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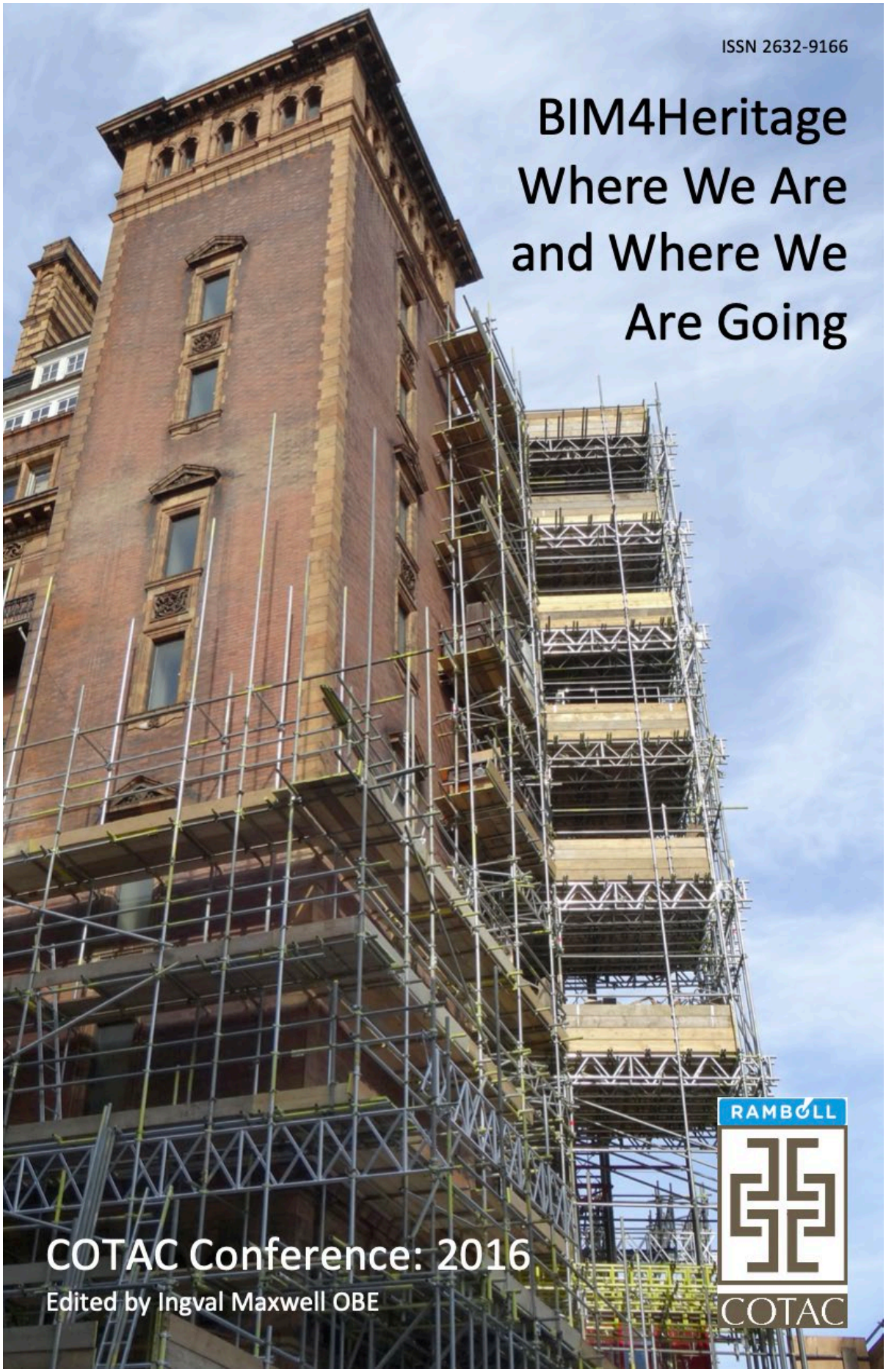
BIM4Heritage Where We Are and Where We Are Going



COTAC Conference: 2016

Edited by Ingval Maxwell OBE

RAMBOLL

COTAC

BIM4Heritage:
Where We Are and Where We Are Going

A COTAC Conference in collaboration with Ramboll

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

March 2017

Acknowledgements:

This Report continues on the theme of the various presentations offered at the COTAC Conferences *"Improving Thermal Performance in Traditional Buildings"* in 2011*, "Past Caring? BIM and the Refurbishment of Older Buildings"* in 2012*; "A Digital Future for Traditional Buildings: Practical Applications for Survey and Management"* in 2013 and *"Fire and Flood in the Built Environment: Keeping the Threat at Bay"* held in 2014, and published on-line by COTAC. These events collectively aimed to start scoping the relevance of BIM, and the issues that need to be considered, in the context of the traditionally constructed built environment. (See, http://www.cotac.global)

