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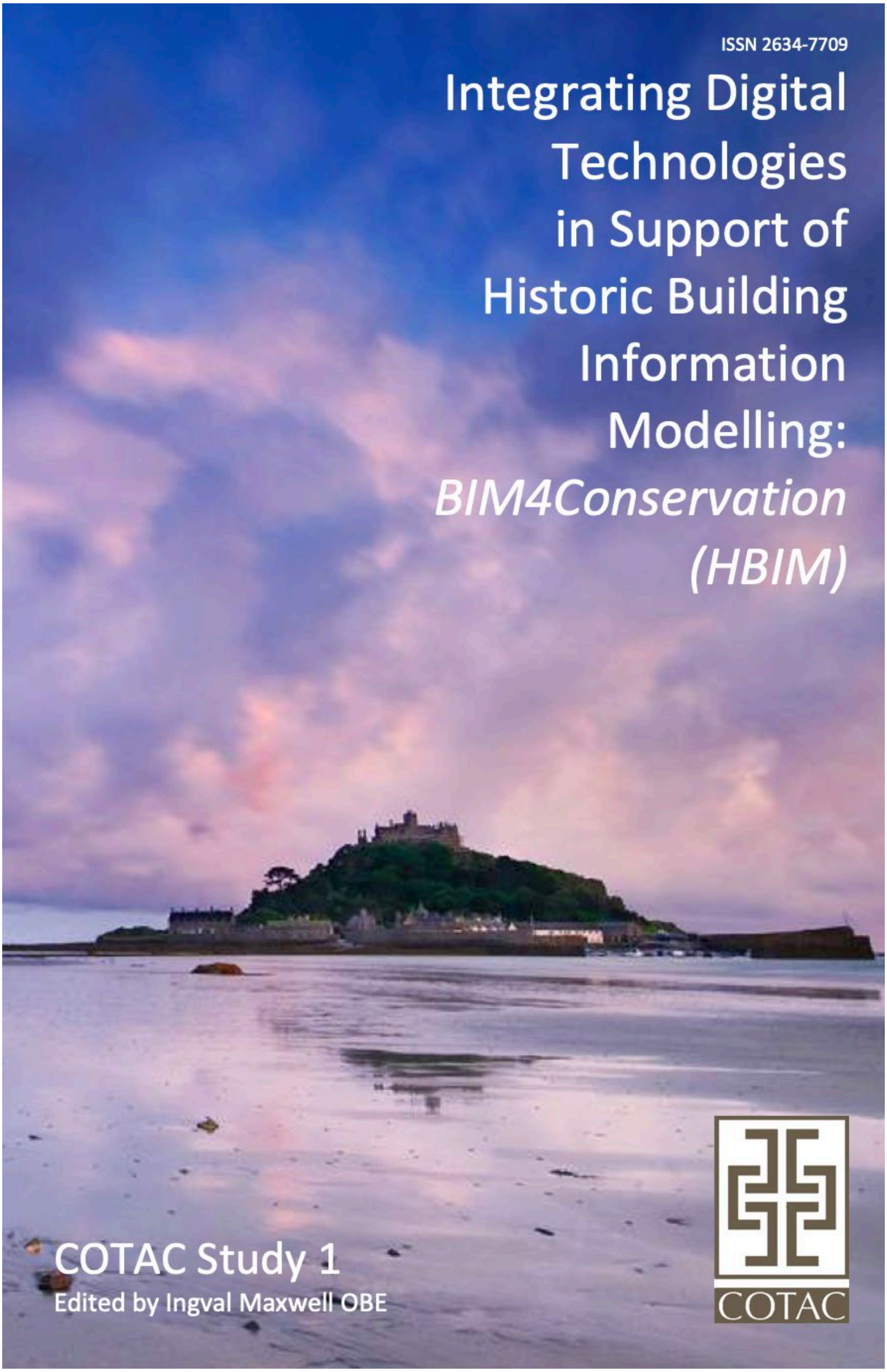
Integrating Digital Technologies in Support of Historic Building Information Modelling: *BIM4Conservation (HBIM)*



COTAC Study 1

Edited by Ingval Maxwell OBE

Integrating Digital Technologies in Support of Historic Building Information Modelling: *BIM4Conservation (HBIM)*

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Edited by Ingval Maxwell OBE DADun RIBA FRIAS CAABC ACA FSAScot
Chairman: *Conference on Training in Architectural Conservation* (COTAC)

Acknowledgements:

The development of this Report was founded on the various presentations offered at the COTAC Conferences *"Improving Thermal Performance in Traditional Buildings", "Past Caring? BIM and the Refurbishment of Older Buildings"* and *"A Digital Future for Traditional Buildings: Practical Applications for Survey and Management"* held in 2011, 2012 and 2013. Whilst focussing on describing 3D reality capture techniques informed by the 2013 event, it aims to start scoping the relevance of these to the essence of BIM, information management, and how that needs to be considered in the context of the traditionally constructed built environment.

Thanks are due to all conference presenters for the information they readily imparted to inform COTAC, and attendees, of current developments in the field of BIM and digital technology. The detailed illustrations provide by Ruth Parsons, Director, CyArk Europe and Chris McGregor, Historic Scotland have been especially valuable.

Particular thanks are due to Michael Brown, formerly of CIOB; David Cracknell, formerly of CIC; Chris McGregor and colleagues, Historic Scotland; and to Annette McGill, COTAC Director of Implementation, for their helpful comments and advice in the compilation of the report.

The Conference on Training in Architectural Conservation (COTAC) has been in existence for 55 years. At its inception in 1959 it was Initially concerned about the poor quality of repairs to the fabric of churches. In the interim, it has broadened its sphere of influence to obtain recognition of the need for the construction industry to properly specify and oversee the work involved in maintaining, repairing and conserving historic and traditional buildings.

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1 Executive Summary

It is increasingly being recognised that the requirements to deal with the existing built heritage - and especially that which was traditionally constructed prior to 1919 - calls for a different professional expertise and understanding from that which has been more commonly developed for the ‘main-steam’ new-build construction industry.

Whilst BIM is still in its formative state for the UK’s new-build sector, an interesting range of digital technologies are beginning to emerge that could result in distinct benefits for practitioners thinking about adopting a Historic Building Information Modelling (HBIM) approach for work on the existing building stock.

With conservation, repair and maintenance (CRM) currently amounting to some 42% of all industry activity, the current emphasis on new-build orientated BIM risks leaving related developments in the CRM sector in the shadows. At the heart of an HBIM CRM approach is a fundamental requirement to establish value, significance and accurately surveyed data of the asset that is anticipated being worked upon.

In addition to the available ‘high-end’ digital survey applications, a number of related techniques offer the prospect of relevant low-cost opportunities for building survey, investigation and recording work. Whilst much still needs to be done to clarify their potential, looking at their various capabilities and advantages should help HBIM practitioners determine a relevant approach to take.

But, as case-by-case needs have to be considered with regard to complexity, applicability and cost, practitioners will inevitably also have to make “horses for courses” decisions based on what information is prevalent at the time.

This COTAC Report aims to set out to scope a preliminary understanding of the issues that might be considered and addressed in devising an HBIM approach. It is founded on internal work carried out by COTAC over the past four years and, in particular, the outcomes of the three related annual COTAC Conferences held since 2011.

April 2014

2 Introduction

It is generally recognised that the built heritage is under threat from a variety of influences - including a lack of knowledge by the professions, and from a lack of understanding by the 'main-stream' construction industry. But what is 'main-steam' when the entire sector virtually operates in two equal halves? In the recently published *Farrell Review* (April 2014: p71) it is remarked that:

> *Today, most architecture is subject to the design of components by others …... The trusses, cladding systems, windows and doors and the kitchens, wardrobes and bathroom elements all the way down to the door handles have already been "pre-designed", so what is it that the architect does? As Farrell Review Expert Panel member Sunand Prasad has said, the role of the architect today is increasingly about selecting, synthesising and integrating, and they are well placed to do this.*

Whilst this may well be true in the de-rigueur of building anew from catalogued sources, it is far from the case in dealing with the existing built heritage - and especially so with that which was traditionally constructed prior to 1919 - where all the selecting, synthesising and integrating has already been pre-determined from a portfolio of parts and elements that are generally no longer available. The requirement here requires a different professional expertise and understanding.

With the titles of *"Improving Thermal Performance in Traditional Buildings"*, *"Past Caring? BIM and the Refurbishment of Older Buildings"* and *"A Digital Future for Traditional Buildings: Practical Applications for Survey and Management"* in 2011, 2012 and 2013 COTAC delivered three conferences that moved the focus towards the potential of digital technologies aiding the care and future wellbeing of traditional buildings.

The COTAC Conferences were also conceived and planned to offer a continuing integrated approach in accordance with the 1993 ICOMOS Education and Training Guidelines, and the emerging ICOMOS CIF 'Umbrella Document' on Capacity Building in the CRM sector. In promoting the needs of a range of participants to gain a better understanding of the issues, the Guidelines call for:

- An understanding of the setting of a historic asset, its contents and surroundings in relation to other buildings, gardens or landscapes; together with,
- The need to find and absorb all available sources of information relevant to what is being studied; coupled with,
- The ability to inspect and make reports intelligible to lay readers with appropriate illustrations, whilst also,
- Documenting and archiving the information.

Set against these issues, this scoping report looks at what was learned about the potential of the new digital technologies for the conservation practitioner, and highlights some of the issues that still need to be considered.

3 BIM and its development into HBIM

With the construction industry, the UK Government embarked on a four-year programme for sector modernization in 2011 (1). The key objective is to reduce capital cost and the carbon burden from operational activities in the built environment by 20%. Central to this ambition is Building Information Modelling (BIM) where the intended adoption of technologies, process and collaborative behaviour aims to unlock efficient ways of working at all stages of the project lifecycle.

The American National Building Information Model Standard Project Committee (2) has defined Building Information Modelling (BIM) as:

> *'… a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition'*.

In the UK, *'BS 1192: 2007: Collaborative production of architectural, engineering and construction information. Code of practice'* establishes the methodology for managing the production, distribution and quality of construction information, including that generated by CAD systems (3). It is applicable to all involved in the preparation and use of information throughout a project's lifecycle and its supply chain.

In describing BIM, Stephen Hamil, Head of NBS Software Development, offers his views (4), and the NBS Information Specialist, Michael Smith (5), has indicated that:

> *'Building Information Modelling (BIM) covers geometry, spatial relationships, light analysis, geographic information, quantities and properties of building components, project management and post-construction facilities management. BIM data can be used to illustrate the entire building life-cycle, from cradle to grave, from inception and design to demolition and materials reuse; quantities and properties of materials, which can be easily extracted from the model; and the scope of works, including management of project targets and facilities management throughout the building's life. Furthermore, systems, components, assemblies and sequences can be shown in relative scale to each other and, in turn, relative to the entire project'.*

The NBS *National BIM Report 2013* (6) offers the third national BIM survey on uptake and progress to date. It provides an intriguing insight into the changes that have taken place, in addition to those still required, in order to achieve the UK Government's target of Level 2 BIM by 2016.

BIM is classified into maturity Levels. Although, depending upon the referenced source, some contradictions do exist in defining these, in one approach the use of the terms:

- Level 0D refers to the zero baseline
- Level 1D refers to (the initiating) point
- Level 2D refers to traditional 2D line drawings.
- Level 3D refers to the three primary spatial dimensions (width, height and depth)
- Level 4D refers to the fourth dimension of time and sequence
- Level 5D refers to 3D + time (schedule) + costings

- Level 6D refers to Lifecycle Management and Facility Management in what is delivered

However, this approach seems to conflate BIM maturity levels with spatial dimensions/ time/cost/Facility Management and is, therefore, incorrect as BIM maturity levels refer to the sophistication of information management and not to spatial dimensions (i.e. BIM Level 2 does not refer to 2D drawings).

The UK's *BIM Working Party Strategy Paper* (2011) (7) gives the following definitions:

- Level 0: Unmanaged CAD, probably 2D, with paper (or electronic paper) as the most likely data exchange mechanism.
- Level 1: Managed CAD in 2D or 3D format using BS1192: 2007 with a collaboration tool providing a common data environment, possibly some standard data structures and formats. Commercial data managed by standalone finance and cost management packages with no integration.
- Level 2: Managed 3D environment held in separate "BIM(M)" tools with attached data. Commercial data managed by an ERP. Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as "pBIM" (proprietary). The approach may utilise 4D Programme data and 5D cost elements.
- Level 3: Fully open process and data integration enabled by IFC/IFD. Managed by a collaborative model server. Could be regarded as iBIM or integrated BIM(M) potentially employing concurrent engineering processes.

To date most (new-build) activity in the UK has been focussed on addressing the needs of BIM maturity Level 0 to Level 3, as above.

In the Proceedings of the 2010 International Conference on Computing in Civil and Building Engineering, Brazilian authors Barison and Santos published a paper entitled *'BIM teaching strategies: an overview of the current approaches'* (8). Through a Literature Review this offered a brief understanding on how BIM was being introduced into universities around the world. They reported that, by 2007, BIM was not being widely addressed in the educational institutes, and although greater progress had been made with its introduction into American institutes by 2009, it was more commonly only being offered as a component within traditional courses.

