terms of mandatory processes and defined information management responsibility and accountability.

Data Analysis

The use of a template document, the ‘Future Recommendations Worksheet’, for planning future CRM works is described in the UKAHT data analysis example. The different goals, or identities, of network actors was traced, noting the Carpenters aim of getting all repair works completed while weather allowed, and other actor’s primary interests in ensuring sufficient data was collected for future planning. In this case, Character G failed to enrol all actors into the problematisation of collating and managing the historic building information for future analysis, despite intressement activity. Negotiations were made that transformed the process (Harty, 2008), meaning templates were completed at a later date, however overall, the intended network failed and the templates were not completed at all.

In the English Heritage example, similar to the future recommendations worksheet, the K2 C Set Condition Audit Report is discussed. Like the UKAHT case, it was noted that the effectiveness of this report relies on the data in the first place. Observations demonstrated that a failure to use the template spreadsheet at all times led to inefficiencies and different procurement routes and failure to manage data led to inaccurate condition and defect data within the database. This in turn affects the effectiveness of planned CRM.

Of the four CRM process steps, data analysis could be considered the critical step in ensuring efficient and effective delivery of CRM. Data analysis however can only be effective where data has been captured accurately, and suitably managed to ensure information can be accessed and that it is kept up to date. None of the steps can be considered in isolation but to make a step in the right direction, the sector must begin with the first two steps.

Data Use

Data use in the two examples presented relates to the scoping of CRM works, and decisions that are made surrounding CRM approaches. While with the UKAHT example decisions are required to be made while on site, at the point of delivery, these decisions are made prior to any works taking place in the English Heritage example. The reason for this difference is identified to whether a conservation management plan and/or consent process is in place.

Noted above, the efficiency and effectiveness of any CRM work heavily relies on data capture and management and so again, emphasis is placed on the need for digital, formalised processes to support heritage asset management.

In this research ANT offered a useful ‘follow the action’ method, and the ANT ‘process of translation’ (Shiga, 2006) offered a common language that was applied across the data analysis. The approach has proven to be successful in identifying network actors, tracing associations and exposing failed enrolment and mobilisation that was found to be common across all four steps of the CRM process. By considering the issues encountered when implementing conservation maintenance strategies through a study of network actors, it is proposed that a better understanding of the implementation of new technology or processes can be achieved. Moreover, it is suggested that this in turn can add significant benefits when developing and introducing new digital, formalised processes that have the potential to support conservation professionals.

The examples demonstrate that the way people work, or how they will interpret or perform a process cannot be assumed and so enrolment or mobilisation of a process cannot be guaranteed. Moreover, it was illustrated that CRM processes are critically affected by a vast range of unknowns. Attempts to mobilise data capture and 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. The range is wide and varied, and as such cannot be predicted.

Despite this, CRM work continues to be delivered. This suggests that the network has transformed to adjust to the observed issues. While transformation has taken place, accuracy, efficiency and effectiveness are all factors of the process that have been affected. It is suggested that mandatory, or formalised processes may improve this situation.

For successful adoption and implementation of digital, formalised processes to support conservation professionals with CRM planning the factors discussed above must be taken seriously and measures to mitigate the challenges should be drawn into industry guidance. BIM information management processes determine roles and responsibilities, including the Information Manager. The heritage industry must also adopt such roles to support and manage the implementation of new digital data management processes.

Further, identifying information requirements is a key task missing in the survey and data capture, and data management steps of the CRM process. BIM processes have acknowledged this requirement to improve efficiencies and effectiveness and so should be considered for new heritage workflows.

BIM principles can be used to support conservation professionals with heritage asset management

In Chapter 8 it is demonstrated that BIM principles can be used to support conservation professionals with heritage asset management, improving the known issues of fragmentation that lead to inefficiencies in the sector. Significant benefits for the heritage sector, and the particular task of CRM planning, are identified from the wider AEC field e.g. (Becerik-Gerber *et al.,* 2012; Bosch *et al.,* 2015) and are further summarised as follows:

Improved understanding of critical information requirements for CRM planning
Improved management and access to information used for CRM planning
Improved accuracy of information used for CRM planning

Despite such benefits, methodologies and defined information management processes with practical guidance for the heritage sector are lacking (McArthur, 2015; Maxwell, 2017), contributing to barriers to implementation and adoption.

This chapter therefore considered existing HBIM guidance and workflows to identify what is missing, and how new guidance can be improved. Using the BIM research framework (Succar, 2009) as a basis for comparison, it was noted that the BIM lens used for all of the existing workflows was the wider process of heritage building intervention, including planning, design and delivery. Case studies reviewed used a facilities management lens which includes the planning of CRM work, but these do not provide guidance for the industry to follow. Limitations of the existing workflows and case studies were noted to include:

No specific implementation guidance
Unclear BIM principles or methodology
No cost/benefit analysis for the use of 3D parametric modelling
Do not state what the heritage information requirements or conservation dataparameters should be
Confused definition of the asset information model

Further, lessons from this research, and a comparison between the functions of existing heritage asset management systems studied in Chapter 5 and the functions of a BIM system are made. Information gathered from these two sets of data is used to produce a list of key requirements for a Heritage BIM workflow that can be used to support CRM planning which is subsequently used in the development of the Heritage Information Management (H-IM) Workflow.

To offer a read across from standard BIM principles, and an original piece of work, the H-IM workflow has been developed based on the principles of the BIM information delivery cycle / management process (BS EN ISO 19650-1:2018). It comprises 4 simple steps based on the BIM information management process but can be equally understood and adopted by the heritage industry with a range of skills and funding. The approach has been developed in line with the UK BIM Alliance 'Back to BIM Basics' agenda, focusing on BIM at its simplest. The use of information management processes and defined roles and responsibilities turns the attention away from 3D parametric modelling which to date has seen barriers to implementation due to the cost and skills required to adopt such approaches.

While other chapters contribute to the academic contribution of knowledge, this chapter is specifically aimed at providing a practitioner contribution. The proposed Heritage Information Management (H-IM) Workflow positions this research as an original piece of work, offering significant contribution to the heritage sector and specifically for those involved in CRM planning.

Research outputs include the following:

Industry guidance in the development of heritage asset information models:
BIM for Heritage: Developing the Asset Information Model (Hull & Bryan, 2019)

Template documents to support heritage professionals in defining and documenting heritage information requirements (available for download from - BIM for Heritage - Developing the Asset Information Model | Historic England) :
BIM for Heritage Technical Guidance – Organisational Information RequirementsTemplate
BIM for Heritage Technical Guidance – Asset Information Requirements Template BIM for Heritage Technical Guidance – Exchange Information Requirements Template

The H-IM Workflow Diagram

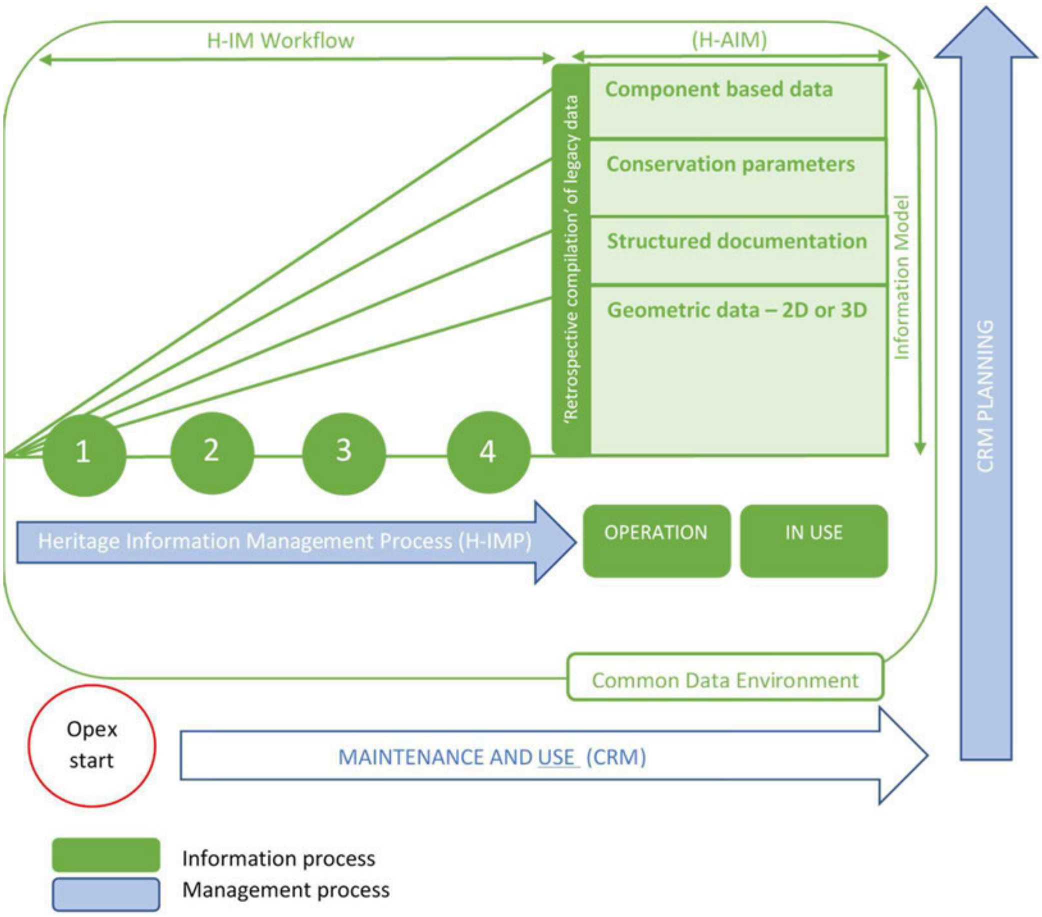


Figure 9.1 The Heritage Information Management (H-IM) Workflow developed by the Author

It is noted that the development of a standard template for the industry to use for documenting their heritage information management strategy would encourage adoption and aide standardisation. This should be developed following this research.

Organisations need to be clear on their heritage asset management and information strategies to achieve success, further stressing the importance of the OIR. The Client needs to take control of the process, define their requirements and state the expected deliverables (Mayo and Issa, 2014; Mcarthur, 2015).

Roles and responsibilities identified in Step 3 of the H-IM Workflow are proposed as a solution to mitigate these challenges but, the roles must include responsibilities to review the implementation of processes and provide support and training to ensure adoption.

Further, they must also include the ongoing management of the process.

At an industry level, the following steps should be taken to see adoption of the H-IM Workflow:

Training and Education
Industry promotion of best practice and standardisation
Further industry support – guidance and templates

These are considered as areas for further development following this research.

9.2 Reflection on research aims and objectives

This section provides a reflection on the success of the research in answering the main research question and the four secondary questions that formed the aims and objectives. A guide to the research questions is provided in Table 9.1.

Table 9.1 Guide to research questions and where these are addressed

Main research question:	**Addressed in section:**	**Addressed in chapter:**
What are the challenges of heritage asset management, and how might digital, formalised processes, such as BIM, support conservation professionals with CRM planning?	9.2.5	All
Secondary research questions:		
How does conservation asset management differ from conventional asset management and what impact does this have on data management?	9.2.1	5
How do people engage with formal process and guidance, and why don't they always follow it?	9.2.2	7
What features would Heritage BIM need to have to support conservation professionals with CRM planning?	9.2.3	8
What are the specific challenges that conservation professionals face when engaging with information management and digital technology?	9.2.4	All
Chapter questions:		
Is asset management different in heritage and non-heritage contexts	9.2.1	5
Do different heritage organisations carry out asset management in the same way	9.2.1	5
What challenges to heritage organisations face when implementing asset management programmes	9.2.1	5
What information is used, and how is it used, in heritage and non-heritage settings	9.2.1	5
What are the critical information requirements for heritage asset management	9.2.1	6

The aim in answering the secondary research and chapter questions was to draw a conclusion as to *how* digital, formalised processes could support CRM planning, therefore allowing the researcher to present a proposed workflow to support this activity.