As part of this on-going appraisal and assessment, Ramboll arranged and hosted this conference *'BIM4Heritage: Where We Are and Where We Are Going'* in their 240 Blackfriars Road, London Offices, on 9 December 2016. It was held in collaboration with COTAC who, previously, championed the BIM4Heritage concept, spending time developing and gathering knowledge on the importance of utilising BIM for conserving, maintaining and managing our heritage assets.

Conceived as a 'warts and all occasion', the conference aimed to offer an honest appraisal of the use of BIM within heritage buildings and their environments, and to provide guidance on how BIM might be adopted for the range of heritage conservation and repair and maintenance processes. In reviewing the risks and opportunities concerning this specific adoption of BIM and to explore its increasingly advanced applications, speakers were invited to address the topics:

- BIM de-bunked
- Capabilities of information capture
- The conservation Conundrum
- BIM sensitive analysis
- Beyond the clouds

Thanks are due to Jez Foster, Director, Ramboll, and to his team, for taking the initiative and undertaking all the administrative preparations to arrange and hold the event. Thanks are due to all speakers upon whose presentations this reports is founded. In addition, thanks are

due to Jackie Heath, Tiziana Meciani and Fay Newham, all from Ramboll, whose helpful notes taken during the day augmented the oral presentations to further inform this report.

As and when discussion periods raised various related issues to the presented topics, in addition to the concluding discussion session, these have been appended to the various reports. By raising essential questions and comments, participants readily flagged up the issues of where BIM, and its application to the build heritage, 'might be going in the future'.

Supplemented by related observations, whilst every care has been taken in the preparation of this publication, the Presenters, COTAC and Ramboll specifically exclude any liability for errors, omissions or otherwise arising from its contents. Readers must satisfy themselves as to the appropriateness of the content, and validity of any described principles and practices.

COTAC, the 'Council on Training in Architectural Conservation'

COTAC, the 'Council on Training in Architectural Conservation', originated in 1959 as the 'Conference on Training in Architectural Conservation' in response to the need for training resources for practitioners so they could properly specify and oversee work involved in repairing and conserving historic buildings and churches.

Since its inception COTAC has successfully, persistently and influentially worked to lift standards, develop training qualifications and build networks across the UK's conservation, repair and maintenance (CRM) sector, estimated at over 40% of all construction industry activities. This has involved working partnership with national agencies, professional and standard setting bodies, educational establishments and training interests.

Ramboll

Ramboll works across the areas of Buildings, Transport, Planning and Urban Design, Water, Environment and Health, Energy, Oil and Gas, and Management Consulting. Founded in Denmark in 1945, it is a leading engineering, design and consultancy company, employing 12,300 experts and has a strong presence in the Nordics, North America, the UK, Continental Europe, Middle East and India, supplemented by a significant representation in Asia, Australia, South America and Sub-Saharan Africa.

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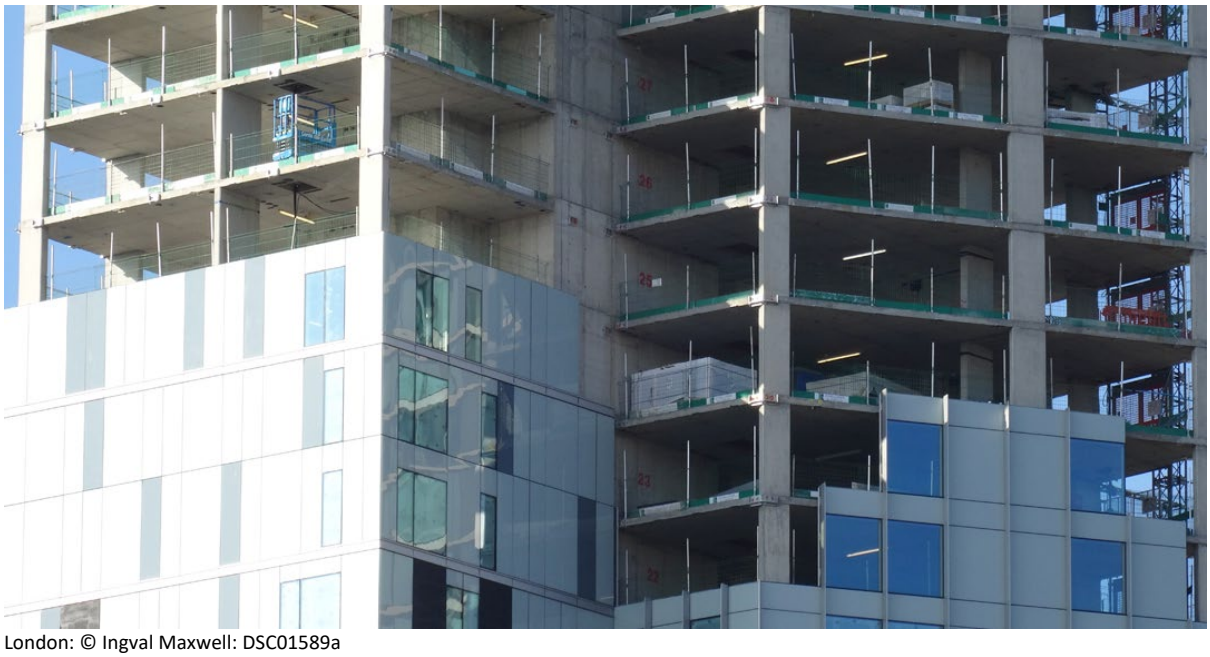
1 Overview and Context