The March 2014 COTAC Survey Monkey results (See Section 18 Report Addendum, page 43) somewhat mirrored these findings as, perhaps, being inevitable, even with the passage of time. As BIM is a complex and involved topic, it does not readily stand on its own without an understanding of basic architectural and other principles. So, it has predominantly remained an add-on to other courses in its slow evolution (See Northumbria University Text Box, page 36).

However, Barison and Santos offered a set of principles on the introduction of BIM into a related subject that:

- Focused initially on the individual skills of modelling and analysis of the model
- Subsequently focused on teamwork and complexity through collaboration
- Finally dealt with an actual construction project in collaboration with companies

Aligning with this international trend, the University of Salford is currently offering a '*BIM and Integrated Design MSc/PGDip/PgCert'* course in Manchester (9). The University website states:

> *'This course addresses currently emerging needs of new skills for architects, engineering and construction professionals: efficient multidisciplinary collaboration through the design and construction processes, enabling the delivery of integrated design and solutions with the support of advanced technologies such as Building Information Modelling (BIM)…….. It addresses the benefits that can be achieved through the adoption of BIM and discusses:*
>
> - *Integrated processes*
> - *Improved value to clients and users*
> - *Improved design coordination, information management and exchange*
> - *Clash detection*
> - *Clearer scheduling*
> - *Improved sustainability outcomes'*

On the wider UK front the *'Embedding Building Information Modelling (BIM) within the taught curriculum'* report of June 2013 by the BIM Academic Forum UK (10) considered the impact that BIM was having on the learning needs of undergraduates and postgraduates in programmes within the built environment and architectural schools and faculties.

The report discusses some key findings from an interactive workshop held at the University of Salford in November 2012 that flagged up the issues of:

- Up-skilling of staff to support the delivery of the desired learning outcomes;
- Student employability;
- Framework for learning;
- Keeping pace with the development of BIM

The view has also been expressed that It would be wise if institutions who wished to be involved in teaching BIM might employ more "bright young people" - who are already at the cutting edge of digital technology - to help bring the ideas more speedily into the workplace, and initiate a quicker change in the way people use data – particularly 3D data.

Clearly, much more needs to be done to formalise a fully structured approach to the teaching of BIM that addresses the fullness of its intentions and capabilities. More specifically, this could be especially demanding when considering its relevance, application and use in dealing with the existing built heritage.

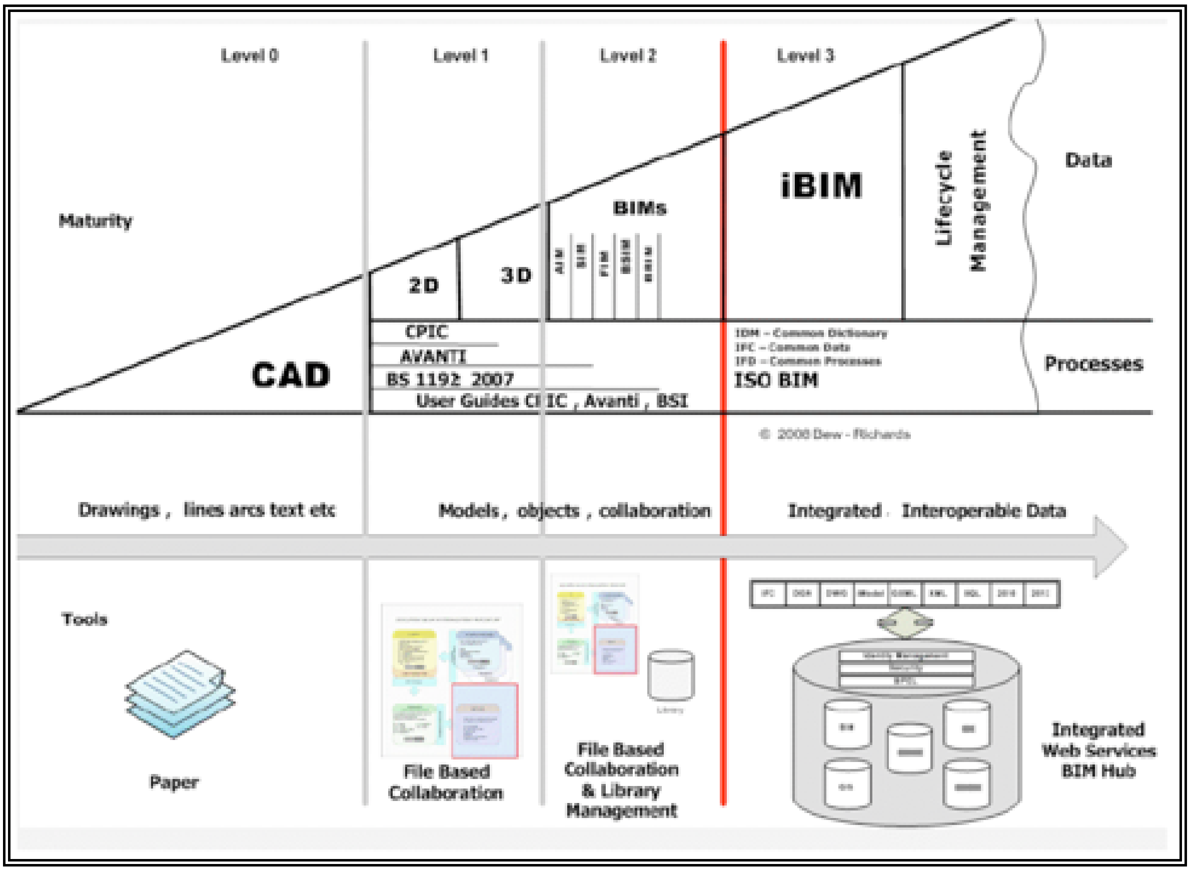
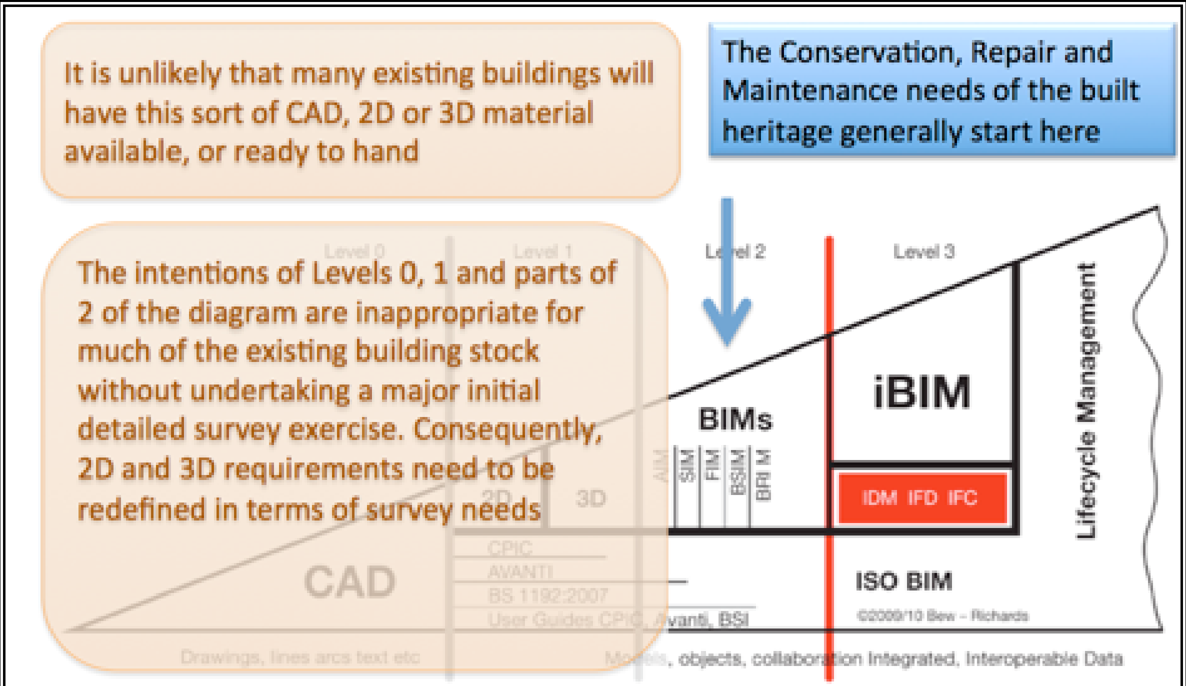


Figure 1: Bew-Richards BIM Maturity Diagram
'Strategy Paper for the Government Construction Client Group from the BIM Industry Working Group'

Diagrammatically, Appendix 3 of the 'Strategy Paper for the Government Construction Client Group from the BIM Industry Working Group', dated March 2011, built upon the 2008 Bew-Richards BIM Maturity Diagram (11). This set out the first 4 Levels of BIM thinking (Levels 0 - 4). It, however, assumes a zero based initiating point for the project. In a new building scenario this would be highly relevant, but it is less so when structures already exist.

Consequently, to date, the general emphasis of BIM thinking, its application in use, and work ethic has had a new-build bias where a 'cradle to grave' concept in the construction industry is more readily understood. But what of structures, with little or no associated archival materials, that are currently in use that have already achieved 'middle or old age' and are still performing a functioning life?

With little progress having been made by BIM (in its currently common accepted sense) in accommodating the more difficult world of dealing with long-established existing buildings of many architectural periods, styles and structural compositions, the emergence of a meaningful Historic Building Information Modelling (HBIM) approach is virtually non-existent. In pursuing this comparatively untouched avenue, a detailed and fundamental understanding of existing structural conditions, material degradations, and performance-in-use circumstances, is essential for each structure being incorporated into the approach.



The **Construction Project Information Committee** is an advisory group, comprising representatives of major UK construction industry institutions, which provides best practice guidance on the content, form and preparation of construction production information, and disseminates this throughout the industry. Has limited relevance to the CRM needs of existing buildings

BS1192:2007 offers definitive guidance on how to implement collaborative work, and on the technicalities of how to use well-structured names for the directories, files and layers. Has limited relevance to the CRM needs of existing buildings

AVANTI was established in 2002 by the DTI to formulate an approach to collaborative working in order to enable construction project partners to work together effectively. Has limited relevance to the CRM needs of existing buildings

Figure 2: Bew–Richards BIM Maturity Diagram in the context of HBIM CRM considerations

In dealing with existing buildings, as part of an HBIM initiative there is a fundamental requirement to acquire and integrate accurate digitally based drawings and records of each asset. Few existing built heritage structure are fully and adequately recorded in any form other than, perhaps, by photography. As HBIM is applied to existing structures, this basic necessity concentrates on the need to establish issues such as value and significance, and to secure accurate on-site survey based information as an initial step, with associated costs commensurate with project needs and intention. Because they have such individual needs, inevitably, for heritage buildings requirements, this must be on a case-by-case basis. The key lies in aiming to get the eventual deliverables more fully worked out before a project is initiated.

As these issues develop it is inevitable that a greater emphasis will have to be placed on achieving preliminary surveyed data prior to undertaking a historic building project from BIM Level 0. But, questioning whether this approach is the best use of the available technology can be debatable. In progressing matters, Historic Scotland reports the possible relevance of the Bew Richards wedge to a historic building project as follows:

- Level 0: This could refer to a scenario where survey information is manually obtained on site using tapes and dumpy levels, drawn up using a CAD package in an unstructured format, and then communicated using paper plots.

- Level 1: This could be a scenario where the site data is obtained digitally with an EDM and then transferred to a 2D or 3D CAD environment that uses standardised data structures.
- Level 2: This could be a scenario where the site data is obtained digitally in an-inherently 3D format using a laser scanner, for instance, which is then transferred to a discipline-specific, standardised, parametric 3D modelling environment. Each project discipline maintains its own 3D modelling environment, but communicates and collaborates with other disciplines using industry-standard interface tools (e.g. IFCs).

The crucial issues is that, possibly, an inordinate amount of time and effort will be taken up in getting a fully understanding of the physical asset in advance of effective decision-making taking place.

The physical acts of conservation; restoration; rehabilitation; repair and maintenance (CRM) are defined in (Revised) BS 7913: 2013 (12). All require different degrees of information and detail about the building, or area to be worked upon. This, in turn, will dictate the level of sophistication and depth of understanding that will be required from the survey activity.