Three data collection chapters have been presented in the thesis (Chapters 5, 6, 7). Each was designed to answer one or more of the secondary research questions and in most cases were based around a chapter specific question as noted above.

The success of data collection and methods employed, along with the ultimate success in answering each of the secondary research questions is now considered. The success in answering the main research question is discussed last.

9.2.1 How does conservation asset management differ from conventional asset management and what impact does this have on data management?

This question was answered in Chapters 5 through a study of the asset management processes of the 3 key organisations and 5 chapter questions as noted in the table above.

The data provides an interesting look at 3 organisations responsible for the management of a built estate. The organisations were chosen based on access opportunities. Despite a potentially limiting approach, the researcher considers the 3 organisations to have been good case studies covering the breadth of heritage organisations, from a small heritage trust responsible for a small portfolio, to a large national heritage organisation. The non-heritage organisation was very typical of private sector organisations responsible for the management of a varied estate comprising existing buildings both historic and modern. All 3 organisations were interesting to study, and the opportunit to travel to Antarctica as part of this research is greatly appreciated. Not only has it provided an exceptional personal experience, but also an extremely interesting case study and data set that stands out in the literature.

The research data in Chapter 5 successfully identifies differences and similarities of asset management processes in heritage and non-heritage contexts, and the impact this has on data management. While issues of silo working, fragmentation and analogue practices were identified across both contexts, resulting in inefficiencies and loss of data, these were perhaps not a surprise given the lengthy and sometimes repetitive reference to such issues across the literature review e.g. (Ciribini *et al.,* 2015; Pärn *et al.,* 2017).

In all cases, organisations are managing existing estates and legacy data which is a significant challenge in the O&M phase of the building lifecycle (Gu *et al.*, 2014), and while digitisation methods such as BIM are researched to examine their potential to improve fragmentation issues quite extensively, little attention is given to the actual processes involved in adopting such methods. This research has demonstrated that those organisations wishing to implement new digitisation methods must first deal with the management of this existing data (Letellier *et al.*, 2011).

'Retrospective compilation' is a term that has been developed as a result of this research and is a key contribution to literature in the fields of BIM for O&M, BIM for FM, or Heritage BIM. Retrospective compilation is a step in the wider digitisation adoption for existing and heritage buildings that must consider:

Critical information requirements for existing or heritage CRM

Barriers to implementation in the heritage context

Socio-technical factors in the heritage context

The research established that before a proposed workflow to support CRM planning could be presented, the critical information requirements for CRM planning needed to be defined. While identifying critical information requirements for the adoption of BIM in the wider AEC industry is represented in the literature, there is a significant gap for the same within a heritage context.

This research addresses this gap (Hull and Ewart, 2020). In addition to contributing to knowledge that considers differences in asset management or maintenance strategy across different contexts, the varying definitions of strategy approaches such as maintenance backlog, and the impact that this has on information requirements, the research provides a practitioner contribution with the development of a standardised set of conservation data parameters to be used in CRM planning processes.

9.2.2 How do people engage with formal process and guidance, and why do they not always follow it?

In the previous section, reflection on the lack of research that considers the actual process of implementing and adopting new digitisation processes was offered. It was highlighted that before any digitisation method for existing or heritage buildings can be adopted, a process of managing the legacy data must be instilled. Managing legacy data is not just a significant challenge for ongoing O&M, it is a critical issue in the heritage sphere discussed in dated literature. It was noted that first the critical information requirements must be established but, moreover, consideration of socio-technical factors that affect these early steps in the process must be understood and managed to ensure effective adoption. This must include a study of the people, how they engage with formal processes and guidance, and why they don't always follow it.

The researcher identified a social element to the research that if studied using robust methodology offers significant benefits to a wide field – the implementation of new technology and process. Chapter 7 referred to academic literature that focuses specifically on issues that impact the implementation of conservation maintenance strategies. This was identified to be limited, presenting an additional gap in the literature that is filled by this research. Existing literature across both research areas have considered barriers to implementation, and some within the wider AEC arena have used socio-technical network oriented approaches as a way to study them, however the same is not currently present in the heritage literature. Actor network theory has been adopted in studies of heritage tourism but not for heritage CRM or maintenance strategies. The adoption of an ANT oriented approach to this research therefore offers an original contribution to knowledge.

The use of ANT was not straightforward for the researcher. At times the method can feel quite abstract. Following the action and recording human and non-human actors, that in respect to the UKAHT case study involved snow, jerry cans, batteries, documents and so on, feels a little unusual. At the time of making field notes it is not always clear if the data will be useful or what it might identify. It was found important to try and forget about the research or the end result, instead simply carrying out the 'day job' of CRM related tasks and making field notes in relation to action. Analysis should be left as an activity post 'field season' instead of trying to work out what it might mean at the time.

In the UKAHT case study, a range of ethnographic activities were undertaken to gather as much data as possible however, field notes surrounding the main UKAHT CRM activities were ultimately the only data that was analysed as part of the research having discarded other data. This included data that had studied visitors to the Antarctic hut on Stonington Island, such as the routes they had taken when visiting the island to identify their main interests, Q&A sessions that were held onboard the visiting cruise ships, and photos sent by visitors to the researcher following their visit. This data had followed a principle of following the action, which was adopted as part of the Actor Network Theory approach however, ultimately, this was action that was not related to, and had no impact on, the CRM processes, bringing no actors into being as part of the CRM planning network, and so was not found to be useful.

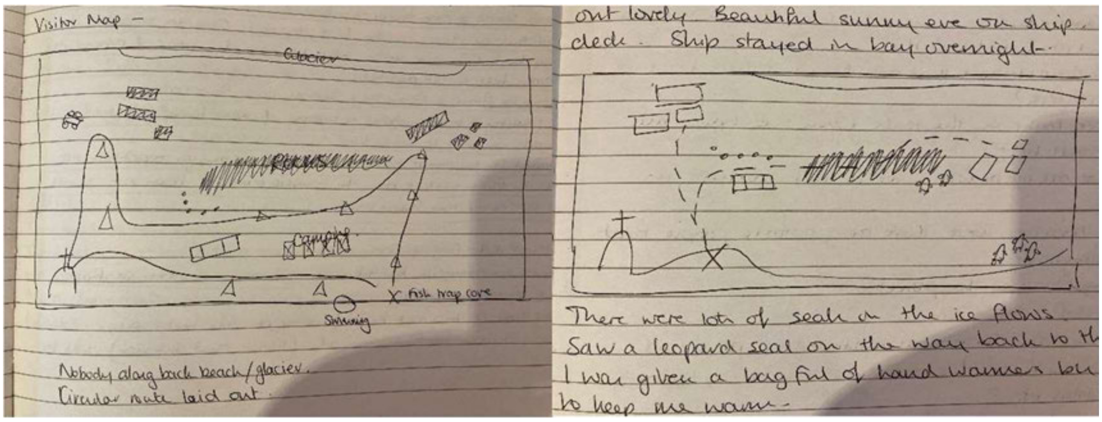


Figure 9.2 Visitor Route Sketches from field notes (Source: Joanna Hull)

Despite some data not being used, the data presented in Chapter 7 illustrates that the approach was an overall success. A range of human and non-human actors across the two case studies were identified to allow further analysis of the socio-technical network and factors that affect the implementation or adoption of a new process. The vignette style used to present this data in the UKAHT study was enjoyable, and is intended to provide an interesting read to both the academic world and conservation practitioners. It was particularly useful for describing the process of translation that either resulted in the effective implementation of new processes, or as in this case, failed mobilisation. Elements from this chapter have been used to develop presentations for the conservation sector and in the writing of a number of trade/industry journal articles. On the other hand, the multi methods approach adopted to gain information about English Heritage provided less rich description for a vignette style and discussion of the process of translation. Initially this presented a challenge, however this has been successfully overcome with the use of actor network diagrams that are used to illustrate the networks and support the process of translation discussions.

The researcher was often challenged by peers when she talked about heritage stakeholders as being somehow different to other construction industry and process stakeholders. However, a key finding of this research is the surprisingly novel observation that while large organisations such as English Heritage display similar characteristics to typical AEC organisations, the majority of heritage organisations are in fact substantially different.

Traditional construction roles such as the building surveyor, project manager or technical/information manager are not always present in small heritage trusts. Instead, these services may be bought in as consultancy, but for day to day management they are not always present. Often heritage trusts rely on long standing team members with no formal conservation, project or information management qualifications. As demonstrated, this impacts the way CRM planning activities are conducted.

In response to the secondary research question and as a reflection on the success in answering this, Chapter 7 did successfully identify how characters from conservation teams engaged with formal process and guidance. Further, the research offers the following conclusions as to why they don't always follow it:

Network actors (human or non-human) affect the network which may impact whetherpeople follow process or guidance

Traditional construction roles may not be present within heritage teams and so standard construction or surveying type processes might not be followed as expected

The nature of people is that they will often follow a process that is most comfortable tothem – entrenched/existing ways of working for example

If the wider process, strategy or business need is not communicated or understood by the wider conservation team, they may not understand the importance of following certain processes

9.2.3 What features would Heritage BIM need to have to support conservation professionals with CRM planning?

Heritage BIM, or the application of BIM methodologies within a heritage context, have been identified through this research as a potential digitisation approach to support conservation professionals with more accurate and efficient CRM planning. However, for this to be successful, a clear understanding of the required features, or functions, needs to be established.

Existing literature focuses on how BIM methods may be adopted by the heritage industry, but with little in the way of considering the conservation professionals themselves and the reality of implementing BIM methods within the sector. For example, this research has noted several times that a focus on the 3D parametric modelling aspects of BIM, while certainly offering benefits to the industry, is not the best solution to support CRM planning.

Through the data collection and analysis used to answer the secondary research question in section 9.2.2. it was demonstrated that traditional construction roles might not be present in small heritage trusts, and that people are generally more comfortable with processes that seem familiar. In Chapter 3, sections 3.5, issues affecting the implementation of digitisation within the heritage sector were considered. It was noted that both digital skills, and funding for digital projects present significant barriers to implementation. This combination of factors cannot be ignored. This is not to suggest that the industry should not seek to adopt digitisation methods, but a realistic view of industry requirements and feasible options to meet these requirements should be the focus of ongoing research. In Chapter 8, HBIM workflows or case studies were intentionally focused on those based on information management processes that can be adopted in a number of ways, ignoring those that are purely focused on the use of multiple hardware and software which is not feasible for small heritage organisations.

Following the UK BIM Alliance 'Back to BIM Basics' approach this research has intentionally switched the focus from 3D parametric modelling, the single aspect of BIM that presents the biggest challenge, and thus barrier, to BIM adoption within the heritage sector. The research has been specifically aimed at CRM planning rather than wider heritage themes such as public engagement, historical records and digital archiving or large scale heritage restoration projects.

Heritage BIM (HBIM) has been used quite loosely to date by the heritage sector. The literature review presented in Chapter 3, section 3.4, demonstrates clearly the variable definitions of

HBIM. CRM planning falls within the theme of conservation maintenance strategies and so this research has limited its scope to consider BIM within this sphere only. This offers a new but important contribution to the HBIM literature, along with a required development of the dated literature on the theme of conservation maintenance strategies. Similar to the BIM research framework (Succar, 2009) adopted to frame this research, future research should also consider a similar HBIM research framework to ensure that confusions within HBIM do not persist and to clearly delineate publications.