For a number of years attempts have been made to relate and develop the operations with the U.K.'s construction industry to align its approach with that of the increasingly automated automobile industry. In the new-build sector, such an analogy is not unreasonable given the various strategic and policy-framing reports that have been produced to emphasis the potential that could ensue. But, in the process, the conservation, repair and maintenance sector of the industry tends to be somewhat subsumed in simplistic terms within the overall lead to make the new build sector more efficient, cost effective and less wasteful. It is also not unreasonable to build upon the assumption that the purchase of every new vehicle will be provided with a detailed service and maintenance manual that has been compiled and designed to keep it operational, and that new building could be similarly supported.

Arguably, with the range of new vehicles currently on the road, and their need for maintenance, it can be easily assumed that matching spare parts will be readily at hand should that need arise. However, with more vintage vehicles such an acceptance starts to flounder as increasingly demanding challenges arise of keeping them roadworthy and safe whilst, at the same time, retaining their significance and value intact. Such a commitment to vehicles is easily and consistently accepted. But, this issue becomes more acute with elderly vintage vehicles where, perhaps, no service or maintenance manual ever existed and where the challenges of keeping them in operational good repair become significant. Spare parts may not be so readily available when trying to maintain a 1907 Silver Ghost Rolls-Royce, or for economically repairing a 1948 XK120 Jaguar.

If we draw a parallel with the built heritage, and its need to be maintained to ensure its future survival, the analogy of working with a service maintenance manual is not so readily recognized. This lacuna is often and glibly overlooked, especially since virtually all of the construction industry has been solely educated and trained in new-build construction for the last half century.



London: © Ingval Maxwell: DSC01589a

In the series of reports produced by the National Heritage Training Group (NHTG) during 2007-2009, it is repeatedly indicated that there are over 6 million traditionally constructed pre-1919 buildings in the UK, of which half a million are listed, and some 33,000 scheduled monuments. In the *NHTG UK Built Heritage Sector Professionals* 2008 (1) report professionals identified that worked on pre-1919 buildings made up an average of 35% of their workload, and that increased to 76% for those operating in specialist conservation heritage activity. However, related evidence indicated that there was a low awareness level regarding the importance and long-term benefits of regular maintenance, despite the identified need to increase the amount of maintenance carried out on pre-1919 buildings using appropriate techniques and materials. Resulting in a demand for suitably skilled building conservation professionals there was a need to improve the relevance of national building standards relating to such work to drive up the demand for the requisite knowledge to successfully deliver projects.

Norwich: © Ingval Maxwell: IMG_2641a

As to the scale of the mismatch, it was calculated in 2008 that there was, broadly speaking, one conservation-accredited architect for every 15,000 traditional buildings; one conservation-accredited surveyor for every 85,000 buildings; and one conservation accredited-engineer for every 250,000 traditional buildings. Whilst, in the interim, these statistics have only marginally improved, the implication remains that there is a real lack of skills and awareness in almost half of the construction industry there will be charged with the safeguarding of the U.K.'s built heritage.

Putting that in the context of BIM and the need to apply that knowledge and understanding to build an effective central data environment, the scale of the mismatch becomes critically evident. Although progress is being made, as evidenced by the various presentations offered, a considerably discrepancy exists before there is an equal understanding and acceptance that needs to take place within the sector regarding a fully relevant balanced approach to the overall introduction of BIM.