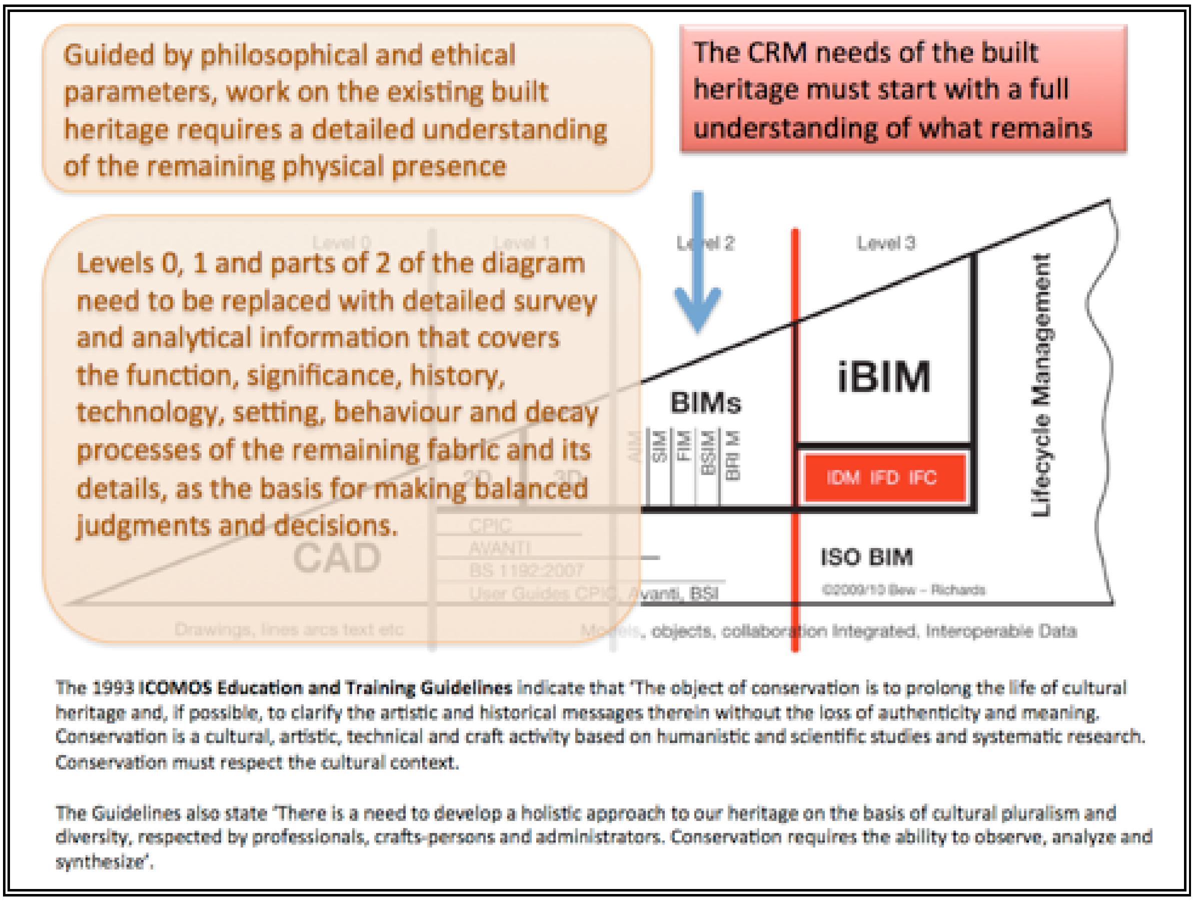


Figure 3: The basis of HBIM in relation to the Bew–Richards BIM Maturity Diagram and the ICOMOS Education and Training Guidelines - accepting that the built heritage already exists in a physical form.

The likely financial cost of achieving the relevant degree of information will also have a direct bearing in determining what the adopted approach might be. The key requirement for developing an effective HBIM approach is obtaining relevant survey information.

Some related advances are being made at an international and national 'high level' of interest to explore what is, and might be, possible by exploiting digital survey technologies to the maximum. The question arises as to how might the emerging indicators from this work be economically transferred into the more every-day situations that practitioners face?

The potential for this might be best promoted through an evolution as displayed in the following two diagrams.

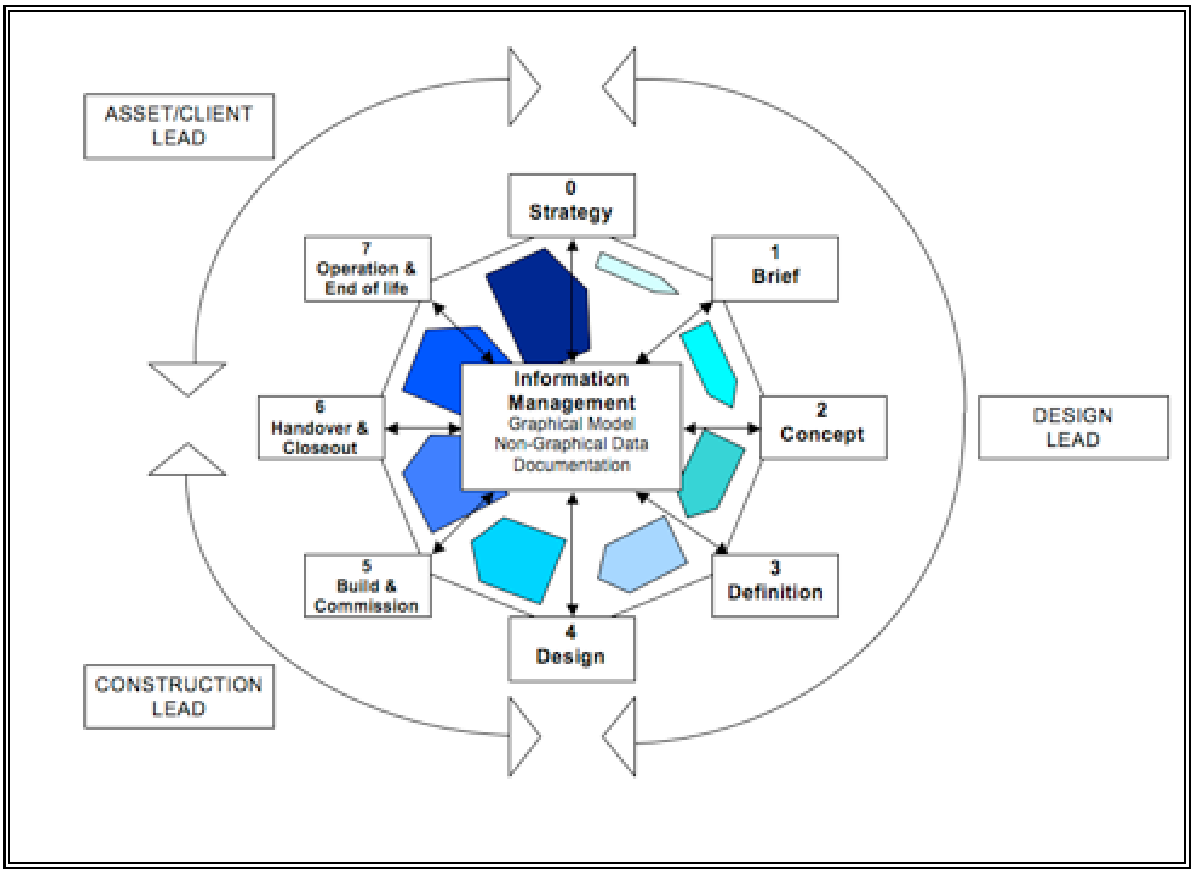


Figure 4: The whole BIM life cycle principle (CIC)

To see the potential need for an HBIM approach it needs to be set in the wider context of the functioning of the entire built environment sector. In support of the whole BIM life cycle principle CIC developed the above framework. It was originally set out in linear form but, given that aim of total integration, there was logic in turning it into a circular format.

Stages (0 - 7) are taken directly from the central PAS/Task Group/industry guidance, which sets out the overall life cycle stages in this way. The main reason for these specifically identified stages was to create a single industry model that overcame the various interpretations that different parts of the industry have about the processes involved in the life cycle. In a further explanation of the issues involved, the BIM Task Group have compiled and issued a set of Frequently Asked Questions (13)

But, looking across the entire construction industry it is now more commonly accepted that the conservation, repair and maintenance (CRM) sector accounts for some 42% of all work activities. Consequently, the suggested terminology for most of the stages (or at least the determined 'Design Lead' sector) does not fit too well for ready adoption in the CRM sector. In trying to bridge this gap, there is a need to get the right words in place across the Stages that could offer a better 'read across' to match the industry intentions as near as possible. From the conservation (CRM) perspective, this approach, understandably and logically, primarily focuses on the need for a redefinition of the terminology for initial four Stages.

The most important aspect that needs to be introduced in this discrepancy is to acknowledge HBIM in the wider setting of the functioning of the whole built environment sector. Increasingly, a whole-life approach to work across the sector needs to be a collaborative team effort, involving both those who primarily practice in the heritage/conservation area, but also those who don't. For this reason, it is imperative that all forms of built environment 'specialist' activity are seen, and are capable of integration, in information terms, with all disciplines. In effect, this desire basically restates the international recognised framework for activities in the conservation sector, as set out in the adopted ICOMOS Education and Training Guidelines (14).

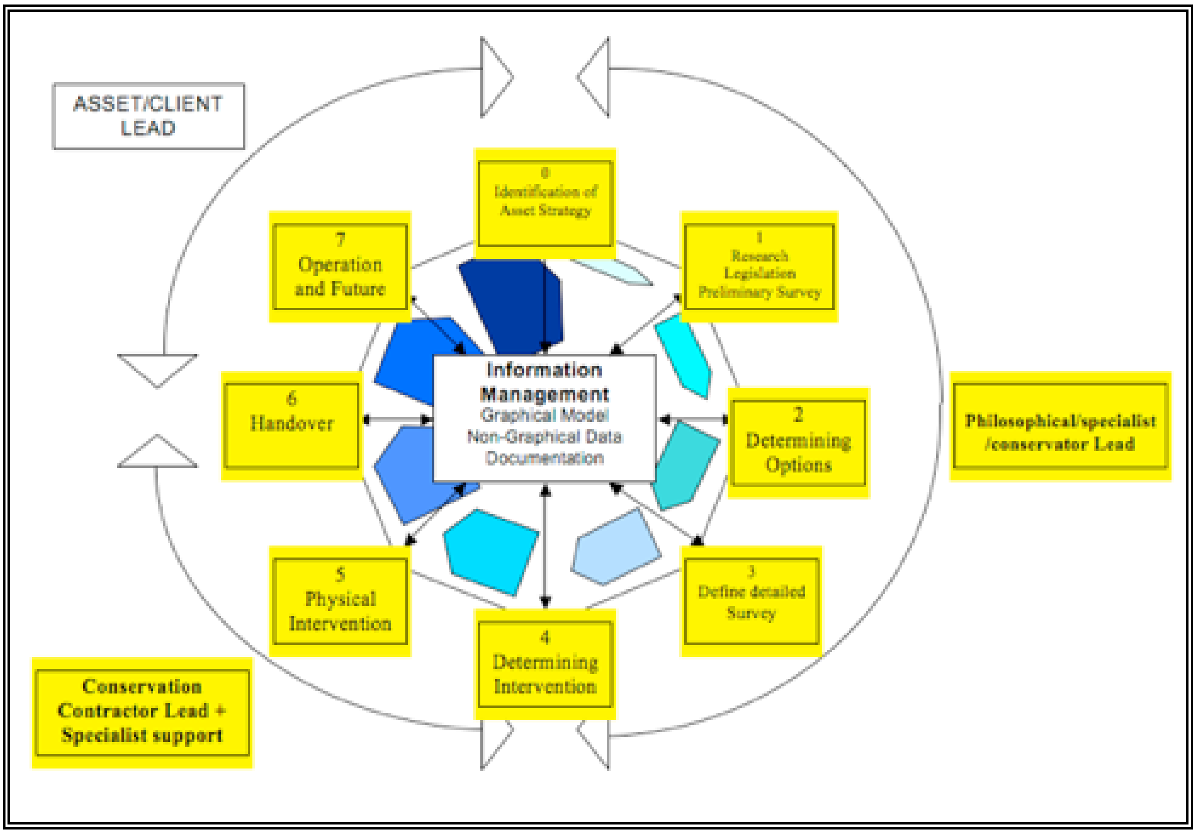


Figure 5: The related whole HBIM life cycle principle overlying the CIC approach (COTAC)

The challenge, therefore, is not insurmountable. As illustrated by the terminology used in the diagram above, to keep the CRM approach and requirements in tune, it should be a simple matter of recognising the more specific conservation functions as being set in a further outer circle, outside the main one, and feeding into the underlying relevant key inner Stages, as determined by the CIC format.

As the CRM terminology in the diagram indicates, and unlike a 'clean sheet' approach of briefing and designing a new-build project from scratch, where work is anticipated on an existing asset, a more constrained start is inevitable. Substantial consideration needs to be given to identifying what these constraints, limitations and potential opportunities are in a manner that pre-determine what options might be possible.

A key understanding of the needs and developmental potential of the existing built heritage and its environment therefore emerges from detailed research and survey of what is already there.