Returning back to the secondary research question, having positioned this research in the HBIM for CRM planning context, the researcher has been able to identify the features that would be required for an HBIM workflow that supports CRM planning. The key points to take from this is that a 3D parametric model is not noted as a requirement. Instead, requirements are based around strategy, information management processes and the digitisation of critical / heritage information requirements, and roles and responsibilities, all of which are BIM concepts that can be adopted to support CRM planning.

9.2.4 What are the specific challenges that conservation professionals face when engaging with information management and digital technology?

This question is answered through a review of the 3 data collection chapters. This allows conclusions to be drawn from the full range of data, analysis, and discussions presented which is an extremely effective approach.

There is some cross over here with the conclusions drawn in sections 9.1.2 and 9.1.3 in that the challenges experienced when implementing a new digital information management process were demonstrated, and challenges were further reviewed to determine the requirements for a Heritage BIM information management process.

In this section the challenges are noted, along with the proposed solutions identified through this research, and presented in Table 9.2. It is acknowledged that the proposed solutions in response to the first challenge match those presented in Table 8.4, but instead in a format that shows them as a direct response to an identified challenge.

Table 9.2 Challenges faced by conservation professionals when engaging with information management and digital technology, and proposed solutions

Challenge	Proposed Solution
Retrospective compilation of legacy data	Defined asset data management strategy
	Identify critical heritage informationrequirements (HIR)
	Standardised conservation data parameters
	Asset information model in a common dataenvironment
	Defined information management process including naming conventions and roles and responsibilities
Defining Heritage BIM	Training for the heritage industry
	More literature
	An HBIM research framework
3D parametric modelling of historicarchitecture	BIM information management concepts:Strategy Information requirementsAsset information model Information management process
	The H-IM Workflow
	Training
	Further literature
	HBIM research framework

Throughout the research issues of fragmentation have been highlighted, illustrating the effects of neglect on building information. Further, management of legacy data in relation to existing and heritage buildings was noted as a challenge to building or information managers. It was noted that this legacy data must be managed, structured and updated to ensure accuracy and easy access before any new information management or digitisation methods can be implemented. The research coined the term 'Retrospective compilation' as a key task, particularly in a heritage information management process where this is identified as a challenge for conservation professionals.

More specifically in relation to BIM, as both a digital technology and information management process, conservation professionals seem to be confused over the definition of BIM. This was touched on in the previous section but to add some further depth to this, tools used within a BIM approach, such as hardware (e.g. Laser Scanners), software (e.g. REVIT) and outputs (e.g.

3D parametric models) are often individually referred to as BIM. Of course, BIM is the whole process/methodology for information management rather than the individual parts, but getting this message across within the heritage sector is failing.

The constant confusion within the sector between BIM tools (which are well recognised and championed), and the concepts and methodology of BIM (which are largely ignored or misunderstood) resulted in another significant research output: the publication of an explanatory article in the leading trade journal ‘Context’ from the leading trade body the Institute of Historic Building Conservation (IHBC).

This is an area that requires much more attention in the coming months and it is intended that this will be addressed by working with the BIM4Heritage Committee and the publication of further academic papers following publication of the thesis. The development of an HBIM research framework will help to correctly frame HBIM research and provide some clarity within the heritage sector.

Comprehensive literature review has identified the significant challenge that is faced in the 3D parametric modelling of historic architecture. Along with limited digital skills and funding within the heritage sector, this is considered a barrier to the implementation of BIM for heritage. However, this research has repeatedly suggested, and demonstrated, that 3D parametric modelling is not a critical requirement in the adoption of BIM methodologies for CRM planning. While benefits have been considered, particularly in the visualisation of building components and their related significance, condition, risk, and thus overall status for the purposes of CRM planning, they are identified as an area for future research. Cost/benefit analysis of such approaches must be considered before they are presented as a requirement for the industry. Instead, the use of BIM information management concepts are considered critical for digitisation, improving the fragmentation and inaccuracy of historic building information, and thus preventing digital decay. Moreover, this will improve efficiencies in CRM planning and reduce the risk of our built historic environment falling into decline.

9.2.5 What are the challenges of heritage asset management, and how might digital, formalised processes, such as BIM, support conservation professionals with CRM planning?

This research has been successful in identifying the challenges of heritage asset management as summarised below. The relationship of these challenges to information and data management is clear:

Fragmented historic building information

Large amounts of legacy data

Silo working

Analogue data and processes

Lack of heritage asset and data management strategies

Difficulty in establishing/no standardisation for critical information requirement

The roles and skills within teams of heritage stakeholders are not necessarily focusedon strategy and information management

Entrenched or existing ways of working may be a barrier to the implementation of new processes

A wide range of unknowns (human and non-human actors) impact processes, such thatthey may not be followed, workarounds may be developed, or they may fail

The large number of challenges should not be seen as a negative, indeed, this suggests an area ripe for positive change and action, and this research has demonstrated that digitisation can offer significant benefits for CRM planning.

A change from analogue, legacy data, and paper based archives often seen in the fragmented historic building information, to a systemised and controlled digital format will offer significant benefits for CRM planning.

This is partially demonstrated in the English Heritage example described in Chapter 5, where a number of steps towards digitisation have been employed. Illustrated in the image below, English heritage have started a process of 'retrospective compilation' and the development of a heritage asset information model (H-AIM).

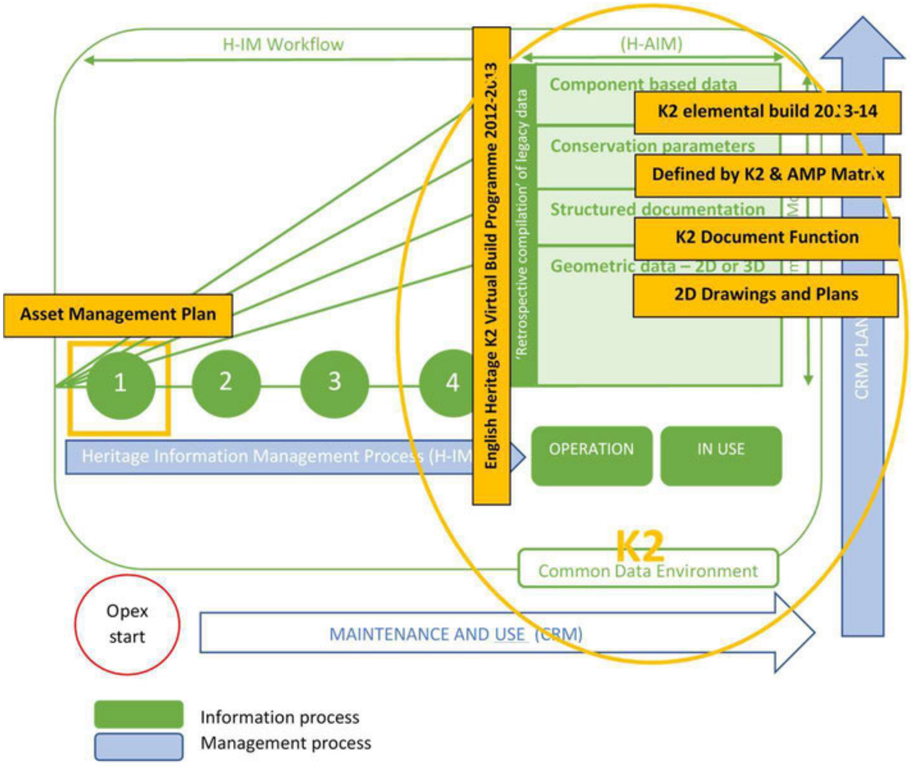


Figure 9.3 English Heritage AIM Development Diagram developed by the Author

However, the research demonstrated that there were still some failings in the process. These are reviewed against the steps of the proposed H-IM Workflow.

1 Step 1 – Develop the heritage information management strategy

2 Step 2 – Define heritage information requirements (HIR)

3 Step 3 – Define the heritage information management process (H-IMP)

4 Step 4 – Implementation and Management

In Chapter 5 it was noted that while English Heritage do have an overarching heritage asset management plan/strategy, there was no formalised information management strategy. Further, they had not formally identified critical, heritage information requirements (HIR) other than those defined by the AMP, which were also required by K2 the asset management database. With regards to the structured documentation, it was not clear how the information to be added to K2 had been decided, and this was not formally defined anywhere.

English Heritage had developed guidance for completing the 'virtual' builds in K2, setting up building sub-blocks and components for example, along with guidance in how to add component based data such as condition, significance or priority data, but there was no written, formalised information management process. In Chapter 7, sections 7.5.1 and 7.5.2, it was noted that following data capture stages information was not always successfully filed in the central common data environment. Further, following interviews with various stakeholders, a number of comments were made suggesting that the management of information was not wholly successful.

Considering English Heritage do have a dedicated team for survey and asset management data it is surprising that a formalised process is missing. It is suggested that implementation of the H-IM Workflow would address the failings with minor disruption to existing processes. It has been demonstrated that a large number of unknowns, human, and non-human actors can impact enrolment and mobilisation of new technologies and processes and so ongoing management of the implementation is required.

9.3 Reflection on research approach

The research approach was outlined in Chapter 4, and within that chapter some reflection was given to the chosen methods. Further reflection on the different methodologies adopted has been discussed in the previous sections. A final summary of the research approach used for this PhD is therefore provided here.

Given the successes in answering the research questions, it is clear that the chosen research approach was overall effective.

In the early stages of the research, significant time was spent in considering methods that would allow a successful understanding of some of the reported issues of failed attempts to implement best practice conservation maintenance strategies (Forster and Kayan, 2009a), along with barriers to implementation of BIM in a heritage context. Existing research fails to apply sufficient examination of network actors and the impacts they have on the implementation of new technology or process and so, ethnographic research offers a critical perspective.

Ethnographic research was new to the researcher and so research, literature review, and an initial case study at the English Heritage site, Witley Court, was conducted. This presented some challenges and limitations. Participant observation felt awkward and it wasn't always easy to identify what data to record or how this might help to successfully answer the research question. Accepting that one does not know what they will find out through this method at the outset of a project was difficult to accept.

The use of a range of methods was therefore chosen as this felt more comfortable. A combination of active participation and participant observation fitted in with the various types of access available, either as an employed member of one of the teams, or as a visitor to an organisation. Further, the use of formal and semiformal interview and document analysis provided a further level of data in response to specific questions.

The ANT 'process of translation' was useful in offering a framework and terminology to be used across the data analysis. The data presented is unique to an already limited bank of literature that considers conservation maintenance strategies and CRM planning.

Use of the BIM research framework to frame and position the research has been useful, particularly as a way to describe the scope of the research. It has allowed for a proposal to be made for a new HBIM research framework to be developed which will add significant contribution to this research field.

9.4 Research Limitations

In any research there are limitations. In this section the research limitations are presented with a short discussion, followed by how they were mitigated. In cases where mitigation was not possible, the resultant implications are discussed.

Limited specific literature

It is observed that there is limited specific literature in the field of heritage asset management or conservation maintenance strategies. This is acknowledged in earlier chapters where a heavy reliance on just a few academic papers that discuss these topics e.g. (Dann and Wood, 2004) is noted. These papers observe failings in the implementation of effective conservation maintenance strategies illustrating a topic requiring much more attention as addressed in this thesis.

While there was a lack of similar research, this thesis has found parallel sources from a broader range of literature such as O&M in the AEC industry more generally, and maintenance backlog from varied sectors such as petroleum and road/highway maintenance. Barriers to implementation are also reviewed in the wider literature. A focus on barriers to the implementation of digitisation within the AEC industry opened up parallel sources including; stakeholder groups, skills and attitudes and funding and resource. These were considered in the heritage context to draw conclusions regarding failings in the implementation of effective conservation maintenance strategies. Furthermore, the lack of specific literature has been addressed using direct observation and study of organisations responsible for the management of historic or existing buildings, and the structure and processes they adopt for such activities.