Post Conference: Assessment and BIM Pointers

Although, as the following reports reveal, BIM is making some impact on heritage projects from a conservation, repair and maintenance perspective, a significant number of issues still need to be considered and addresses. Revealed in the presentations and discussion sessions, some concerns clearly exist in the clients' and small professional practices perception of how BIM can be used in a cost-effective and supportive manner on-site.

Whilst illustrating the value of BIM, more influential ways need to be found to encourage a greater degree of uptake, including the need to:

- Provide BIM Guidance for owners and clients
- Understand the roles and responsibilities as indicated in the PAS documents
- Use technology that aspires to offer relevant data, but also reveals its limitations
- Be competent at Level 1 before embarking upon Level 2
- Improve collaborative working through active engagement
- Keep it simple and relevant

On associated technology, there was recognition of the need to:

- Agree on the use of a 'common language' for data, information exchange and use
- Migrate easily and effectively from existing workflow patterns
- Have the ability to incorporate data from various systems
- Enable transparency in all stages of involvement
- Have essential software interoperability
- Enable the use of mobile devices on-site
- Ensure site connections were 'fast' enough

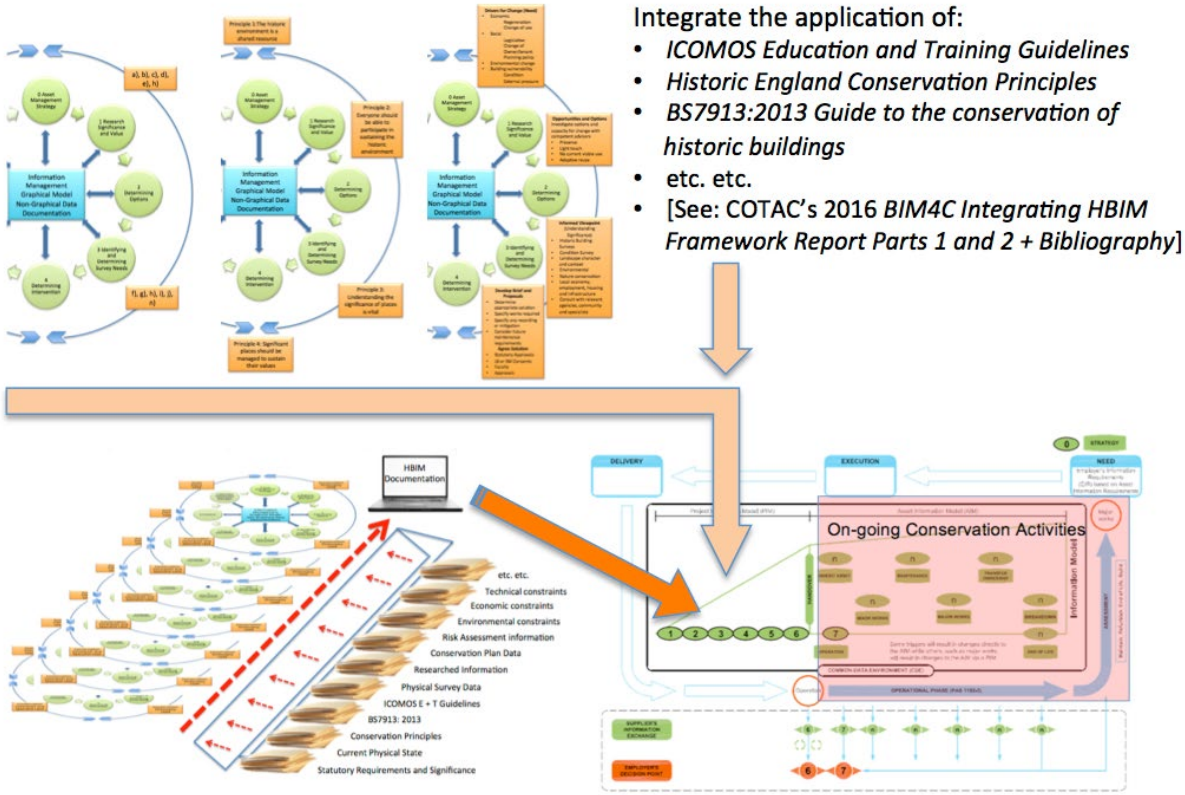
More general issues touched on included:

- How to make the approach more economically acceptable and cost effective whilst mastering information delivery
- Address and abridge the 'too high delivery level' to create a more adoptable approach
- The lack of promoted and relevant conservation BIM case studies
- How to achieve the required level of data-centric one-to-one training
- How to link BIM to other views