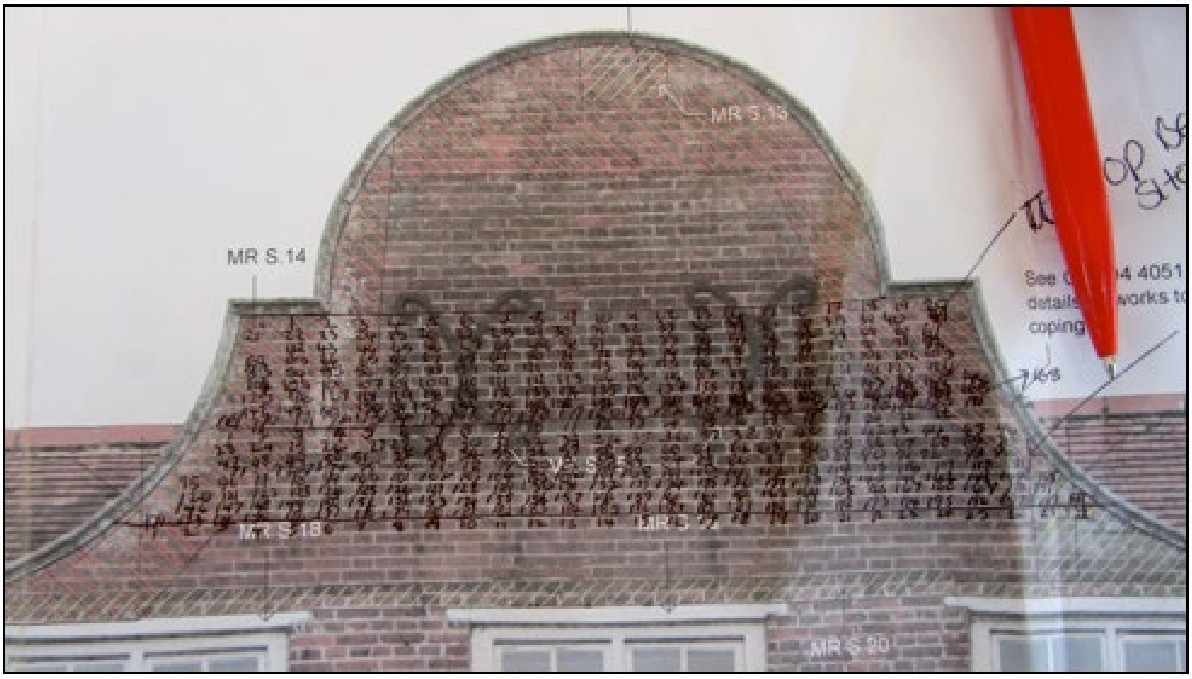


Figure 6: 18th C Brickwork Photo Survey marked up for dismantling.
Photo: I Maxwell

In recognising that rapid development in digital surveying technologies and potential obsolescence of equipment, software programs etc. can make it difficult to ensure future access for legacy planning and successors in an HBIM approach, many practitioners face a struggle to keep up to date with the emerging knowhow. Integrating these concerns, and acknowledging the client's point of view, the recent COTAC Conferences (15) set out to explore the options, and to try to demystify the processes across a range of currently available digital techniques. The following section aims to summarise these results and how they might emerge as informants of a developing HBIM approach.

4 A Brief Digital Survey Background

Using lights, cameras and projectors, 3D scanning technology was academically prototyped in the 1960's. Due to equipment limitations of the era, this approach failed to flourish but by the mid 1980's, more advanced scanners emerged to survey surfaces.

A 3D scanner is an electronic device that can accurately record the appearance of a building and it's setting with data that can be subsequently used to construct accurate digital three-dimensional models at variable scales. It can do this because the data from the scanner is always recorded at a scale of 1:1, and output products can be produced at any scale in consequence.

With the addition of digital photography superimposed on the scanned data, a real-world appearance of what has been recorded can also be produced. In basic terms, the scanner produces a 'cloud of points' or 'point cloud' that can then be used to extrapolate the shape of what has been recorded. Some limitations do exist in the type of objects that can be recorded, particularly if they are shiny or transparent, and line of sight requirements are essential.

Founded in 1993, 'Cyra Technologies' produced one of the first scanners to be used by the surveying and engineering professions. As a leader in 3D laser scanning software and equipment, 'Leica Geosystems' acquired 'Cyra' in 2001. Significant research developments in academia, and the emergence of numerous commercial companies offering scanning services have also materialised in the interim.

3D scanning works by the scanner projecting laser light beams onto a surface. The scanner calculates the positions of where the beams fall by measuring the horizontal and vertical angle of the laser beam in a very mechanical way – in exactly the same manner as an optical mechanical theodolite. It is only the distance to the surface that is measured by the laser. With 'time of flight' scanners this formula is *[distance = (speed x time)/2]* i.e. there and back again. Collectively, the computation and aggregation of these individual points allows a computer to recreate a virtual replica of the surface being scanned (resulting in a 'point cloud').

As the delivery of 'point cloud' data could be anywhere up to 100gb (or, increasingly with recent technological developments, much greater in size) initially this rendered its use in most CAD programs of the time inoperable. Consequently, many cutting-edge practitioners, who pioneered and tested the potential of laser scanning, discovered that the supplied data was unusable. Primarily, this may have resulted in the suppliers of the scanned information not communicating accurately what the limitations of the final product would be but, equally, the problem may also have emerged from the practitioners themselves not fully understanding the technology. With hindsight, it likely such difficulties emerged because the expectations of the requisitioned survey were not managed correctly. Clearly, established requirements and deliverables should be agreed in advance. If that data cannot be used correctly, any subsequent blame, resulting from the incompatibility of intentions and results, should then be shared between the project requisitioner and the team who supplied the data. But, the adoption of scanning technology has advanced considerably in recent years as bandwidth and hard drive storage has increased and become more economic, in both the suppliers and requisitioners' fields, such difficulties should become less of an issue.

Terrestrial Laser scanning offers multiple applications and benefits as a conservation and urban planning tool. They provide an immediate 3D snapshot of the as-built environment from each survey station, securing remarkable accuracy in doing so.

A 'time of flight' scanner measures distance by shooting a laser beam out to a surface and measuring how long it takes that beam to bounce back. For example, equipment such as the 'Leica C10' scanner measures the horizontal and vertical angle by the scanner head moving in a grid fashion on a 360° horizontal plane, and 330° in the vertical plane. With a 'laboratory stated' range of 300 meters, and an acquisition speed of about 50,000 points per second, other manufacturers' scanners do not necessarily produce the same results as this.

'Phase based' scanners, such as the Leica P20 scanner, uses waveform technology: a kind of crossover between 'time of flight' and 'phase based' scanning. These can acquire data at a rate upwards of a million points per second, but their current range is limited to around 80 meters. This makes them more suited for surveying close range building exteriors and interiors.

Handheld 3D scanners are used for close range scanning work of moulded artefacts or sculpted surfaces. To compensate for the uneven motion of the human hand, most systems rely on placing reference markers (reflective adhesive tabs) to align elements and mark spatial positions. Working around objects of almost any shape, the 3D scanning system has been developed to enable maximum flexibility. Some systems have the capability to capture highly textured organic and inorganic surfaces in true full colour 3D, with best resolutions extending down to approximately 250 micron.

3D Laser Scanning involves:

- Non-contact, rapid, accurate and objective method of documentation/recording of as-built architectural heritage and ancient monuments in their environmental setting.
- Laser beam scanning of line-of-sight surfaces.
- The returning reflected laser light being used to compute individual distance to surface measurements up to 1,000,000 times every second.
- Millions of points being computed and used to produce 3D 'point clouds' which defines the surface geometry of what has been scanned.
- Each individual point in the 3D 'point cloud' having an XYZ coordinates in the 3D space, together with RGB data and intensity value.
- Point clouds being acquired from several points of view to overcome occlusions on line-of-sight zones due to variable surface geometry, that are joined together to produce a 3D image with accurate dimensions.

In dealing with large tracts of ground such as archaeological remains, estate policies or designed landscapes Airborne Lidar (light detection and ranging) measures the height and features of ground surfaces with considerable resolution and accuracy, providing highly detailed surface models at metre and sub-metre resolution. Lidar operates by using an oscillating side scanning pulsed laser beam as a survey aircraft flies over the area measuring between 20,000 to 100,000 points per second. Given the high number of points that can penetrate through foliage, the system is able to record ground level features below the tree canopy. In summary, the speed of data capture by the various techniques, as compared to conventional methods, is considerable. The resulting 'point cloud' surveys can be readily integrated with, and into, other datasets including 2D CAD (if operating AutoCAD 2014, or later), 3D printing, and other 3D visualisations - all aspect of which would have a positive relevance in a developing HBIM approach.

5 CyArk: An International Aspiration

Following the acquisition of 'Cyra Technologies' by 'Leica Geosystems', CyArk (16) was founded in 2003 to help ensure heritage sites could be made available to future generations, whilst making them uniquely and easily accessible today. CyArk's Mission was spurred by the Taliban's destruction of the 1600-year-old Bamiyan Buddhas in Afghanistan. As a non-profit organization, it operates internationally in partnership arrangements to use the available technologies with the aim of creating a free 3D online library of the world's cultural heritage sites.

Figure 7: A Composite Digital Photo and Laser Scanned Point Cloud: The Tower of London
Photo: CyArk

CyArk works with experienced teams using 3D laser scanning, photogrammetry and traditional survey techniques. Dependent on the method of data acquisition and the skill of the operators, the resultant 3D data can be used to create highly accurate documentation drawings for site conservation and realistic visualizations for education and interpretation. Its target is to record 500 of the world's heritage sites with the data being lodged in CyArk's secure two-petabyte archive in perpetuity.

CyArk offers an impressive international insight into virtual reality technology. Its approach offers a striking and challenging methodology that is resulting in a considerable contribution to conservation education and awareness raising.

Well illustrating what is possible through working on a high-level survey approach with inspiring techniques and technologies, the potential impact and value for the interpretative industry, and the training and educational world is ably determined. The benefits of freely available access to the recorded information offer a number of pointers for future consideration and development.

The Benefits of Laser Scanning

To continue the development, growth and uptake of the benefits of laser scanning technologies, at an International level there is a need to achieve:

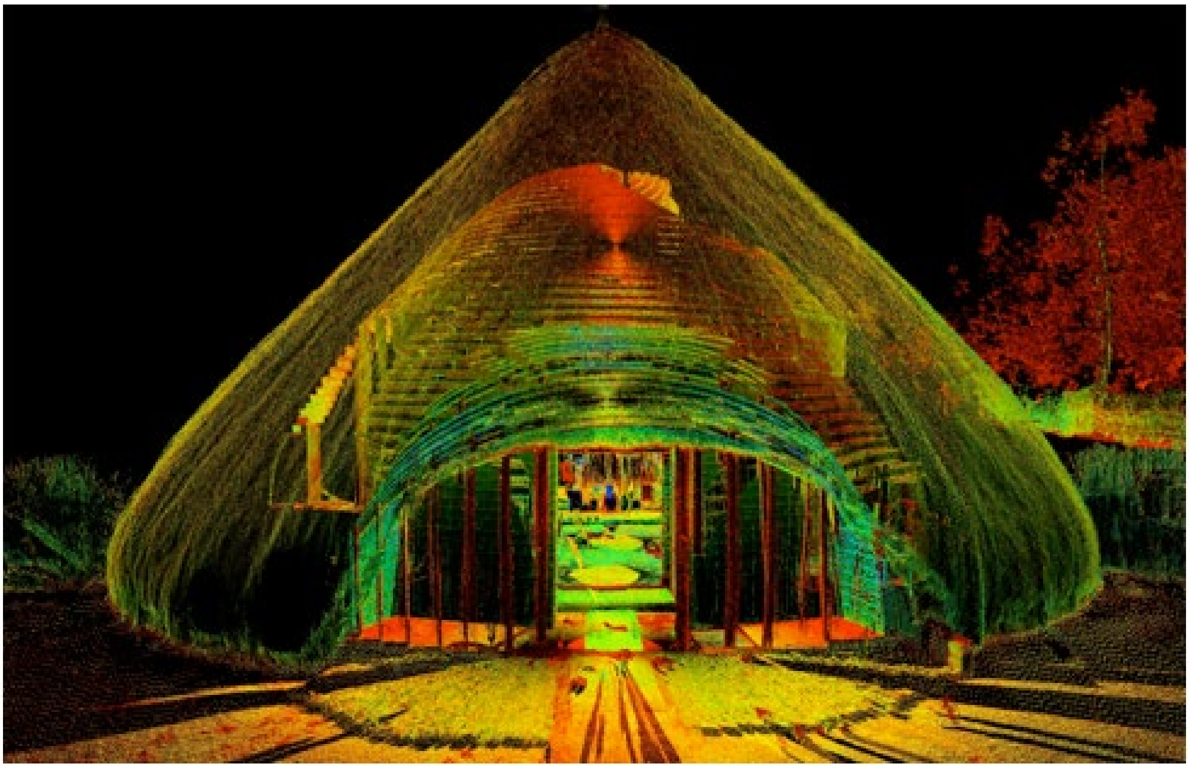
- Enhanced collaborative cross-border approaches to the issues
- Recognition of the degree of concern at the high levels of loss to the built heritage
- Recognition of the benefits of digital surveying techniques
- Recognition of the limitations of digital surveying techniques
- Determination of the range of users and beneficiaries
- Resolution of acquired data ownership
- Future proofing the scanning and recording technology
- Future proofing long term archiving storage systems
- Future proofing ready accessibility to the archive
- Bringing the techniques and approach into an economic range of usable options

From the range of international experiences and results achieved to date, these could be disseminated on a wider basis in support of a developing HBIM initiative in accordance with the ICOMOS Education and Training Guidelines.

Specifically, related electronic media and superbly illustrated presentations, documentation and reports could greatly aid multi-disciplinary working to develop strategies and solutions to suit a range of requirements. Through creating easy access to the visualisation of complex locations, a variety of community engagement initiatives could be developed and enhanced, including:

- Applied research
- Conference presentations

- Education and training
- Future projections
- Partnership working
- Profile-raising
- Reconstructing history
- Reinterpreting history
- Remote access to information
- Social media
- Video presentations
- Virtual learning and interpretation
- Virtual reconstruction
- Virtual tourism



Figures 8 a, b and c

The 700 year-old UNESCO WHS of the Royal Tomb Kasubi, Buganda Kingdom, Uganda. Constructed of wood and thatch: Digitally scanned in 2009: destroyed by fire in 2010

Photos: CyArk

6 *Historic Scotland: A National Approach*

Recent work by the Scottish Government' s Heritage Agency, Historic Scotland, offers a dazzling, inspiring, and a somewhat intimidatingly impressive and exciting resume of scanning activities (17). The approach is both innovative and forward-looking in concept and strategy. Utilising a range of cloud mapping and data capture initiatives that span from recording for city planning interventions and modelling to detailed archiving and interpretive possibilities on specific objects, the Agency has created a bench mark that links record keeping, interpretation, education, training and pragmatic conservation requirements.