3 key organisations

The research has been limited to the study of 3 key organisations. When considering how organisations undertake asset management to allow a study of the challenges faced, a larger number of organisations would have provided breadth of data however, time would have restricted the depth of that data. To undertake significant study of any organisation takes time. Information is gathered over many months, following various activities, meetings, and so on, and so short visits would not provide the required level of data.

To mitigate this, in this research I adopted an approach of depth and detail as opposed to breadth. To gain this type of access to any organisation is not easy and so opportunities in which I was employed by the organisation, while limited, offered the best source of research data. Fortunately, I was already employed by English Heritage when the PhD began in October 2016 and after leaving in July 2017, the relationships that had been formed allowed me ongoing access to the organisation.

No strict plan

The approach taken in this PhD relied on the use of data that presented itself depending on the jobs in which I was employed, as opposed to having a strict research plan. This meant that at the outset of the research it was not clear how data would be gathered and which organisations would be studied. Further, required anonymity, or restrictions on the data that could be used for research purposes, is a limitation that has resulted in some sections of the thesis being less detailed than others. Descriptions of the organisations and their respective asset management processes in Chapter 5 for example has been limited as a result of this.

This type of approach is risky to research as it can delay the overall process or result in a need to change the focus depending on what research data can be obtained. Despite this, I was lucky enough to be able to take advantage of fortune alongside a determination to secure quality research data. It is only through this that I have been able to present this remarkable set of data.

The advertisement of the Heritage Programme Manager role for UKAHT was extremely well timed but it was not a given that I would win this contract, or that the organisation could be used as a research case study. I put in significant effort to bid for the contract and obtain consent to use the case for research study. Opportunely, the study of a heritage organisation responsible for historic buildings in Antarctica offered a unique angle that draws much needed attention to the topic within both academic literature and heritage industry journals, and is a major contribution of this work. Equally it provided a once in a lifetime opportunity for myself, and an additional passion for the research that will motivate ongoing engagement with the research, publication, and further research.

Criticisms of Actor Network Theory (ANT)

It was noted in Chapter 4 that the active participation research method adopted, partially as a result of the decision to study organisations by whom I was employed, combined with the ANT method of following the action may have led to bias. Having prior or detailed knowledge of an organisation may have influenced the 'action' that was studied and may have led to certain associations being missed. Criticisms of ANT note this subjective nature, allowing the researcher to choose which actors are important to the network. Furthermore, the idea that both human and non-human elements have the capacity to be actors with intentionality can be criticised.

This has been mitigated in the approach adopted. In the ANT network diagrams presented in Chapter 7, actors are brought into being through their associations, and so the concept of agency is employed without presupposing any intentionality (Sayes, 2014). Moreover, using this approach to consider why processes are not always followed has allowed the discovery that a network of socio-technical factors impact the implementation and adoption of new technology or process in often surprising and unexpected ways.

Figure 9.4 Joanna Hull and colleague on Stonington Island (Source: Joanna Hull)

Interviews

Finally, reflection in Chapter 4 noted that the interview methodology adopted, and small sample used, could be a limitation to this research. Interviews were selected to answer specific research questions which could again result in bias or, result in important information being missed. Furthermore, it was found that professionals with an understanding of both BIM and heritage within the networks available for direct/face to face interview were limited. While this reinforces the need for further research, engagement and education on the subject of HBIM, it also suggests a limitation in the approach.

Potential bias was mitigated in the use of the informal research technique, allowing discussions to take a number of directions to reveal potentially useful data however, this did not reveal any new or surprising information.

While the small number of interviewees is acknowledged, this was part of the mixed methods approach intended as a way of trangulating data gathered via the alternative methods, such as the K2 user guide or my observations in Antarctica. It is noted that the combination of the data gathered through the various methods has provided significant, detailed data for analysis that could only have been possible through this approach.

Stave off decay by daily care

9.5 Contribution to body of knowledge

In the reflections above research contributions to the existing body of knowledge are touched upon. Existing research themes to which this research offers significant contribution are noted and summarised here:

Implementation of new processes and technology

Conservation maintenance strategies

Heritage asset management

BIM for O&M

BIM for FM

Heritage BIM

In Chapter 1, section 1.7, key research contributions are summarised. It has been identified that this research provides both an academic contribution to existing bodies of knowledge as mentioned above, along with an important practitioner contribution. These contributions are now discussed in further detail.

Reconfiguring the relationship between BIM and the heritage sector

Throughout this thesis I have traced the development of heritage BIM (HBIM), referring to the emphasis on 3D parametric modelling that has been observed in the heritage BIM literature, and the related issues in detailed modelling of historic architectural components, the development of historical parametric object libraries, and the addition of historic building information to 3D parametric models. I have exposed flaws in these current approaches, considering the reasons for this, such as the nature of heritage stakeholders, digital skills and attitudes within the heritage sector and the need for improved digital skills among all stakeholders, and funding and resource within the field. Further, I have revealed that HBIM approaches dominated by a 3D modelling perspective is at the expense of simple, standardised and effective information management, which is ultimately the principal benefit of BIM and a key requirement for the heritage sector to support CRM planning.

This approach reconfigures the relationship between BIM and the heritage sector. A revised focus on simple, familiar and approachable digitisation methods to support information management is used to break down existing barriers where BIM is seen as an approach for 'specialists' only with particular BIM experience. The research clarifies differences between BIM tools such as hardware and software that are used in the development of 3D parametric models, and BIM as an accessible information management method. It identifies a need to define the range of HBIM applications and related challenges, and thus a critical need for the development of an HBIM research framework to avoid ongoing confusion around the HBIM definition, and to support the correct positioning of HBIM research within the literature.

Digitisation approaches for heritage asset management - drawing parallels from the wider AEC O&M field

Where most existing research has focused on the use of BIM to support conservation interventions, and thus the use of 3D models as a visual planning aid, I have chosen to offer a solution for the field of heritage asset management where conservation maintenance strategies have been identified to be failing.

I have taken one aspect of heritage asset management, CRM planning, and used it to delve in detail to the possibilities that BIM offers as a digitisation method, and what a new way of digital data management for the heritage sector might look like. I have drawn parallels from the operation and maintenance phase in the wider AEC sector (through literature review and the case study of Organisation A) to consider adoption of BIM information delivery and management principles to long term asset management, rather than individual projects. Using a socio-technical networks oriented approach I have revealed that a wide range of unknowns and surprises that cannot be predicted impact the implementation and adoption of new technology and process, such as BIM, across all contexts which must be taken into consideration.

The research offers a detailed summary of common approaches, challenges and inefficiencies in heritage asset management processes which are reflective of problems in the wider AEC domain. This offers a useful practitioner contribution that can support organisations in the development of their own heritage asset management processes by providing examples of effective methods and highlighting potential challenges so that these can be mitigated from the outset.

The heterogeneity of heritage assets

In Chapter 1 I described a range of heritage assets including not just scheduled monuments and listed buildings, but also seaside heritage, animal architecture and more. Further, I referred to the William Morris quote that called for the protection of buildings of all times and styles. The literature review conducted as part of this research demonstrated a limited scope in the type of heritage buildings studied to date. Often European churches or cathedrals, or substantial ancient ruins are the focus, with little attention to the less ‘typical’ buildings that fall within the much wider breadth of cultural heritage assets.

My unique data from Antarctica provides a significant contribution to knowledge in understanding the impact of the heterogeneity of heritage assets. It opens up a debate on the consequences of the breadth of heritage assets, demonstrating that while their heterogeneity is both distinctive and interesting, this also leads to logistical and practical problems that must be considered when developing conservation repair and maintenance programmes.

Furthermore, such heterogeneity, whether in the type of heritage asset, location, or otherwise, impacts digital processes in ways that cannot be predicted (as described above) and so a full appreciation of this is necessary before implementing digitisation methods.

Translating academic research into practical knowledge and practitioner guidance

My research has allowed me to translate a substantial body of academic research into practical knowledge that I have been able to disseminate to non-academics through various publications, such as industry journals, peer reviewed journal articles and technical/practitioner guidance. Translating academic research in this way will support the ongoing skills development of heritage practitioners.

Articles in industry journals provide vitally needed awareness of the opportunities and benefits of BIM methodologies for information management to support asset management. It has been demonstrated through this research that there is ongoing confusion around BIM (Ashworth, 2020), particularly in the heritage sector, and these articles help to provide some clarity, explaining the difference between BIM tools such as software and hardware, laser scanning and photogrammetry for example, and BIM methodologies and information management processes.

It has been noted throughout the research that to support implementation of new processes, such as the adoption of BIM information management approaches, stakeholders require support and guidance (Maxwell, 2016a). Technical guidance published by leading industry bodies or organisations such as Historic England, and the document published as a result of this research, provides this much needed guidance. The document has been well received, with over 3500 downloads in the first 18 months of publication. This demonstrates the industry's interest in this subject and should now be supported by further stakeholder engagement, training and support.

Presentations and lectures provide the required training and support to ensure the heritage industry understand the benefits of BIM, and to clarify confusion surrounding BIM terminology, tools and methods. The presentations/lectures delivered as an output of this research have made positive steps to support the implementation of BIM information management processes in a heritage context.

Significant outputs that have supported the dissemination of this academic research are summarised below:

Industry journal articles

Understanding the Potential of BIM to support Heritage Asset Management –Geomatics World, May 2019

3D BIM Models for Heritage Asset Management – GIM International, January 2020

BIM for Heritage Asset Management – Context (The Journal of the Institute of HistoricBuilding Conservation), June 2021

Peer reviewed journal articles

Conservation Data Parameters for BIM-enabled Heritage Asset Management – Automation in Construction (Hull and Ewart, 2020)

Technical guidance

BIM for Heritage: Developing the Asset Information Model - Historic England (Hull andBryan, 2019)

Presentations/Lectures

Heritage BIM – Building Information Modelling for the Historic Environment - Historic England, 2018

Managing data for heritage building conservation – Online Lecture - University of Reading, School of the Built Environment, November 2020

Development of the BIM information delivery cycle for the heritage sector

The H-IM Workflow has been developed to introduce 4 new steps to the existing ISO 19650 BIM Information Delivery Cycle that are required to support BIM adoption by the heritage sector. While ISO 19650-3:2020 sets out the requirements for information management using BIM during the operational phase of an asset's life, and can be used for any type or size of building, and any organisation, guidance has not been specifically aimed at heritage professionals.

To date BIM has been considered a specialist subject by heritage professionals, and a perceived lack of skills, knowledge and experience are considered barriers to the implementation of such digitisation methods. The H-IM Workflow is an original contribution that is critically based on the existing BIM information delivery cycle and provides 4 simple steps that do not require input from specialists to implement. Furthermore, given the observed issues with both digital skills and funding in the heritage sector, the 4 steps offer a feasible solution to support improved information management for CRM planning in the heritage sector.

9.6 Future research

Throughout the thesis the research scope has been defined and areas for future research have been identified.

In Chapter 1 high costs of CRM, and issues of limited funding were considered a challenge that could benefit from the implementation of conservation maintenance strategies. The research focuses on the adoption of digitisation methods to achieve efficiencies where budgets are limited, but through literature review a brief review of opportunities for supplemental funding for heritage conservation was discussed (section 1.2). It was noted that it is perhaps public spirited benevolence (Throsby, 2012) that offers the biggest opportunities for the funding of heritage projects, and research has considered models that seek to achieve many, but relatively small contributions to targeted projects, to realise much larger donations (Dimitriyadis *et al*, 2012).

This crowdfunding type approach is seeing bigger traction in the sector (Child *et al.*, 2017; Marchegiani, 2018; Jelinčić and Šveb, 2021), and opportunities to donate to specific conservation projects are often incorporated into stakeholder engagement activity delivered by heritage trusts. The English Heritage 'Conservation in Action' initiative noted in Chapter 5, section 5.3.2, is one example of this approach, and the Arti.City project has been developed based on a global crowdfunding platform for heritage restoration in Venice (Child *et al.*, 2017).

While it is not suggested here that further research into crowdfunding or stakeholder engagement for the funding of specific cultural heritage restoration projects is required, crowdfunding opportunities to supplement budgets for wider scale, or longer term maintenance projects could be beneficial and so deserve consideration in future research. The cost of regular maintenance is more economical than irregular project work yet funding generally focuses on the 'one off' projects. In a study of asset management failure within the public sector (Chapter 2, section 2.3), it was noted that a similar lack of incentive for maintenance strategies was evident due to media and political preference for new build, or large projects, compared to maintenance (Giglio *et al.*, 2018).

In Europe, initiatives that offer grants and subsidies for the maintenance of heritage assets have been successful but the failure of a UK maintenance grant initiative – Maintain our Heritage (Chapter 3, section 3.1.3), suggested a culture within the UK that does not value maintenance. It was noted in Chapters 1 and 3 that formalised processes and frameworks for conservation and maintenance management of the built historic environment are lacking and this research has relied on just a few papers that research this specific topic. While this research presents one option for improvements in heritage maintenance programmes, focusing on simple, cost effective and feasible information management processes that could be standardised across the industry, alternative options should be considered.

It was discussed, particularly in relation to English Heritage, that heritage asset management strategies rely on the collection and management of condition/defect data to understand maintenance backlog and prioritise and plan CRM programmes. Cyclical survey programmes for large estates are resource heavy in both cost and labour. Future research should consider alternative ways to plan and prioritise maintenance programmes, either using alternative data parameters, or using volunteer resource to collect up to date information on the condition of historic buildings. The volunteer contingent is high within the heritage field so could offer further benefits to more strategic activities. Citizen science research could be considered to investigate this further. A programme launched by Historic England to allow the public to carry out simple condition surveys on Grade 2 listed buildings using a standard survey template could have offered huge benefits but with these buildings often in private ownership, the focus was flawed, and results and the current status of this initiative are not publicly available. A similar initiative for visitors or volunteers to large historic estates, such as English Heritage or the National Trust could support the organisation's heritage asset management strategies.

A similar option was considered and discussed with UKAHT and polar tourism operators during this research. I had no authority at the time to investigate this further in connection with UKAHT, but it does present an opportunity that I would like to explore further on completion of the PhD. The unique nature of the Antarctic research huts, and the particularly remote location, presents significant challenges to UKAHT in their heritage management programme. There is significant cost involved in accessing the huts to carry out survey and thus plan for CRM programmes. Citizen science programmes are common on polar cruises so the more frequent visiting tourists could be a valuable resource to support the collection of condition/defect information to support CRM planning. A sample inspection proforma was created in the course of this research and is attached at Appendix 6.

In Chapter 2, section 2.6, emerging technology and alternative digitisation methods such as digital twins were discussed. It was noted that digital twins may offer benefits where BIM has shown limitations. It was stated that the scope of this research was limited to BIM as a digitisation approach for the heritage sector. Digital twins may offer benefits in the management and updating of 'as-is' building information which is required to ensure accurate and up to data information is used for maintenance planning. The ability of digital twins to integrate various data sources such as Internet of Things (IoT) connected building systems, and to automate these processes through the use of point cloud data and machine learning, offers centralised access to the accurate, real time operational state of a building (Stojanovic *et al.*, 2018). In the field of facilities management there is ongoing research into this potential (Lu *et al.*, 2020; Götz *et al.*, 2020). However, the potential of digital twins to support CRM planning is an area ripe for future research.

The use of point clouds, rather than parametric models could be an advantage where the heritage industry has experienced barriers due to the complexities of modelling unique historical architectural features. Further, the use of sensors and IoT could allow live data to be modelled in relation to historic fabric degradation, the weathering of stone facades for example, or for structural monitoring. Research has begun to consider this, as described in Chapter 3, section 3.4. While the Jewel Tower, London, case study was based on parametric models, the use of weather forecasting models and other monitoring sensors and models could be used in a heritage digital twin.

It is suggested that for the purposes of CRM planning in the heritage context, the use of digital twins is limited. Where traditional facilities and asset management deals with assets such as plant, from which real time data could be accessed, CRM is based on significance based planned and preventative maintenance of historic fabric. It was described in Chapter 5 that a matrix of conservation data parameters that include *significance, risk, condition* and *vulnerability* are used to plan CRM programmes. These parameters are subjective, rather than factual data that can be obtained through sensors so it begs the question, how could this data be automated through the use of digital twins?

While digital twins do not offer a simple solution to support CRM planning, there may be other significant benefits and so this area should be researched further.

The areas for future research discussed above cover a range of topics that have been discussed in this research. They cover opportunities to improve heritage asset management and CRM planning, including funding, citizen science, and alternative BIM application such as the addition of conservation data parameters to 3D parametric models. However, one of the key areas identified for future research is the development of an HBIM research framework, similar to one that has been developed for the wider BIM field (Succar, 2009). There is confusion in the literature around the definition of HBIM. While some research applies this to the development of parametric object libraries of historic architectural components, others discuss the development of information rich 3D models. As has been demonstrated, focus leans towards 3D modelling, software and hardware used in the BIM process. Further, while this research is clearly targeted at CRM planning, other HBIM research is about conservation intervention, adaptive reuse for example, digital archiving, or visualisation and engagement.

If an HBIM research framework existed categories in the existing framework could be adjusted to suit the context. This has not been researched as part of this PhD and is not a complete or final list however, an initial suggestion is offered as a starting point in Table 9.3.

Table 9.3 Suggestions for an HBIM research framework

BIM Field	**HBIM Field**
Technology	Technology
Process	Process
Policy	Policy
BIM Stage	**HBIM Stage**
Stage 1: object based modelling	Stage 1: digitisation strategy
Stage 2: model based collaboration	Stage 2: adoption of the H-IM Workflow
Stage 3: network based integration	Stage 3: 3D data capture
	Stage 4: object based modelling
	Stage 5: model based collaboration
	Stage 6: network based integration
BIM Lens	**HBIM Lens**
Selected aspect of the AEC industry	Digitisation of historic building or estate
	Library of historical parametric objects
	Information rich 3D models
	Model simulations – structural / deterioration
	Conservation intervention
	CRM planning
	Engagement and Educations

As can be seen, the BIM and HBIM Fields are identical however, the HBIM Stages and HBIM Lens’ could be altered to make them more applicable to the heritage context. Additional HBIM stages are added to support a ‘Back to BIM basics’ approach. Addition of the digitisation strategy, adoption of the H-IM Workflow, and 3D data capture are the simple steps that the heritage industry needs to consider to understand their future BIM requirements.

BIM lens’ in the BIM research framework might cover any aspect of the AEC industry. The same is applicable for the HBIM lens but a number of suggestions are provided here based on the literature review completed as part of this research.

While the use of the BIM research framework was useful in positioning this research, if an HBIM research framework had been defined, this research could be clearly positioned in the *process field, Stage 2: develop information management process,* and *CRM planning lens* allowing other academics in the heritage field to unambiguously search for relevant research, and distinctly categorise their own research.

9.7 Final thoughts

Having developed a career in heritage and on ongoing passion for the built historic environment, I have been extremely grateful for the opportunity to study opportunities for development in the sector and contribute a significant body knowledge to the research field.

Through this 5 year research project, a deep understanding of the building information modelling (BIM) digitisation approach has been gained. In particular, the various steps in a BIM approach, technology and tools, application examples, and the various stakeholders engaged inboth BIM and heritage processes, and their knowledge, attitudes and skills to these subjects.

The success of this research in demonstrating how digitisation can support conservation professionals in efficient and effective CRM planning consequently provides a significant practitioner contribution. Development of the H-IM Workflow, along with a standard set of conservation data parameters and the HIR_OIR_V1 and HIR_AIR_V1 templates meets the request of COTAC in their 2016 report (Maxwell, 2016a). This is the first UK Heritage BIM research that specifically addresses the need for improved conservation maintenance strategies and offers a solution based on feasibility, taking into consideration heritage stakeholders, skills, attitudes and funding. I am proud to have been able to produce the first research in the UK to offer free, publicly available guidance and templates that assist the adoption of BIM to support digitisation and information management for heritage asset management.

This thesis started by reflecting on preventative conservation repair and maintenance which has become a well embedded practice within conservation philosophy following the plea of the great William Morris to ‘stave off decay by daily care’ (Morris, 1887). A notion of ‘digital decay’ was introduced, the result of the neglect of digital assets, causing loss of coherence and structure. Observing that CRM planning relies heavily on real time, accurate data, ‘digital decay’ could have serious impacts on the future protection of historic buildings. This research has shown that over 100 years after the publication of the SPAB Manifesto and that historic plea, the ‘stave off decay by daily care’ principle applies equally as a modern plea for the preservation of digital assets. It presents a lesson from the past that should guide and inspire our approach to the future, demonstrating a critical requirement for the heritage industry to adopt the H-IM Workflow as a standardised approach to information management.

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Appendices

Referenced on:

Appendix 1 – BIM and Heritage Professionals Prepared Interview Questions

Research Interview Questions

Edonis Jesus - Lendlease

22/08/18

Consent Form: YES

- What does BIM mean to you?
- How do you think Heritage BIM differs?
- What outputs would you expect to deliver / receive from an HBIM led project?
- If you have undertaken a BIM or HBIM led project, can you describe your experience – did the project deliver what you expected? Did you experience any difficulties? What worked well?
- In your experience, how have you found the interaction between project stakeholders and new technology such as HBIM and what effect has this had on the development or implementation of such technology within your organisation?
- How do you think BIM technology and processes could improve / facilitate digital data management for conservation, repair and maintenance activities - do you have any examples?
- What is your understanding of how BIM technology and process is used in the operational / management phase of a building – specifically for historic buildings?
- Do you, or does your client, intend to use data collated during an HBIM led project for ongoing asset management?
- How will this data be managed – is there an existing asset management or CAFM system?
- What involvement do you have in developing EIRs and, what consideration is given to existing data management systems, naming conventions, classification, required data parameters etc in the development of EIRs?