Positioning Scotland as a world leader in the documentation and visualisation of the historic environment, Historic Scotland is currently (2014) working in partnership with Glasgow School of Art's Digital Design Studio. Jointly, they have been using laser scanners to create a range of digital records and imagery in a project that will aid in the conservation, maintenance and management of Scotland's globally important World Heritage Sites.

The 'Scottish Ten" (18) is an ambitious project that is using cutting edge technology to create exceptionally accurate digital models of Scotland's five UNESCO designated sites.

In addition to the five Scottish sites – The Heart of Neolithic Orkney; The Antonine Wall; the Old and New Towns of Edinburgh; New Lanark, and St Kilda – the team are also recording five international sites. Four overseas sites have been selected to fulfil Scottish Government International objectives in North America, India, China and Australia. As a result, the team have worked on the Presidential heads at Mount Rushmore National Memorial, South Dakota, USA, and the Rani ki Vav Stepwell in Gujarat, India. They have also recorded the Eastern Qing tombs, Zunhua, China and the Sydney Opera House, Australia. The choice of the fifth site is pending.

The primary aims of the Scottish Ten project are to:

- Digitally preserve important historical sites for the benefit of future generations in Scotland and overseas.
- Share and promote Scottish technical expertise in conservation and digital visualisation.
- Foster international collaboration and build lasting partnerships that capitalise on cultural connections with Scotland.
- Provide 3D digital models and data to site staff to better care for the heritage asset.
- Create digital documentation and accurate 3D surveys of the sites for future development of innovative world class and innovative research, education and management.

As the work is completed, the CyArk archive will host the digital models in perpetuity.

Historic Scotland has also embarked on the 'Rae Project' where it is also intended that Scotland will be the first country in the world to digitally document its national collection of monuments. Using scanning technology, the intention is to record all 345 ancient monuments and sites that are in State Care. Reinforcing the Scottish Government's commitment to Scotland's cultural heritage, the completed archival material will be made available to the public.

Figure 9: Glasgow: Digital Wire-frame and photo-realistic rendering.
Photo: Historic Scotland CDDV

In taking its work forward Historic Scotland operates with a high-end digital toolkit that includes:

- Mid-Range Laser Scanner capable of operating within the range from 2 meters to 150 meters -
- Close-Range Laser Scanner capable of operating within the range up to 3 meters
- Close-Range Structured Light Scanner is a 3D scanning device for measuring the three-dimensional shape of an object using projected light patterns and a camera system.
- Global Navigation Satellite System (GNSS) Global Positioning Equipment
- Gigapixel Imaging Systems. (A gigapixel image is a digital image composed of one billion pixels or 1000 times greater than the information captured by a 1-megapixel digital camera).
- High-Resolution Digital Single Lens Reflex Cameras
- High-Specification Workstations designed to meet the demands of working with work with large and complex datasets, and intricate 3D models
- 2D and 3D CAD Software for design, drafting, modelling, architectural drawing and engineering
- Thermal Imaging Cameras that form images using infrared radiation
- 3D Moisture Meters utilizes the latest microwave and microprocessor technology to measure moisture content in various materials.

In doing so it has illustrated numerous gains that are to be had from combining the various technologies that prove to be mutually enhancing in delivering a greater insight and conservation awareness of what has been recorded.

Examples, such as combining thermography with point cloud imagery to reveal more precise information on hidden voids, areas of in-depth dampness, and surface area heat loss etc. to identify where additional specialist knowledge is required, and assist in determining maintenance strategies and operational policies.

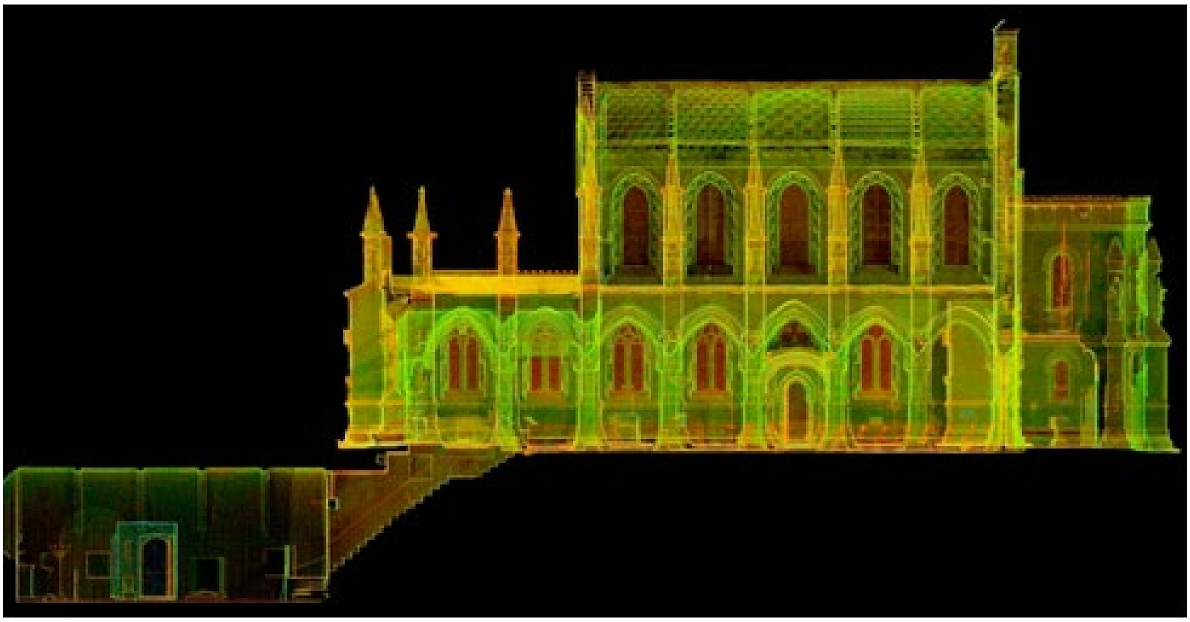


Figure 10: Roslyn Chapel: Longitudinal Section created from Point Cloud data.
Photo: Historic Scotland

From a National point of view, the Historic Scotland experiences offer an insight into determining what category and range of assets should/need to be survey assessed and recorded.

As its programmed survey material of monuments in State Care becomes more publicly available inevitable advances will be made in:

- Determining the full range of available and applicable options
- Illustrating acceptance and progress by promoting exemplars
- Educating and training operatives in the processes that are involved

7 Integrating Digital Technologies in Support of HBIM

The recently published Farrell Report (April 2014) (19) identifies with the later issue in noting (p29):

> *Commonplace among architects for at least the last two decades, the possibilities of digital technology in areas like city and building information modelling and 3-D printing are potentially extraordinary. At the same time, the possibilities for interacting with the public and related professionals have risen exponentially through information and communications technology. But rapid technological growth brings its own problems, not least of which are training and education and continuously retraining and re-equipping as technological change accelerates.*

The Report further states (p61) that:

> *With the unprecedented advances in computer technology, many advise that we should continually reappraise the effects of computer-aided design (CAD) and the digital revolution on professional training and education. Recommendations put forward during the Farrell Review included creating a standing education group to monitor, adjust and re-programme training. Digital technology has affected recent generations in a more radical and accelerating way than ever before, and we need to deliberately prepare for this continuing apace.*

Capitalise on the full panoply of available techniques a range of 'fitness for purpose' needs to be identified and promoted for uptake in support of an HBIM, and to include knowledge dissemination in:

- Archiving
- Asset management
- Automated replication
- Interpretation
- Management Action
- Prioritising work
- Programming work
- Progress recording
- Quinquennial inspections

Fundamentally, practical guidance and advice on how to get the conservation project team to work in unison using shared digital platforms will be essential. In the interim, practitioners need to be as aware as possible of the currently available options and possible combinations.

A possible way of doing this would be through the promotion of associated Case Studies to illustrate how to inform the development of HBIM through:

- Illustrate working up a fuller understanding from the basic level
- Explain why the adopted systems were chosen
- Reveal how buildings/assets were digitised
- Recognise the problems of securing hidden void data
- Integrate traditional data captures technology

- Show how projects may change to incorporate the new technology
- Show intervention recording during maintenance cycles
- Reveal the drawbacks in dealing with different approaches for work and needs
- Show how to ensure the potential of ready accessibility issues with the implementation of digital technologies e.g. from the contractor's point of view

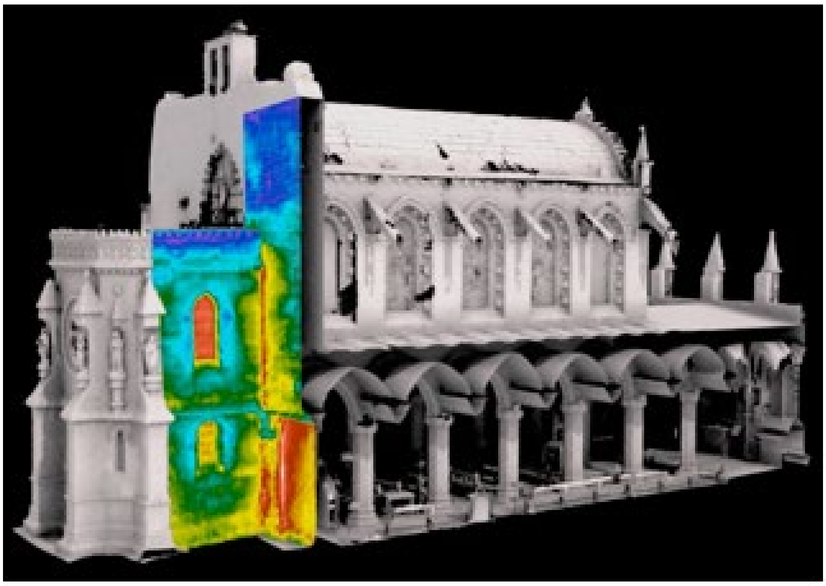


Figure 11: Roslyn Chapel: Thermal imagery applied to Point cloud data
Photo; Historic Scotland

Figure 12: Laser Scanning in operation.
Photo: Historic Scotland

8 Survey Options

Internet Facilities

Technically a desk-based assessment approach, rather than an on-site survey technique, readily available information on the Internet can be of value in helping to determine outline information in appropriate circumstances.

Fundamentally, although some of the available economic options may not be sufficiently accurate for the required level of accurate survey information, they could satisfy many low-cost situations where less demanding needs and details are acceptable. The most readily available of these approaches might be freely found on the Internet in Google Earth, Google Elevation (20) and Google Streetview, Microsoft MapPoint (21) or Bing. Coupled with SketchUp (22) some relevant solutions can be achieved quite economically.

Drone Survey vehicles

With the development of low cost digital cameras, GPS and other sensory systems, technology has now advanced toward an increasing use of unmanned fixed wing and rotary wing Remotely Operated Aerial Vehicles (ROAVs). These allow the acquisition of detailed high-resolution images and surveys using off-the-shelf cameras, and other equipment.

- Operating at much lower altitudes than traditional fixed wing survey aircraft or helicopters ever could, ROAV surveys offer increasingly attractive survey options that are economic to deploy and significant in the quality of their outputs.

- However, certain restrictions can apply. Commercial operators must have a CAA permit to fly the devices (23), and have appropriate insurance. There may be a specific operational ceiling, and a limitation on the horizontal visual line of sight (VLOS), to ensure an appropriate control of the device and its flight operations, and specific CAA permission is also likely to be required if operating inside an air traffic zone.

Fixed wing ROAV's

Aerial inspection and land surveying techniques using fixed wing ROAV's can cover in the region of one square kilometre a day at a rate that is up to 50 times faster than a ground-based land surveying approach with multiple teams. With rapid deployment and data collection capabilities, they can survey areas with minimal ground access.

- Providing vertical and oblique photography, this can be combined with accurate topographic data, digital terrain modelling and volumetric analysis. Such techniques are ideally suited to recording large archaeological sites, fortifications and designed landscapes

Rotary wing ROAV's

The use of multi-rotor ROAV's (helicopters) in and around specific buildings and structures can result in an efficient, cost effective and rapid solution to gaining a detailed visual survey. Producing high definition aerial photography, video and multi sensor results, they allow ready access to areas that traditional photography and other applications cannot cover.

- Multi-rotor ROAV's are compact, lightweight, easy to transport, and can be launched from virtually any location. Provided 'line of sight' controls can be assured, depending upon the model, they can work within an 800m horizontal range, up to 150m in height, flying in winds of up to 30km/hour.