Appendix 2 – UKAHT Example Task Schedule

KEY		TASK		
	repairs	**T12**	**Condition Survey and prioritize tasks**	**Assess and plan for further detailed investigation and emergency repairs** To appraise, plan and prioritize work within the time and resources available

Task	Task description	Items included	Tools/equipment	Safety
T12.1	**Initial appraisal**	**Purpose of appraisal** To appraise, plan and prioritize work within the time and resources available To provide UKAHT with an outline record of the condition and construction of the buildings, structures and contents To establish a priority for a more detailed survey of areas considered to be in need of emergency repair and/or longer-term repair and maintenance (T20-24). Emergency repairs are to be prioritized The investigation should assess stability and weather tightness as top priorities **Emergency repairs only** are proposed for this trip, and assimilating adequate information to plan for future work **Purpose of repairs** To prevent ingress of snow, wind, rain and wildlife and reduce rate of decay until full repairs can be implemented in the future. Temporary repairs only are planned for this season. These will be followed by a fuller project of conservation based on information gathered in 2018. In the outbuildings rapid decay has set in due to ingress of snow, wind and rain and therefore planned maintenance is included but the team needs to prioritize the work after this initial assessment **Note re. East Base** At East Base emergency works are not planned but this should be appraised by the team and if emergency propping for example is needed then this may be planned during the trip		Sea, landscape, w
T12.2	**Roof initial assessment** Base Hut Generator Shed Pup pens Emergency Store	**Roof assessment** to establish priority for further detailed investigation and emergency repairs (T20) and to inform planned further work in the future, to prevent ingress of water snow and wind, to leave the buildings secure until longer-term conservation work can take place **Method of Appraisal** Initially appraise the condition of the roof of each building, by eye and using binoculars and/or telephoto lens. Investigate internal damp areas where internal staining or water penetration has occurred, follow the source back to the outside and inspect whether felt has lifted or come apart at edges; identify likely locations for roofing or flashing failure and mark on plan Check each hut in turn; make an initial appraisal before any detailed recording to be undertaken in T20. **Risk Assessment** Plan to access by ladder / scaffold any areas that might require attention to assess fully. Plan safe access and method **Safe access (weather dependent)** Provide access to investigate from safe ladder or scaffold. Carry out a more detailed inspection to plan for any emergency work and record further work needed in T20 **Ruberoid felt** Note the locations of any fragments that look as though they might be from earlier coverings in Ruberoid and plan for sampling any suspected asbestos **Condition Appraisal** Check roof, flues, flashings, verges, abutments and fixings. Pay attention to all joints. Mark up plans adequate to plan the work. Detailed assessment and recording will be carried out as task T20 (carpentry and roofing), T22 (flues), T23 (structure), T24 (guy wires) **Base Hut** The main building two-storey roof was built in 1961 with Ruberoid which may have contained asbestos, coated in tar and battens. The tar was regularly re-applied and the roof patched or re-felted during the period of occupation until 1975. Regular inspection and maintenance are now limited by the difficulties of access. Emergency repairs to roofs and flues were carried out by BAS in 2014 and they reported that "*most of the felt is perished to a degree"* **All buildings** Assess condition of felt, battens, flashings, etc. from the ground then detailed assessment from the roof as stated above **East Base**: Roof access is not envisaged as it is known that these huts are in need of repair but emergency repairs and detailed investigation are excluded from this year's scope **After the inspection** Make an initial assessment of the time needed for detailed in investigation/emergency repair/detailed recording to allow future work. Prioritize the further investigations and emergency work to be carried out in T20-24 Re-programme to suit. Amend the programme and plan the work to suit other tasks as this may affect the whole team		**Asbestos** **Base Hut roof**: I the original Rube have contained as assumed the orig removed before re is possible that tra could remain. **Outbuildings**: R coverings are like Ruberoid contain take all necessary and adhere to all in training & see T
T12.3	**Guy wire initial assessment** Base Hut	**Method** Assess visible signs of damage: Check for signs of leaning structures. Check steel cable anchors, cables, hausers, eye bolts, associated foundations and timber blocks. Inspect and assess where further investigation / temporary repairs are required. Plan temporary repair work	Camera + Telephoto zoom lens / binoculars; May require ladder and stays to secure or tower scaffold; plan safe access	Working at height PPE Don't carry out in

Appendix 3 - UKAHT SharePoint File Structure

Future Recommendations Reports – all coded correctly

Received from Al, Geoff and Michael and re-coded

This PC ▸ Seagate Backup Plus Drive (F:) ▸ Consultancy ▸ Clients ▸ UKAHT ▸ Stonington ▸ Stoningto

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FW_E_B2_ChippyShopRoof_GC_2017-18	2/10/2018 5:40 PM	Microsoft Word D...	1,407 K
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FW_E_B2_Rigging_AF_2017-18	1/29/2018 2:31 PM	Microsoft Word D...	3,857 K

Conservation Worksheets – all coded correctly

Received from Al, Geoff and Michael and re-coded

e View

his PC ▸ Seagate Backup Plus Drive (F:) ▸ Consultancy ▸ Clients ▸ UKAHT ▸ Stonington ▸ Stonington_

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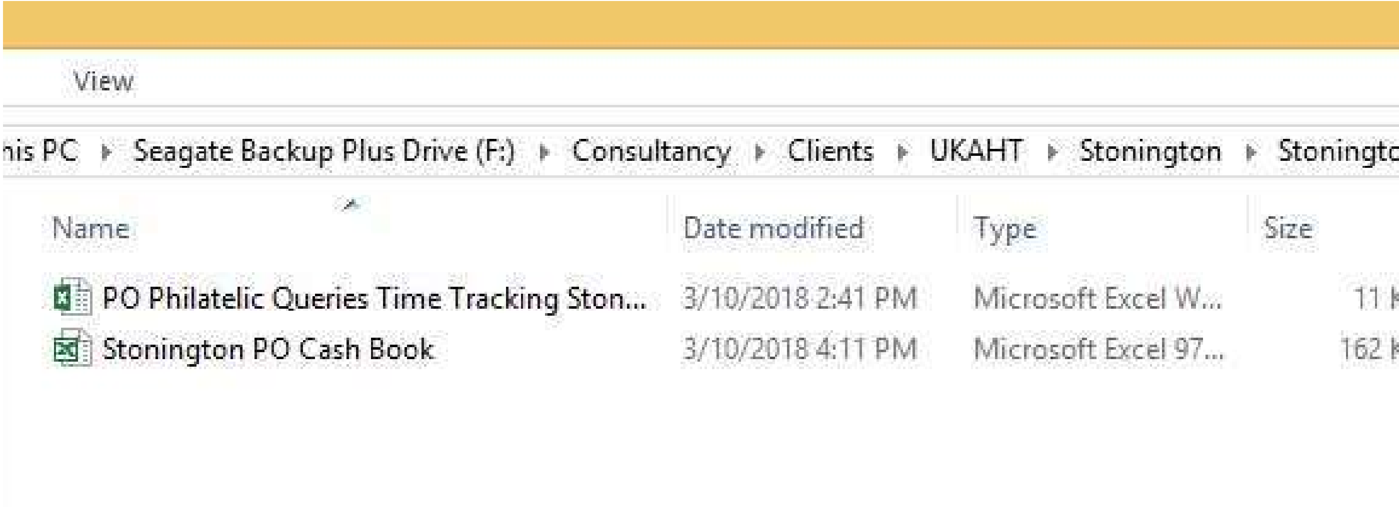
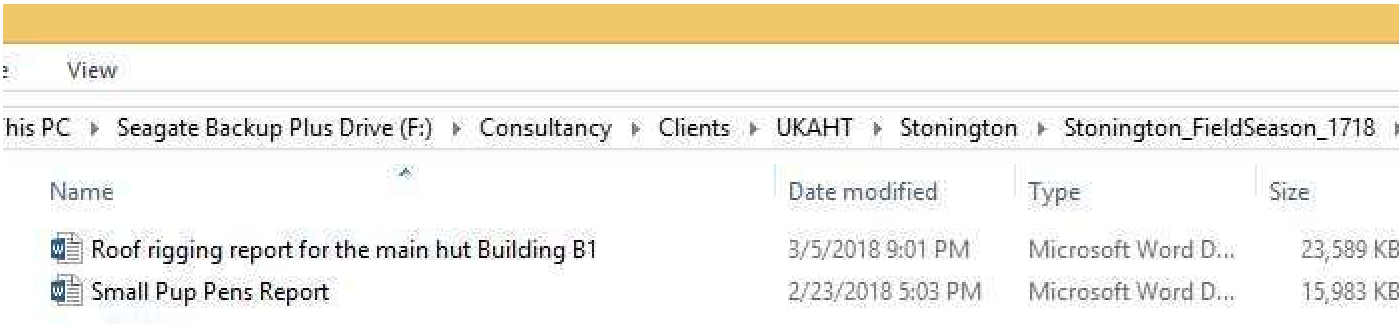
CW_E_B2_Exterior Cladding_AF_2017-18	1/27/2018 8:55 PM	Microsoft Word D...	7,531 KB
CW_E_B2_Glazing_MDP_2017-18	2/10/2018 3:51 PM	Microsoft Word D...	1,046 KB
CW_E_B2_R4RoofRepair_MDP_2017-18	2/24/2018 8:54 PM	Microsoft Word D...	662 KB
CW_E_B2_Rigging_AF_2017-18	1/27/2018 9:12 PM	Microsoft Word D...	3,854 KB

Post Office

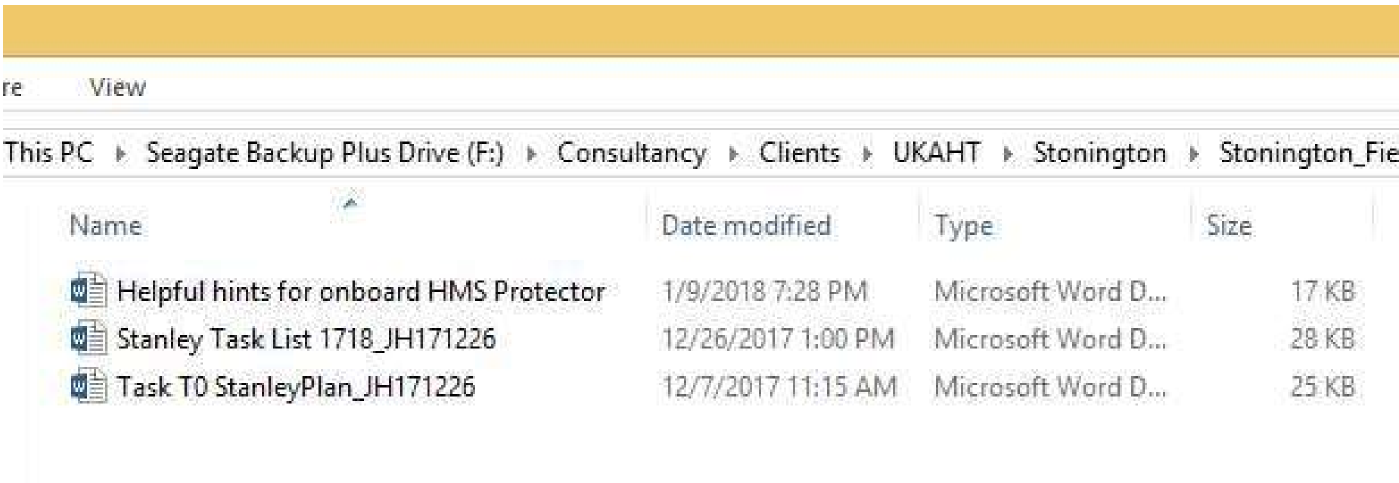
Stave off decay by daily care



Reports



Task Document Uploads - T0



T3 – Datalogger Readings

T3_Dataloggers

are View

This PC ▸ Seagate Backup Plus Drive (F:) ▸ Consultancy ▸ Clients ▸ UKAHT ▸ Stonington ▸ Stonington_FieldSeason_1718 ▸ Tasks ▸ T3_Dataloggers

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BaseE_13	3/14/2018 4:48 PM	JPEG image	106 KB
BaseE_13	3/14/2018 4:47 PM	Text Document	12 KB
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GenShed_13	3/14/2018 6:45 PM	Text Document	2 KB

T5 – Gazetteer (MASTER)

View

his PC ▸ Seagate Backup Plus Drive (F:) ▸ Consultancy ▸ Clients ▸ UKAHT ▸ Stonington ▸ Stonington_FieldSeason_

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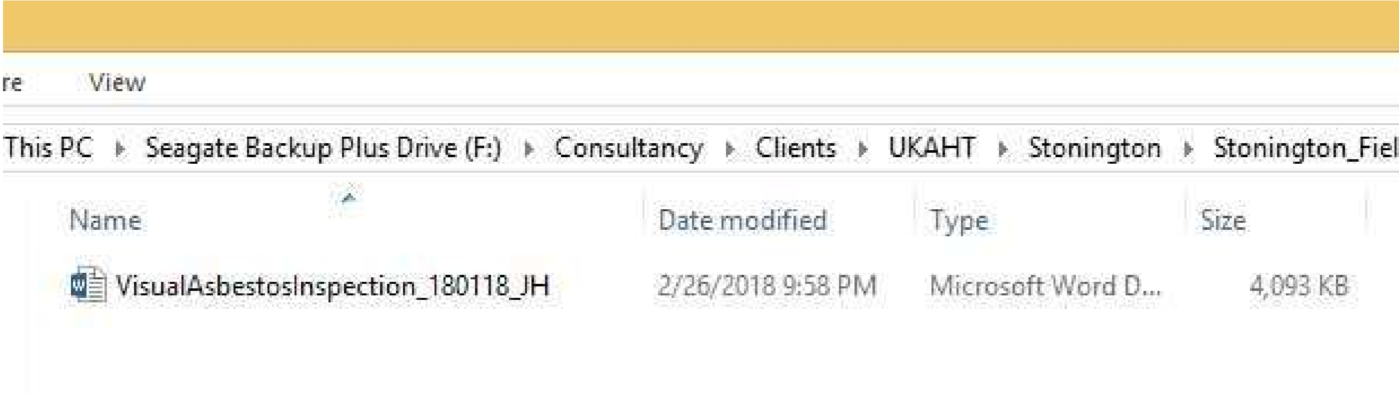
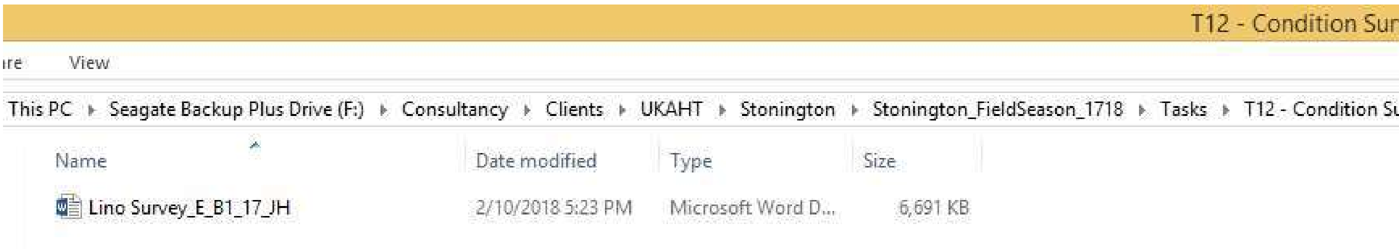
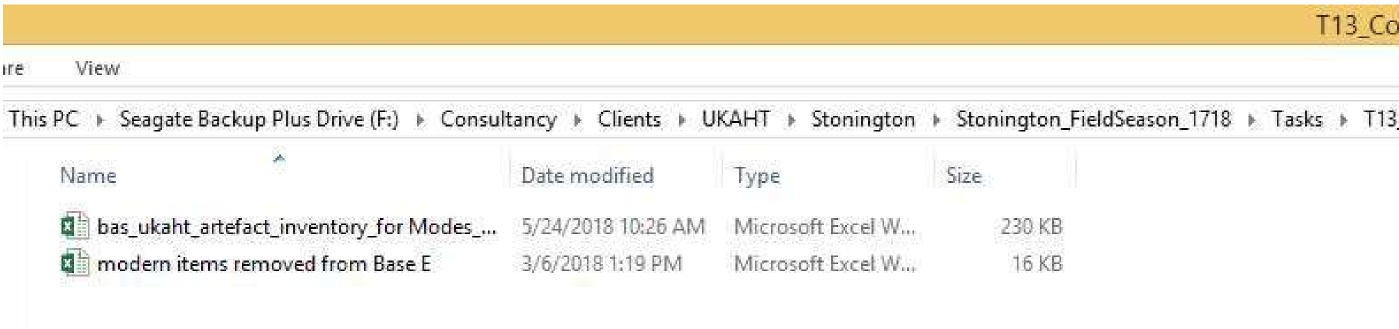


T12 – Condition Survey

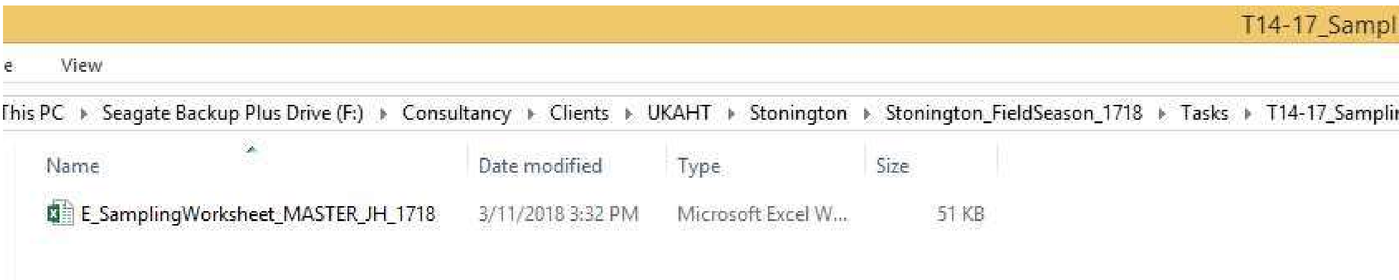


T13 – Collections Audit (Lizzie's master spreadsheet and my spreadsheet of modern items)

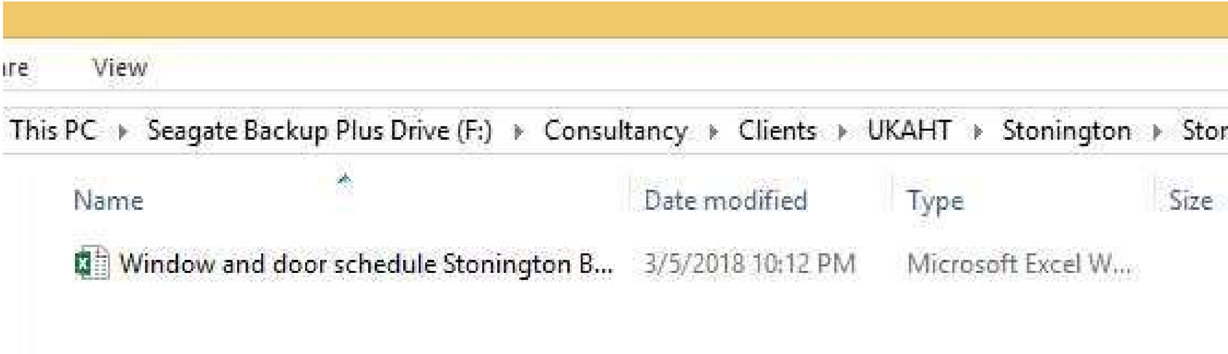
In addition to this Lizzie had uploaded all of her photos and reports which do seem to be there



T14-17 Sampling – MASTER spreadsheet

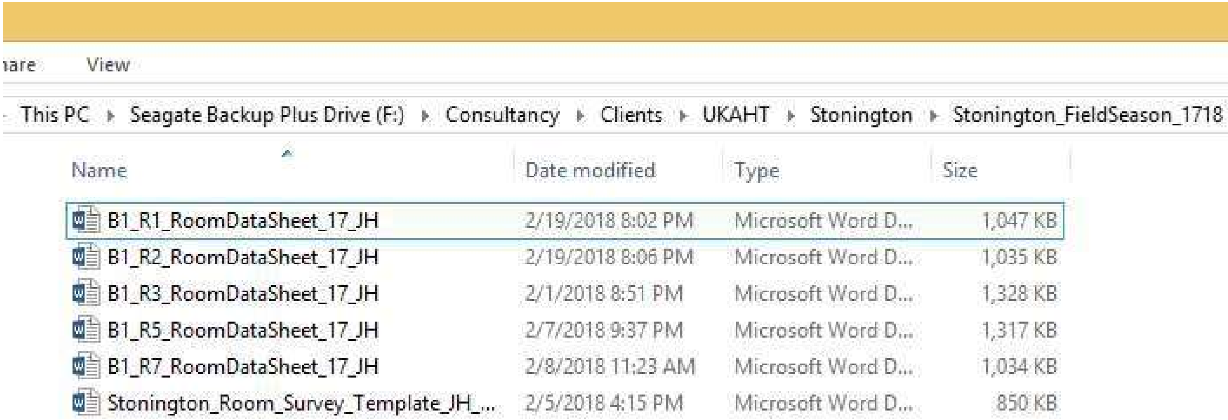


T18 – Window and Door Schedules



T19 – Room Data Sheets

I had uploaded the ones that I managed to type up on site. The rest are awaiting typing up and uploading as discussed yesterday.



Appendix 4 - UKAHT Field Diary Entry 24/02/2018

Daily Field Diary: 2017/18 Stonington Island

Date: 24/02/18

Location: Weatherhaven Tent – Stonington Island

Weather:

Time: 07:35

Temperature: 3

Wind direction: ESE 10-15kts

Visibility: Unrestricted

Cloud cover: 7/8ths

Weather: Windy

Daily Work Programme:

Name	
Joanna Hull: **Room surveys** **Window photos (INT)** **Typing up reports**	
Torbjorn Opheim: **Contact ship** **Base E – chopping ice** **Philatelic Mail** **Moving items to East Base (Michael & Geoff to discuss with Toby – Felt/Wood/Battens)** **Planning for roof work access**	
Michael Powell: **Report writing** **Genny shed roof** **Pup Pens** **Glazing complete**	
Geoff Cooper: **Report writing continued – none complete yet.** **Coal shute** **Flues** **Doors – Main Hut & Genny Shed** **Main Hut - Refelting**	
Lizzie Meek: **Additional photos and hut and completing tasks.** **Modern items report sent to Camilla.**	

Health and Safety Issues/ New Hazards Identified/Mitigation Measures: **Fire Alarm fell off the tent pole and nearly hit Geoff on the head. Toby to re-fix it somewhere else.** **Knobs on the stove are quite dodgy (Lizzie) – noted that they are loose and sticking etc. Maybe use matches to light instead as we can't risk not having a stove that works.**
'Accident/Incident/Near miss': **Near miss – fire alarm nearly hit Geoff.**
Environmental Issues/ Mitigation Measures: **Getting darker – nights are dark.** **Windy today – be careful of loss to the environment**
Artefact Risk Mitigation Measures: **Lizzie asked Toby if he has found anything whilst chopping ice – no. Just logs.**
Camp Tasks & House Mouse:
Other Issues/Things to remember/Comments:
Messages Received: **Nothing new.**
Messages to Send: **Guy – Blog** **Toby to email the Expedition.**
Quote of the Day:

Visitors to site	0	Waste disposed	0	ASPA entry	

Appendix 5 - UKAHT Conservation Intervention Proposal

CONSERVATION REPAIR / INTERVENTION PROPOSAL
STAGE 1 - SUPPORTING DOCUMENTATION

HSM 61: Bransfield House, Port Lockroy

PROPOSAL: SUPPLY AND FIT TIMBER WINDOW SHUTTERS

APPLICANT: JOANNA HULL – HERITAGE PROGRAMME MANAGER

DATE: 24/05/2018

1.0 Introduction

Brief scope of works and rationale for proposal:

A number of windows to the HSM's on the Antarctic Peninsula are protected by timber window shutters:

- Base Y, Horseshoe Island
- Base E, Stonington Island
- Damoy refuge, Dorian Bay
- Base W, Detaille Island

Window shutters were made for Base E, Stonington Island when the base closed permanently in 1974. These match the South Georgia prefabricated new generator shed shutters, with horizontal timber boarding and top and bottom rail. Ex-BAS employee and UKAHT Conservation Carpenter, Michael Powell commented that these are good shutters although they do have exposed end grain. Despite this, the shutters appear to be in good condition and have protected the windows well.