Figure 13: ROAV Rotary wing field equipment.
Photo: I Maxwell

The use of ROAV's would appear to be particularly relevant for small-scale architectural practices as an appropriate tool for assisting in carrying out quinquennial inspections, and for the potential they have for visually aiding work programming in the future conservation of historic and traditional buildings, including HBIM. As a low cost alternative that achieves high quality results from state of the art technologies, ROAV's allow the:

- Rapid deployment of cost effective solutions in the horizontal and vertical planes
- Rapid completion reducing onsite time requirements
- Mapping large areas of land via live mission monitoring
- Production of precise geo-referenced ortho-mosaics and 3D models

- Ability to survey difficult to access areas which cannot be easily or safely reached by conventional methods
- Real time video links with ground operators to enable instant decisions to be made
- Interpretation of buildings/spaces/places as a basis for change

Figure 14: St Peters Church, Frocester: Images from ROAV survey.
Photos: Bexcopter

Lidar

Airborne Light Detection and Ranging (Lidar) uses side scanning pulsed laser beams from aircraft that measure between 20,000 and 100,000 points per second along its flight path to accurately measure ground surface heights and landscape features. It can produce digital models of large surface areas at metre and sub-meter accuracy (24).

Digital Orthophotos

Whether compiled from land-based cameras or ROAV's, Digital Orthophotos (25) are an economic and reasonably efficient method of obtaining a representative near accurate scalable photo plot of a building. But, due to architectural variations and projecting details, surface breaks in the elevation plane and hidden areas must be taken into account otherwise distortions in the images can be presented.

LCD Display and Recording Handheld Video Optic Inspection Tool

Of particular benefit for survey viewing hard-to-access or hidden constructional features with minimal disturbance, various models of this handheld digital device can obtain and record high quality colour video on to memory cards.

9 Integrated Low-cost Techniques

Dublin Institute of Technology

An integrated low-cost option worthy of consideration in certain circumstances is that currently being pioneered by the Dublin Institute of Technology. The process involves the basic creation of digital 3D models of historic buildings and their environments from remotely sensed data. It also requires an integration of freely available Trimble SketchUp (22), and Autodesk 123D (26) photo-modelling software to complete the work. As SketchUp does not model historic buildings on its own, the approach requires the mesh model to be imported into SketchUp as an 'obj' file, and the use of AutoDesk 123D Catch photo-survey software to capture the building and export the photo model. Additional elements, such as windows, doors and mouldings, from a library of standardised historic components are then plotted into the emerging model to enhance the results. (See Text Box: Page 30 and Murphy, M., McGovern, E., et al (2011) *'Historic Building Information Modelling – Adding Intelligence to Laser and Image Based Surveys'* (27))

Compared to using more expensive laser scanning and full BIMs software, such as Revit (28) or ArchiCAD (29), the process that builds the 3-D information model is a low-cost option. But, its limitation in not having the precise individual architectural details recorded, as opposed to utilising a standardised catalogue of library based features, need to be borne in mind. As a result, the approach is perhaps best suited to streetscape and urban planning considerations, rather than building-specific conservation requirements where an accuracy in understanding the building details is important. A useful article, entitled *'How to talk about BIM/Revit without knowing much about BIM/Revit'*, which explores the differences between BIM and Revit, is on the BIMUZER website (30).

Cadw, in conjunction with Cardiff Metropolitan University

With the intention of gathering and using data for managing historic buildings sustainably, Cadw, the Welsh Heritage Agency, in conjunction with Cardiff Metropolitan University's learning programme, is considering the potential of digital technology and what it could achieve by 'starting small and thinking big'.

Through initially focusing on an 1854 masonry and slated 2-storey terrace 'Heritage Cottage' the project aims to ensure that traditional buildings are better understood and treated. By linking building pathology, appropriate skills, energy efficiency, climate change influences, sustainability issues, and retrofit requirements, Cadw is investigating a 'BIM repository for open information sharing' in support of their management needs. This approach brings together an understanding of historic features, condition assessment, repair and maintenance requirements, real energy performance efficiencies, test data and retrofit information, to help provide a total picture. With an aim of making sure that the technologies move in a direction that best suits heritage sector and traditional building needs, Cadw is also using Drones and i-Pads for site inspections and reports.

Integrated Software Options as used by the Dublin Institute of Technology

SketchUp

Available as a freeware download (SketchUp Make), or as a paid version with additional functionality (SketchUp Pro), Trimble SketchUp is a 3D modelling program for use in a wide variety of applications such as architectural and interior design, and engineering. It aims to be easy to use, with an online repository of free-of-charge model assemblies (e.g., windows, doors etc.). The program offers functionality in drawing layouts and surface rendering. It also supports third party "plug-in's", such as near photo-realistic rendering, and the placement of models in Google Earth. Using aerial images from Google as a starting point realistic building façade details can be added from Street View imagery, or any other photograph.

Autodesk 123D

Based on 'Autodesk Inventor', Autodesk 123D is a freely downloadable suite of CAD and 3D modelling tools that is similar in scope to Trimble SketchUp. In addition to basic drawing and modelling capabilities it also has assembly and constraint support and STL export. It automatically converts ordinary photos into 3D models, and a library of ready-made blocks and objects is also available.

ArchiCAD

ArchiCAD is an architectural BIM CAD software developed by the Hungarian Graphisof Company. It offers specialized solutions during the design process for handling all common aspects of aesthetics and engineering. In development from1982, it was the first personal computer CAD product able to create both 2D drawings and parametric 3D geometry representations.

Autodesk Revit

Autodesk Revit is Building Information Modelling software for professional, designers and contractors. It allows the design a building, its structure and components in 3D, the annotation of the model with 2D drafting elements and access to building information from the building models database. Revit is 4D BIM capable, and can plan and track all the construction stages from design concept to demolition.

Comment

The free Autodesk 123D App from Apple's App Store can emulate many of the functions of high-end laser scanning software by stitching together images from an iPhone camera. Using complex mathematical algorithms and determine spatial relationships, the software makes use of digital photogrammetry techniques to analyse photographs. 123D Catch generates a point cloud, from which a mesh model can be "dressed" in texture and colour from the photographs. 123D Catch only requires the user to walk around an asset taking photos with the iPhone's 8MB camera and the resulting model can be imported into the free 3D modelling package Google SketchUp to create a very basic BIM model. The App does not support precise measurements but it can function as an important tool for visualising a building during the early stages of a repair or renovation project.

It might be noted that an important element of high level BIM is that datasets are 'intelligent' – i.e. they are parametric, capable of interacting with adjacent datasets, and contain embedded information. For example a window automatically cuts a hole in a wall, and if the size of the window is altered, the opening alters automatically. In addition, the window element may contain much catalogued, pre-designed and predetermined information as to its construction (e.g. type of timber, glass, ironmongery, U-value, etc.) if the adopted approach is to be considered BIM, it is crucial that the elements in the standardised library are parametric and contain metadata. However, there in lies the dilemma. Whilst this 'idealised' approach is perfect for new build projects, the constraints and reality of dealing with existing heritage assets may not be so accommodating of such required adjustments as, fundamentally, it will often be the multifarious 'constraints of the existing fabric' that will determine what is possible in any adaptation and change. In addition, others report having tested the AutoDesk 123D Catch photo-survey software fairly extensively and found the results to be unreliable, noting that IPR issues can also arise when submitting data to the AutoDesk Website. However AutoDesk's ReCap point cloud software delivers a powerful reality capture workflow for 3D laser scanning, that cuts project time by more than 50% without compromising data accuracy.

10 3D Printing

Although 3D printing (or 'Additive Manufacture', as it is becoming commonly known (31)) has been in use for almost 25 years, it was almost exclusively employed in the engineering sector for prototyping work. But, with an eye to the 'not so distant' future the potential benefits of 3D printing for the conservation sector, and its integration into an evolving HBIM approach, is considerable.

Through using computer aided design packages, or the outputs of 3D scanning technologies, the creation of 3D printed models is becoming more economic as printer costs fall. Every 3D printer needs to print from a CAD (Computer Aided Design) file, generally in STL format. It lays down layers of liquid, powder, paper or sheet material to successively create a physical model through the subsequent addition of cross sectional layers. Corresponding to cross-sections from a CAD model, the layers are automatically fused to create the resulting 3D printed form.

A number of 3D printing marketplaces have emerged over recent years, including the London based '3DPRINTUK' or the French 'Sculpteo' companies, that provide commercial printing services; and the 'Threeding' and 'Thingiverse' websites, amongst others, that share user-created digital design files. As thoughts on the adaptation and use of this technology evolves, it is only a matter of time before such an approach opens out to a wider application that influences and supports the needs of BIM and HBIM.

A major advantage of the technique is its ability to create almost any shape or geometric feature. Consequently, it could readily create, for example, models of complex service runs through historic buildings, replicate intricate carved historic details, or better illustrate the workings of traditional constructional techniques.

3D Milling

Taking 3D scanning and printing a further step forward combined 3D scanning and milling machines are now beginning to emerge in the marketplace. Devices suitable for use in small professional practices accommodate importing 3D files from most the popular computer graphics and CAD applications.

Easy to operate, the machines can be used as an aid to test, modify and perfect relevant decisions in their 3D physical form through allowing rapid prototyping of solutions that can also help reducing errors, time and cost.

11 Built Heritage Issues

It is generally recognised that the built heritage is under threat from a variety of influences. But, at the same time there is a need to ensure its better integration within the planning and construction industry framework, and sustainability initiatives.

The need to develop a specific HBIM approach that is coherent and relevant, whilst also taking fully into account the wide diversity of issues that affect the heritage, remains a distinct challenge.

In commissioning and undertaking digital survey scanning techniques, and considering the potential of linking the results to HBIM developments, a number of basic related issues and steps need to be borne in mind.

Collaboration and Communication

In this process, how to integrate with the fragmentation within the building conservation industry, and the breadth of the heritage sector, will emerge as a significant hurdle, as will the challenge of making the HBIM approach economically viable and workable for owners and practitioners. Learning from the prototyping work that was carried out in the oil and gas industry as they faced similar issues would be beneficial.

Education and Guidance

Little readily available material is to hand to inform conservation practitioners about the complexities of the issues involved. Preparing client and practitioner guidelines for assessing need and choosing the relevant approach will be necessary.

Copyright

Fundamentally, the ease with which digital material can be reproduced and disseminated, at virtually no cost, challenges the concept of copyright. But, with specific reference to long-term access requirements, it should be noted that there is no legislation in the UK that permits preservation copying of copyright material held on discs, without permission (32).

Data Storage

Determining a data storage strategy for retaining the results of using digital technology, such as laser scanning, is essential.

Currently data storage is commonly thought of as a collection of digital data stored:

- On a long-term storage device such as a disk or magnetic tape, or a
- Computer directory of folder that contains copies of files for backup or future reference, or a
- Collection of information permanently stored on the Internet.

But, digital storage media is inherently unreliable and all file formats and physical storage means will ultimately become obsolete. In addition, the lifespan of data held on discs will be determined by the physical life of the discs and the redundancy of hardware and software needed to access them. As laser scanning can produce pretty massive files, this is a critical area that needs some serious consideration and the promotion of appropriate solutions.

Archiving

It might be noted that Data Storage and Archiving is not the same thing, and care is required not to perpetuate a misconception between the two. Archives generally consist of a wide range of records that have been deemed important enough by society to be selected for permanent and long-term storage on the grounds of their enduring cultural, historic and evidential values.

The National Archives supports a free online registry of file formats, software products and other technical components that can assist in determining the relevant approach to adopt for the storage of appropriate materials worthy of such retention (33).

Security and Privacy

Specifically, from the outset, ownership, copyright, intellectual property protection and liabilities need to be resolved and agreed. Where the survey material might also emerge through open access on various Internet portals, the security risk of piracy might also be considered (34).

Figure 15: Laser scanner at the Cadw Heritage Cottage test location, Wales
Photo: Cadw

12 BIM International

A variety of full-scale BIM international initiatives are in development. But, as indicated above, these have a specific new-build emphasis. One such example is illustrated in the *'BIM Essential Guide for BIM Execution Plan'* as developed by the Building Construction Authority, Singapore (35). Their new-build orientated BIM Execution Plan (BEP) provides a baseline document to guide the project team achieve the goals set with regards to BIM deliverables. It specifies the roles and responsibilities of project members at different project stages, and contains detail with regard to the deliverables and process through which they are created, maintained and shared.

The related *'Building Information Modeling in Singapore'* website (36) also provided a comprehensive new-build BIM oversight that flags up educational needs, best practice and associated resources amongst other matters. The linked site '*BIM components'* (37) further illustrates what is currently being developed and available in general support.

Perhaps inevitably the explicit complexity of such an approach, and the emphasis that is placed on supporting modern building design and constriction, does not readily translate to the CRM needs of the Conservation Sector where numerous 'unknowns' can emerge during the course of the more sensitive work. But, these and related initiatives highlight the need for matching detailed consideration to be given to the CRM issue, and to start what is necessary in pursuing a more relevant HBIM approach for the sector. It does, after all, amount almost 50% of all UK construction activities.

In promoting an increasing awareness of this challenge, the abstract of the paper by Fai, S., Graham, K., et al (2011) entitled *'Building Information Modelling and Heritage Documentation'* (38) states:

> *Despite the widespread adoption of building information modelling (BIM) for the design and lifecycle management of new buildings, very little research has been undertaken to explore the value of BIM in the management of heritage buildings and cultural landscapes. To that end, we are investigating the construction of BIMs that incorporate both quantitative assets (intelligent objects, performance data) and qualitative assets (historic photographs, oral histories, music).*
>
> *Further, our models leverage the capabilities of BIM software to provide a navigable timeline that chronicles tangible and intangible changes in the past and projections into the future. In this paper, we discuss three projects undertaken by the authors that explore an expanded role for BIM in the documentation and conservation of architectural heritage. The projects range in scale and complexity and include: a cluster of three, 19th century heritage buildings in the urban core of Toronto, Canada; a 600 hectare village in rural, south-eastern Ontario with significant modern heritage value, and a proposed web-centered BIM database for materials and methods of construction specific to heritage conservation*.