The following extract is taken from the #StoningtonDiaries blog from the 17/18 field season at Stonington Island and highlights the significance of the shutters in the history of the base in terms of preventative measures and historic interest:

"When one of the guests visiting Stonington Island recently was the ex-FID Terence 'Scobie' Pye, it was the perfect opportunity to quiz him for answers to puzzles that have bugged us. In my case, it was 'why were the windows shutters for Base E made in South Georgia, and how is it they fitted so exactly?'. Totally down-playing his own skills he replied, "why, I made the shutters out of timber from South Georgia from measurements sent to me". No easy job that, to get the shutters so accurate when working at a distance. He was so pleased to see that his workmanship had, after over 40yrs of Antarctic weather, saved the base from much dereliction. It was great to speak to him and see how he smiled whilst reliving happy memories. He'd like to pass on his best regards to ex fids Dave Burkitt, Dave Fletcher and Steve Wormald. Michael – 01/03/2018"

Where shutters exist they are often removed each season by expedition leaders on board IAATO tourist vessels or by visiting yachts to allow light into the huts during their visits and, replaced at the end of their visit.

Surveys carried out during our conservation field season to Stonington Island in 17/18 noted that the timber window frames, along with the glazing, were in a particularly good condition given the lack of routine maintenance and the harsh weather conditions. It is likely that this is due to protection afforded to the windows by the timber shutters that have been in situ almost entirely permanently since the base closed in 1974.
Similary, during the 16/17 field season, it was noted that the condition of windows at Base Y was generally good. Although paint was flaking, timber was in good condition.

The historic buildings comprising the Port Lockroy site do not have shutters protecting the windows. Whilst the site is operated for 4 months each year and the windows need to be uncovered, the remaining 8 months do not see visitors to the hut. In addition, the building fabric is subject to cold and wet weather, repeated wetting and drying cycles to the timber and, UV impact on the historic interiors and artefacts. During inspection during the 17/18 field season it was noted that the windows are in a very poor condition.

Following repairs to bring the windows up to a good standard, it is proposed that timber shutters are fitted in order to :

- protect historic and new building fabric, interiors and artefacts
- improve the longevity of timber finishes such as paint and as such, mitigate the risk of deterioration to historic and new timber
- reduce risk of damage to glazing and glazing putty

The same is also true for Wordie House, which too has no shutters and is subject to similar climatic pressures.

2.0 Statement of significance

Extract from Conservation Management Plan / Gazetteer
Designated as an Historic Monument under the Antarctic Treaty 1994; The highest scoring base for its historic importance as being one of 2 bases established in the first year of Operation Tabarin, the best of the surviving bases from Operation Tabarin, and for important scientific research 1944-1962. Recommendation 1: …"that it be conserved and actively managed as an historic site so that it survives for the education and enjoyment of visitors"

Historical Development
Port Lockroy underwent a full conservation/restoration project in 1996, and has been well maintained annually since.

The windows are a mix of historic fabric and new:

New Genny shed/shop window 3 is new - installed in 2008-09
Bunkroom windows 14 and 15 are new - installed in 2010-11
Kitchen window 17 is new - installed in 2010-11

The remaining window frames are thought to date from the different dates of construction: 1944, 1953 and 1959-61.
(W18 and 21 may date from 1944 but the other 1944 windows have been replaced in 2010-11)

Whether new or historic fabric, the historical significance of this site and designation recommendation to 'conserve and actively manage' requires the building to be maintained to a high standard. Preventative measures that mitigate the risk of deterioration to building fabric should be considered of high importance.

Impacts on significance

The proposed timber shutters will be designed to be in keeping with the aesthetics of the historic monuments, using tongue and groove timber boarding or ply panels in line with the typical construction of these buildings and, existing shutters found at sites on the peninsula (see photos from Base E, Stonington

Island, Section 5.0 and Base Y, Horsehoe Island) thus, mitigating risks to architectural interest.

For the majority of visitors the shutters will not be in-situ. However, when they are fixed at the end of the season this should be seen as a positive intervention in the active management and conservation of the site and provide an opportunity to educate in conservation practice and intervention.

Small fixings into timber cover strips surrounding the windows will be used to minimise damage to building fabric. The intervention will be reversible in the sense that shutters can be removed in the future should an alternative and preferred solution be developed. Whilst small holes will be present in the timber cover strips, these could be filled or replaced at a later date if required.

The addition of timber shutters at Port Lockroy, and later at Wordie House, would enhance the evidential significance through protecting the longevity of an historic monument.

3.0 Condition Survey Summary

Below is an extract from the 17/18 field season at Port Lockroy. This information has been provided by the Port Lockroy team rather than the conservation team:

External Windows:
Flaking paint, loose putty, several windows in bad condition, rotten, algae beneath paint. E-wall windows have been scraped back. N-wall windows on left handside of the entrance and the porch windows have been scraped back and loose putty removed. New temporary putty in place
When rain and NE wind, the windows in the shop leak with water ingress

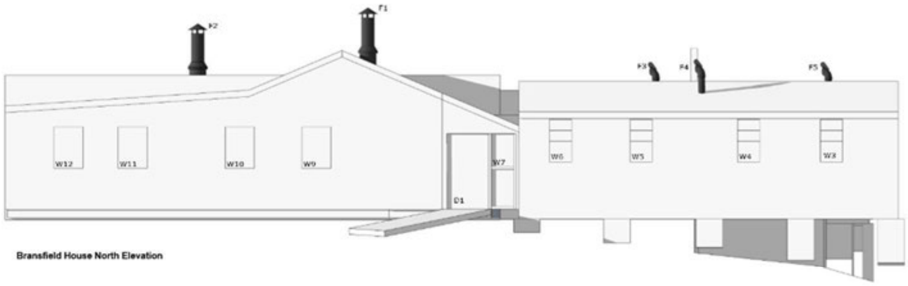
In the 18/19 season, the conservation team will visit PL to carry out necessary window repairs and adjustments to reduce leaks and water ingress. Any rotten timber will be cut out and replaced.

Options for timber treatments to windows, paint systems and glazing putty are being explored. Materials will be specified for the season and material trials and sample panels will be completed as required.

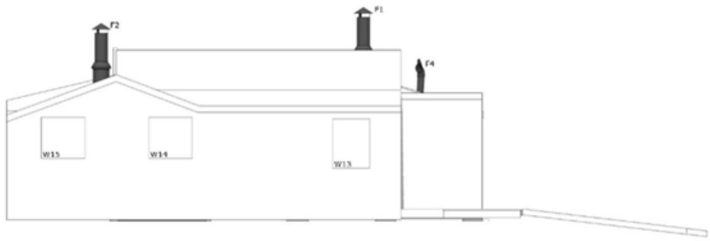
The addition of timber shutters is believed to be beneficial in mitigating the risk of ongoing deterioration of the conservation repairs and should be considered a requirement of active conservation and management of the site.

4.0 Plans and Drawings to illustrate

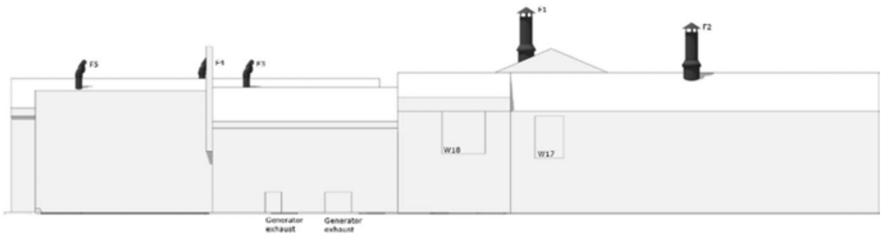
Elevation drawings illustrate the windows to Bransfield House that will require shutters:



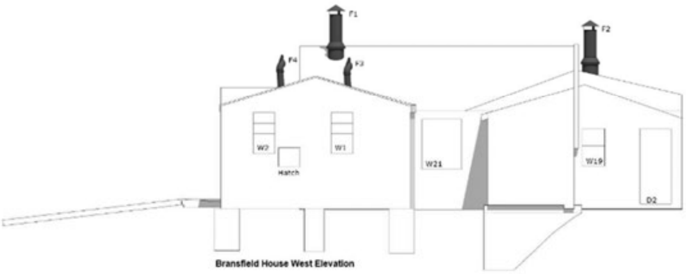
Bransfield House North Elevation



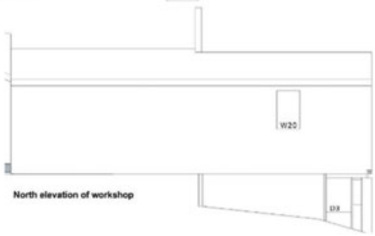
Bransfield House East Elevation



Bransfield House South Elevation



Bransfield House West Elevation



North elevation of workshop

Drawing No. A_A_01_XX_XX_GA Prototype window shutter for review, (attached), illustrates the window types present across a number of HSM's and a design proposal for new window shutters to be installed at Port Lockroy.

5.0 Reference Photographs

Shutters at Base E, Stonington Island

New Generator Shed, Stonington shutters prefabricated in South Georgia that could be used as a prototype

6.0 Outline specification of works

- Give brief outline specification / schedule of proposed works
  To be completed by Architects / Conservation Carpenter

Scheme now available and to be reviewed by carpenters before the Design Team review and approval process.

7.0 Justification Statement

This document has been developed with Historic England's Conservation Principles 2017 in mind.

Principle 1 – The historic environment is of value to us all

Principle 2 - Everyone should be able to participate in sustaining the historic environment

Principle 3 – Understanding the significance of heritage assets is the starting point for effective conservation

Principle 4 - Heritage assets should be managed to sustain their heritage values

Principle 5 - Decisions about change need to be reasonable, transparent and consistent

Principle 6 - Documenting and learning from decisions is essential to inform future management

The UKAHT conservation intervention or repair 2 stage process involves the development of proposals based on a thorough understanding and acknowledgement of the significance of each heritage asset. Through wider engagement with stakeholders including visitors to Antarctic HSM's, FIDs and UKAHT members we are able to explore the significance that different people place on these heritage assets. We promote our conservation programme through a variety of channels giving stakeholders the opportunity to engage with our work.

Stage 1 proposals for conservation intervention or repair are developed with the application of expertise, experience and judgement. A range of experts including surveyors, architects, conservation carpenters, ex-base staff and Antarctic building specialists are involved in the development of proposals.

Stage 2 review and approval of proposals is undertaken by a design team including a range of professionals and stakeholders. The range and depth of understanding and assessment will be sufficient to inform and justify decisions whilst being efficient and proportionate in the use of resources.

The 2 stage process allows for a transparent and consistent approach to conservation decisions that are documented in order to inform future management.

The 2 stage process is followed by requests for permit approval from the FCO as required.

Appendix 6 – UKAHT Inspection Pro-Forma

Station Y, Horseshoe Island Inspection report

Name:
Date of inspection:
e-mail (So we can contact you if we have any questions):

Please enter your photographs into the relevant box below

Reference photograph	Insert your photographs here
 **Base Hut North Elevation**	*
 **Base Hut South Elevation**	*
 **Base Hut East Elevation**	*
Add rows for further reference photographs	*
Reference photograph	**Insert your photographs here**

 **Anemometer Tower**	*
 **Dinghies**	*
Add rows for further reference photographs	*

Comments on condition: (please comment under following headings)

Base Hut –

Pup Pens –

Balloon Shed –

Emergency Store –

Anemometer Tower –

Dinghies –

Mast 1 –

Mast 2 –