Building upon, and developing, their approach would seem to offer the possibility of a relevant way forward for the conservation sector.

13 COTAC Survey into BIM Educational and Training Needs: March 2014

During March 2014 a COTAC online survey was initiated and distributed to 60 UK academic institutes through Survey Monkey. The aim was to take a pulse on the current academic view on BIM educational and training needs, and how that related to CRM requirements. The results were analysed on 2 April 2014. During the one-month survey period, one individual response, and nine academic responses were received from staff at the following eight institutes:

- Department of Archaeology, University of York
- Sheffield Hallam University
- Nottingham Trent University
- Heriot-Watt University, Edinburgh (x2)
- Kingston University, London
- Cardiff Metropolitan University, Cardiff School of Art and Design
- AA Postgrad Building Conservation Course, London
- University of Wolverhampton

Although the 14% response rate was low, a number of key issues emerged. In addition to revealing some positive developments that were taking place, more technical and operational information was required to enhance teaching abilities, and to establish a greater awareness of CRM needs within the BIM environment.

There was a necessity to increase students' awareness of the need to understand BIM, but field case studies were not always at the right stage of their development for integration into the delivered curriculum.

The financial burden of the adoption of BIM, coupled with commercial sensitivity concerns, were noted as issues that could impose a significant burden on the small, specialist, SME contractors who generally populate the CRM sector of the construction industry. (The full analysis is attached as a Report Addendum: See pages 42- 50)

Related Educational Initiatives

A related wider search on the Internet indicated that other educational institutes, such as Newcastle's Northumbria University (See Text Box: page 36), were gearing up meet to the anticipated demand of responding to the UK Governments' target of making BIM compulsory for all public projects from 2016.

Whilst, perhaps inevitably, these courses were orientated towards the new-build design and construction industry, they indicate a growing awareness of the scale of need and the required provision to meet the anticipated demand. But, how this approach, and related initiatives, can be adjusted to accommodate the particular needs of the CRM sector seems yet to be better considered.

Northumbria University: 2014 BIM Course Information (Accessed 9 April 2014)

At the Northumbria University, Newcastle's City Campus, the Engineering and Environment Faculty is currently offering BIM Course Information, with a 2014 Entry, in the following:

Building Design Management and Building Information Modelling (BIM) MSc
1 year full-time (September start)
http://www.northumbria.ac.uk/?view=CourseDetail&code=DTFBBD6

Building Design Management and Building Information Modelling (BIM) MSc
18 months full-time (January start)
http://www.northumbria.ac.uk/?view=CourseDetail&code=DTFBMM6

Building Design Management and Building Information Modelling (BIM) MSc
3 years part-time (September start)
http://www.northumbria.ac.uk/?view=CourseDetail&code=DTPBBD6

Building Design Management and Building Information Modelling (BIM) MSc
3 years distance learning (Sept or Jan start)
http://www.northumbria.ac.uk/?view=CourseDetail&code=DTPBDB6

Building Design Management and Building Information Modelling (BIM) MSc
3 years part-time (January start)
http://www.northumbria.ac.uk/?view=CourseDetail&code=DTPBMM6

Building Design Management and Building Information Modelling Postgraduate Certificate
6 months full-time (January start)
http://www.northumbria.ac.uk/?view=CourseDetail&code=DTFBDC6

Building Design Management and Building Information Modelling Postgraduate Certificate
1 Year distance learning (January start)
http://www.northumbria.ac.uk/?view=CourseDetail&code=DTPBCD6

Building Design Management and Building Information Modelling Postgraduate Certificate
1 year part-time (January start)
http://www.northumbria.ac.uk/?view=CourseDetail&code=DTPBDC6

14 Conclusions

There has been no serious work initiated to date in determining how BIM can be applied to the diverse CRM work activities in the Conservation Sector of the UK's construction industry. As the sector amount to some 42% of all construction activities, pressure will predictably continue to grow to address this discrepancy in the application of BIM. But BIM, in its current guise, does not fit readily with the needs of the sector and a more specific adaptation, in the form of HBIM, will be necessary.

COTAC's Conferences in 2012 and 2013 on related technologies have highlighted the need for practitioners to receive guidance in order to help them to determine what is relevant and fit for purpose. Their challenge lies in satisfying their CRM needs through securing relevant baseline survey data within the generalised BIM context. From a national point of view, current conservation experiences in Digital Documentation, and 3D Surveying and Imaging, can assist in determining some primary HBIM themes on:

- High Resolution collections documentation
- Digital documentation and data management guidance
- Condition Monitoring
- Education and outreach
- Applied scientific research
- Heritage visualisation
- Community engagement
- Local, National and International collaboration

These issues, however, have yet to be sufficiently developed to suit the pragmatic needs of the CRM sector, and the practical requirements of practitioners seeking to implement and pursue an HBIM approach.

15 COTAC Recommendations

From COTAC's perspective a number of initiatives might be promulgated:

Key Elements

Within an HBIM approach, in addition to holding surveyed material, data management systems for historic and traditionally built structures might include information on key elements such as:

1. Significance and Value
2. Legislative parameters;
3. Existing archival records;
4. Historic evolution and developments;
5. Researched findings;

6. Architectural styles and structural details;
7. Location and setting;
8. Environmental concerns;
9. Functional uses;
10. Material performance criteria and degradation details;
11. Material sources and supplies;
12. Vocational skill requirements;
13. Specialist requirements;
14. Maintenance records;
15. Servicing requirements;
16. Ownership;
17. Other pertinent matters.

In addition, based on evolving exemplars, from an assessment of incorporating the range of digital survey techniques within an emerging HBIM system, the following headings and sub-topics might also be considered relevant:

Informing Conservation

The practical requirement of undertaking effective and appropriate conservation work in the CRM sector requires detailed information on:

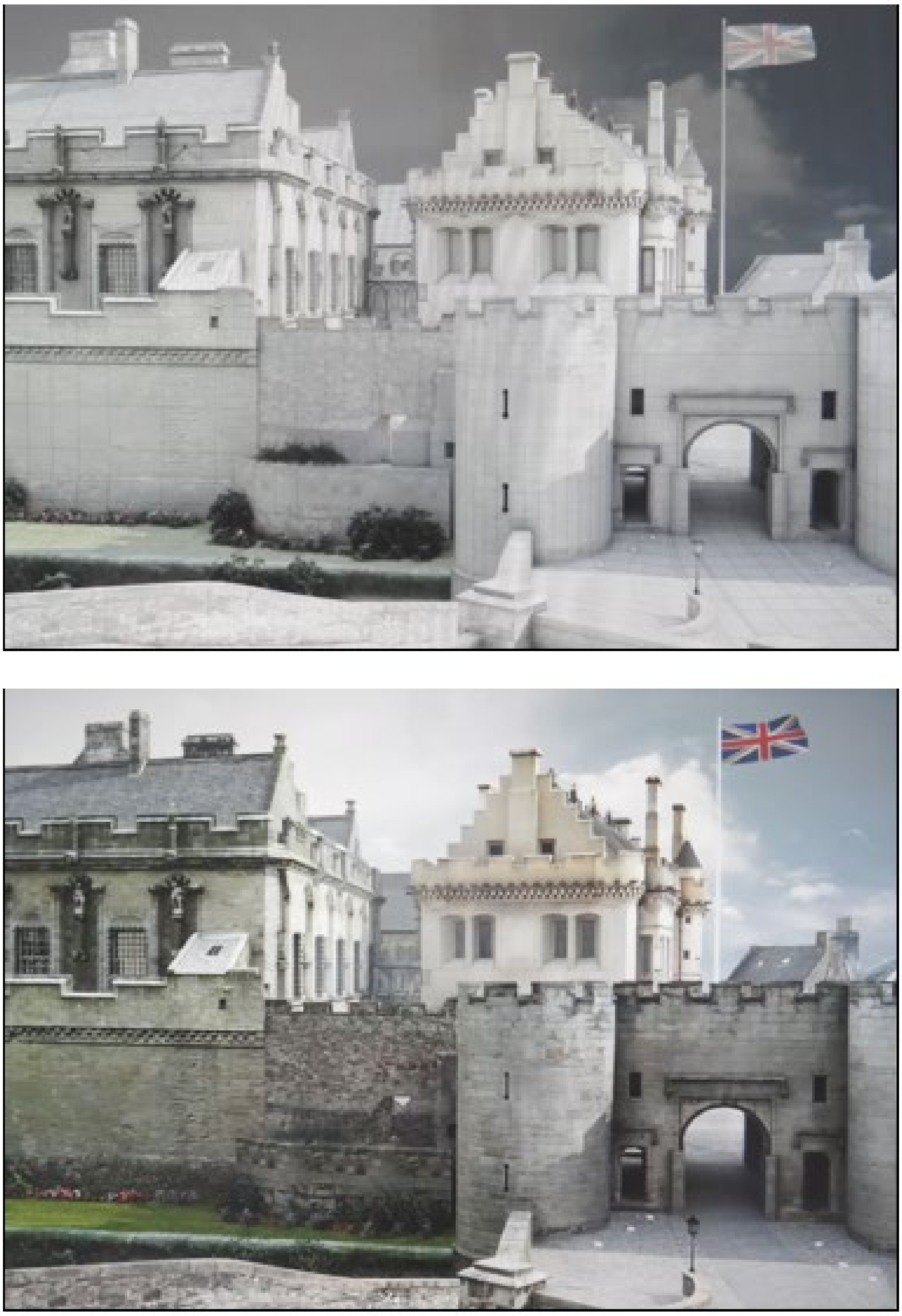
- Condition monitoring
- Deviation mapping
- Integration with 3D microwave moisture meter and thermography to plot:
  - Condensation and risk of mould growth
  - Damp, leaks and water penetration
  - Defective insulation
  - Electrical and mechanical malfunctions
  - Fractures and air leakages
  - Heat loss
  - Thermal bridging
  - Voids and surface disruption
- Monitoring sites at risk
- Physical replication
- Post-disaster recording
- Testing colour renditions
- Understand construction phases
- Replication 3D milling

Management Aids

The practice of conservation is multi-disciplinary with a fundamental need for holistic collaborative action across a wide range of interests, including:

- Application to master planning in context for planners
- Disaster preparedness
- Energy efficiency
- Facilities Management

- Improving accessibility, fire prevention and security
- Link with ground penetrating radar to reveal
    - Archaeology
    - Underground services
- Preventative maintenance
- Quinquennial/routine inspections
- Strategic policy
- Sustainability demands



Figures 16a +b: Stirling Castle, Grey toned and realistic colour rendered views from point cloud data
Photos: Historic Scotland

Digital and Archival Materials

Capitalising on the emerging technologies, an HBIM approach might develop a range of identifiable archival outputs in the form of:

- 2D drawings
- 3D drawings
- 3D modelling and printing
- As built records
- Cutaway drawings
- Gigapixel imaging
- Isometric/axonometric drawings

16 Interim Position

In the interim, it is highly unlikely that many existing buildings will have BIM Levels 0, 1, and part of Level 2, CAD 2D or 3D materials already to hand, and this will take some considerable time to come to fruition. Consequently, a greater emphasis will have to be placed on obtaining appropriate initial survey information to provide the base level understanding required by HBIM. Commensurate with the needs of practitioners, a range of digital scanning approaches could be considered as a way of initiating an HBIM approach that incorporates the basic digital survey material. Depending upon resources and circumstances, these options might include the use of:

- Digital orthophotos for elevations
- Combining Google Earth and Google Streetview (or photographic) information with SketchUp for building elevations and plans
- Handheld scanners for close range scanning work of detailed moulded or sculpted surfaces
- Phased based Scanners with a range of up to 80 meters for building elevations and interiors
- Time of Flight Scanners with a range of up to 300 meters for street elevations and landscape
- LIDAR aerial scanning for large ground surface area.

In addition, key issues that still have to be addressed include:

- How is this data really going to be disseminated?
- Does anybody yet know what the archival requirements for a BIM model are?

Education and Training

On the basis of analysing the COTAC March 2014 Survey results, if a more specific version of HBIM emerged that better fitted the conservation sector needs, it was thought that standard BIM seemed less appropriate in that area. But, more work is required to enhance BIM teaching skills and abilities, and to inform and educate educators in the delivery process. Additional technical and operational information should also be beneficially promoted.

17 Annex

Web References: (Accessed 24 March 2014)

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18 Report Addendum

COTAC HBIM Survey Monkey Questionnaire Results

During March 2014 a COTAC online survey was initiated and distributed through Survey Monkey, with the results being analysed on 2 April at:
https://www.surveymonkey.com/analyze/tVNDDYCfXyj2P7GDH_2F72rtun3MQZqLA68V8u_2BCT3DMU_3D

During the one-month survey period, one individual response, and nine academic responses were received from staff at the following eight institutes:

- Department of Archaeology, University of York
- Sheffield Hallam University
- Nottingham Trent University
- Heriot-Watt University, Edinburgh (x2)
- Kingston University, London
- Cardiff Metropolitan University, Cardiff School of Art and Design
- AA Postgrad Building Conservation Course, London
- University of Wolverhampton

Summary Findings

Although the response was low, a number of key issues emerged. Specifically, if HBIM fitted the conservation sector better, standard BIM seemed less appropriate, but more work is required to enhance the teaching skills and abilities, and to inform and educate educators in the delivery process. Additional technical and operational information could be beneficially promoted on all aspects

There is a necessity to increase students' awareness of the need to understand BIM, but case studies are not always at the right stage of their development for integration into the delivered curriculum.

The financial burden of the adoption of BIM, coupled with commercial sensitivity concerns, are issues that could impose a significant burden on the small, specialist, SME contractors who generally populate the CRM sector of the construction industry.

The following specific questions were asked:

Question 1:
What is your name, institution and your e-mail address?

(See list of respondents)

Question 2:
Is BIM taught as a full subject its own right, or only taught as part of a related course at the University/Institute?

Seven responses were received indicating that BIM was being taught across a range of professional subject areas, such as:

- Archaeology of buildings
- Real estate
- Building surveying
- Quantity surveying
- Construction project management

Two of the respondents indicated that it was being taught both as part of a course and as a subject in its own right, with one respondent indicating that it would be introduced across a range of courses from October 2014. Of those who responded, no mention was made of relating BIM to architectural design, let alone the practical needs of architectural conservation.

Question 3:
What information do you require to keep pace with national/international BIM developments to be able to effectively teach all Levels of BIM?

Ten responses were received to this question. A range of informational requirements were identified, including:

- Information about outcomes from a national and international perspective
- Following the work of the Dublin Research Group
- Sharing an understand about what is happening elsewhere
- Implementation strategies
- The degree of industry engagement
- Succinct knowledge relating to establish needs

- BIM related rules and regulations
- BIM case studies to contextualise matters
- Relevant tools
- Developments in technology to overcome current problems
- Availability of cheaper options for hardware/software/training
- Personal development CPD

Clearly, a significant number of issues still need to be addressed in the promotion and uptake of BIM from the educational perspective. Given the wide range of necessities, spanning international, national, industry, personal, pragmatic and regulatory prerequisites, a central lead needs to be further developed that has a greater commitment to assimilate the required information and disseminate it widely.

Particularly valid points are raised regarding the financial burden that the adoption of BIM will entail, together with the need to inform and educate educators in the delivery process.

Question 4:
What do you think the issues are in relation to the adoption of BIM in the conservation, repair and maintenance (CRM) sector of the construction industry?

Ten responses were received in relation to this question. Amongst the issues raised were:

- Upfront funding to develop BIM
- Awareness of the cost and value to the client
- The cost and complexity of data output and storage
- The growth of data
- Creating unified specifications
- Accessibility of data and its reuse
- How it is universally recorded, searched and accessed
- Commercial sensitivity between contractors
- Elimination of small specialist contractors due to a lack of skills and knowledge
- 2016 implementation in government contracts potentially precluding SMEs
- Current lack of focus on long-term performance on buildings relating to post-occupancy evaluation etc.
- Addressing the needs and capabilities of SMEs, third-party service providers and user-friendly tools
- Expensive and time-consuming commitment to put the asset into model form

One respondent recognised that HBIM was 'a different animal', noting that much of the current thinking on BIM is predicated by its use in new-build orthogonal construction. It was also observed that the mechanisms for constructing a BIM model from commonly used laser survey techniques are either automated gross simplifications, or involve operators tracing key points from the surveys, thus making them subject to personal interpretation and possible simplification in doing so.

However, the Nottingham Trent University respondent indicated that related research was being carried out in conjunction with the Digital Architecture Course at the University. As a member of the BIM group for the School of Architecture Design and the Built Environment, this group is actively pursuing designing a course in this area. But, whilst noting the developing use of BIM for existing assets, and how they can be universally recorded, searched and accessed, it was admitted that there was still much work to do, as the model had not yet being fully determined.

[See http://www.ntu.ac.uk/apps/staff_profiles/staff_directory/131088-2/26/benachir_medjdoub.aspx]

The economic factor significantly emerged in the answers to this question. Relevant issues were also raised regarding commercial sensitivity, highlighting the concern that these two issues could impose a significant burden on small, specialist, SME contractors. In the CRM field of activity these matters could create very real difficulties, and blunt the desire for a general uptake of (H)BIM across the sector.

Question 5:
With reference to the application of BIM to CRM work, do you feel able to teach:
- *The skills of BIM modelling and model analysis?*
- *The need for complex collaborative teamwork?*

The ten respondents were equally split in indicating whether or not they could teach the skills of BIM modelling and modelling analysis, with six out of ten indicating they were able to teach the need for complex collaborative teamwork. This latter aspect may need further exploration to determine whether or not the complexity of teamwork in the CRM sector has been fully appreciated in the application of (H)BIM.

Clearly, and with reference to incorporating some of the issues raised in answer to Questions 3 and 4 above, more work requires to be done to enhance the teaching skills and abilities to address both these areas more effectively.

Question 6:
What is the potential of integrating an actual construction project as a case study, in collaboration with a BIM teaching method?

Whilst, due to the teaching subject and methods, two respondents consider this approach not applicable, all others were positive in endorsing such integration as a relevant approach.

One respondent indicated that they already work collaborative with a number of others to try to address the problem through conservation case studies, and would be interested in forming partnerships to attract research grant activity in this area. This point was made specifically relating to the concerns previously raised in answer to Question 5 as a means of addressing the need to acquire the knowledge to teach the subject in depth.

On a pragmatic note, one respondent indicated the need to have a year's notice in advance to be able to carry out adequate staff briefing, and to integrate the case study as a live studio project for students. The valid point was also made that case studies are not always at the right stage of development in the delivered curriculum for students to gain the most from them.

Question 7:

Do you have enough information to teach BIM related:

- *Copyright issues?*
- *Data storage issues?*
- *Security and privacy issues?*

With a 50/50% split respondents were equally divided on the ability to teach data storage issues.

However, respondents were less certain (40/60% split) to teach copyright, security and privacy issues.

The results from all three areas indicate that there is a need to learn from what is already being taught, with a view to disseminating this information to a greater number of users.

Question 8:

Is pressure emerging from:

- *The student body to have BIM taught?*
- *The construction industry to have BIM taught?*

With a 20/80% split, respondents indicated that there was no significant pressure arising from the student body to have BIM taught. However, mirroring that situation, the reverse was true regarding pressure coming from the construction industry (80/20% split).

Two messages stand out here regarding:

1. The necessity to increase students' awareness of the need to understand that BIM will be a significant part of their future professional life, and,
2. The need for the construction industry to be more proactive and supportive in taking the BIM message to students.

Question 9:
What are your views on having a specific version and standard of BIM that is more relevant to the built heritage conservation, repair and maintenance (CRM) sector i.e. Historic Building Information Modelling (HBIM)?

This question elicited a variety of responses. The most basic challenged whether or not it defeated the objective of having a universal system of BIM. On the other hand, a view was expressed that if HBIM fitted the sector better, then standard BIM seemed less appropriate.

Concern was also expressed that if HBIM tried to systematise the historical analysis of buildings in a way that circumvented, or ignored, the very distinctive and different skills required within the sector, and the role of the building's history in the process, more debate and discussion would be required to clarify the position. Picking up on this point, one respondent noted that there might be special specifications for historic buildings, but also raised the issue of whether or not there would need to be special specifications for any other type of building. Taking an opposing point of view, another respondent thought that HBIM was essential, noting that they were working towards creating an open source definition of such an approach with Cadw. And, yet another, indicated that an HBIM approach would be particularly useful for clients such as English Heritage.

Another intimated that they were looking at the development of such a model with the inclusion of 'additional functionality in the process', where there will be a core similarity with BIM to ensure a universal understanding - otherwise noting that there would be a risk that BIM could marginalise the heritage requirements, and fail to uphold its collaborative intentions. A further view expressed was that, on thinking laterally, the new buildings of today (especially those constructed using BIM) will become the heritage of tomorrow, therefore the eventually models would morph over time.

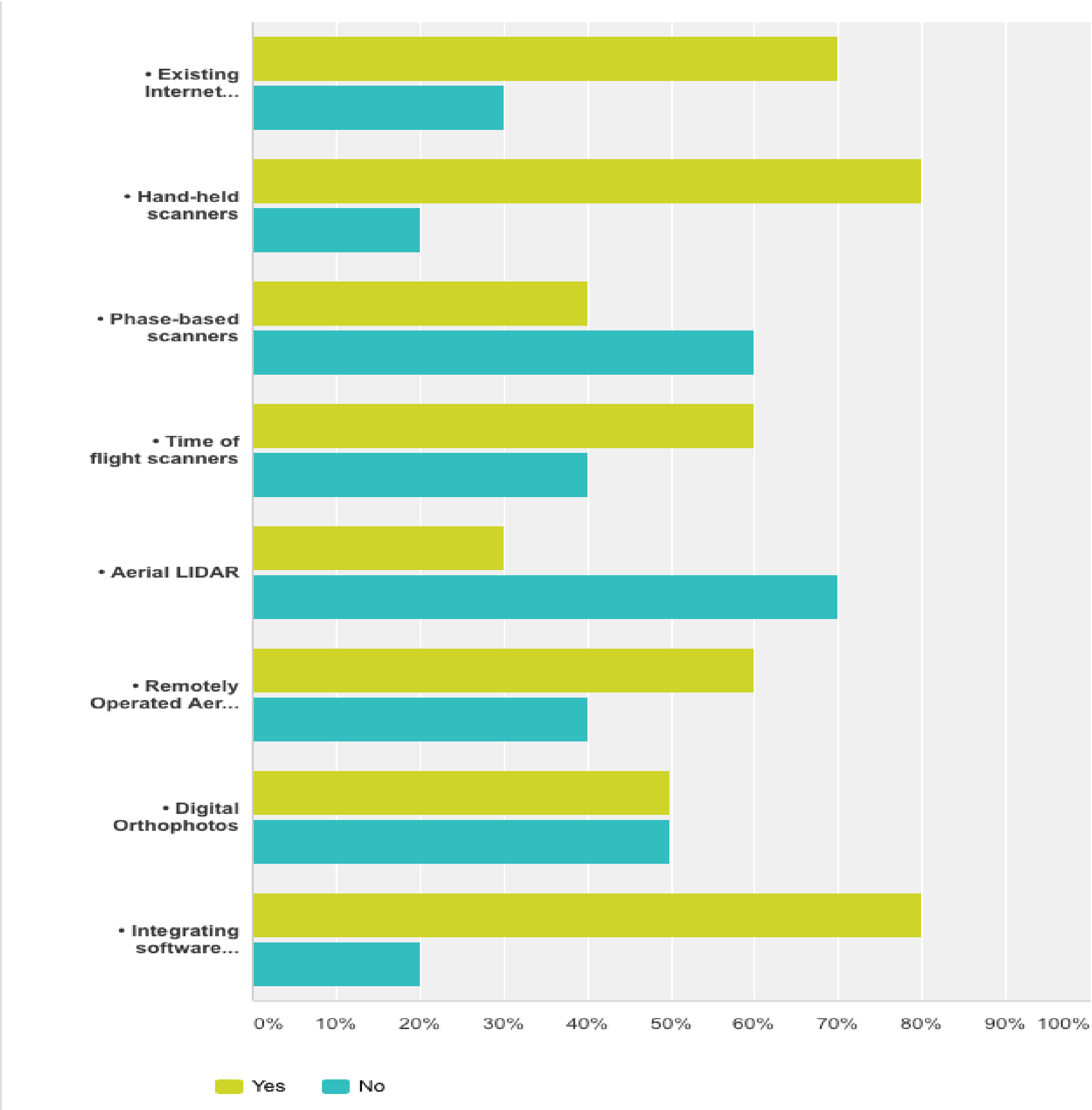
Question 10:
With reference to the potential needs of a CRM HBIM, is there sufficient technical guidance and information available for you to teach the use of:

- *Existing Internet facilities, such as Google Earth/Streetview/Altitude - Y/N*
- *Hand-held scanners*
- *Phase-based scanners*
- *Time of flight scanners*
- *Aerial LIDAR*
- *Remotely Operated Aerial Vehicles*
- *Digital Orthophotos*
- *Integrating software options, such as SketchUp, 3D CAD, Autodesk 123d, Autodesk Revit*

With all respondents answering, the specific results of this particular set of questions are illustrated in the undernoted bar chart.

Whilst additional technical information could be beneficial across all eight areas of interest, perhaps not surprisingly the greatest degree of comfort was expressed in the use of existing Internet facilities and currently available software options. The understanding of hand-held scanners was also high as was the weirdness of time of flight scanners and remotely operated aerial vehicles, but a less explicit awareness of the technicalities of phased-based scanners and aerial Lidar exists.

It is clear that additional technical and operational information could be beneficially promoted on all aspects.



Academic Respondents

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Marie May, Sheffield Hallam University:

Antony Pidduck, Nottingham Trent University:

Dr Ibrahim Motawa, Heriot-Watt University:

Prof Phil Banfill, Heriot-Watt University:

James Ritson, Kingston University:

John Counsell, Cardiff Metropolitan University, Cardiff School of Art and Design:

Andrew Shepherd, Architect in Practice and Director of the AA Postgrad Building Conservation Course:

University of Wolverhampton:

Acknowledgement

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