In 2016 COTAC published three on-line volumes, entitled *BIM4C Integrating HBIM Framework Report Parts 1 and 2 + Bibliography.* (2), (3), (4). In Part 1, *Conservation Parameters,* explored the need for BIM to recognise other views that prevail as recognised standards in the conservation, repair and Maintenance sector of the construction industry. Extracting and overlaying the relevant diagrammatic parts of the Part 1 diagrams, it could be argued that current developmental thinking in the evolution of PAS 1192-3 *Specification for information management for the operational phase of assets using building information modelling* (5) is inadequate regarding the need to accommodate the relevant conservation parameters that hitherto have guided conservation, repair and maintenance projects.

Combining the issues raised in the presentations on the *Capability of Information Capture* and *BIM4Heritage: The Conservation Conundrum – Where BIM Empowers the Conservation*

Process, a set of more integrated requirements and conservation applications emerge to better inform the process stages 1 -6, as illustrated diagrammatically below:



Whilst an emphasis is offered with 'On-going conservation activities' in stage 7 of the PAS 1192-3 diagram, this currently omits the consideration of the not-insignificant range of critical conservation issues that should be better understood in the earlier stages 1-6.

More awareness, and acceptance, of the impact of these needs should be comprehensively incorporated in the evolving PAS 1192-3 process.

Post Conference: Reflections

Notwithstanding the content of the conference it is perhaps of interest to also reflect on the following web-based references:

The BIM Task Force and Technology Strategy Board

A key aspect of the BIM Task Force website (6) indicates that its 'free to use' digital tool aims to transform the procurement of buildings and infrastructure, whilst allowing the cost of storing, sharing and analysing data to be reduced. To achieve this it notes:

> *The UK BIM Task Force is working in partnership with the Technology Strategy Board, and the Department for Business, Innovation & Skills (BIS), to support the development of a 'free to use' digital tool. This will reflect the: new Plan of Works, encompasses the publically available PAS 1192 standards, and uses the CPIC classification system to*

structure the data storage thus exploiting the publically available Level 2 standards being developed for BIM.

The buildingSMART Data Dictionary

In similar vein, the building Smart Data Dictionary website (7) reveals that it is open, allowing architects, engineers, consultants, owners and operators on one side and product manufacturers and suppliers on the other to internationally share and exchange product information so that the building process becomes more efficient.

> *The bSDD is a library of objects and their attributes used to identify objects in the built environment and their specific properties regardless of language, so that "door" means the same thing in Iceland as it does in India.*

With such shared intentions both initiatives, when fully realized, will significantly contribute to the operational effective construction of all new buildings. But, the desire to speak a common language can also be found elsewhere.

ICOMOS ISCS Illustrated Glossary on Stone Deterioration Patterns

The Illustrated Glossary (8) created by the International Council on Monuments and Sites' International Scientific Committee on Stone visually and descriptively categorized stone deterioration and conservation, to help address the terminological confusions that have led to major communication problems between scientists, conservators and practitioners. Its website notes:

> *…it is of primary importance to set up a common language; if degradation patterns can be shown, named and described, then they can be recognized and compared with similar ones in a more accurate way in further investigations…Stone conservation is a crucial topic in monument conservation and…In view of the accelerating decay of our stone monuments worldwide this is an exemplary contribution which will promote the international cooperation…for advice and help from the specialists…*

But, putting initiatives such as this into practice is where significant difference can occur between the application of current BIM thinking and the parallel needs of the conservation, repair and maintenance sector. Regarding this variance, the Introduction to COTAC's April 2014 Conference Report on *'Integrating Digital Technologies in Support of Historic Building Information Modelling'* (9) noted that:

> 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* (10) (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

Events, such as the conference behind this report, can assist in achieving a better and more balanced approach to the application of BIM that full recognises the needs of both sides of the construction industry. With over 6 million of the UK's pre-1919 structures of traditional construction occasioning some £6 billion of industry related activity per annum, correlated developments in BIM are urgently required to create a more realistic balance of need in the approach.

London: © Ingval Maxwell: DSC01712a

2 BIM De-bunked: The Current state of play

Report based on the presentation by Graham Stuart, Ramboll UK Integrated Business Technology Leader

Opening with a quote from Dr Ralf Speth *"If you think Good Design is expensive, you should look at the cost of Bad Design"* the presentation addressed:

- BIM in the UK
- What does BIM look like today?
- The Clients' Role

> *Ralf Dieter Speth is currently chief executive officer of Jaguar Land Rover, having held previous roles with BMW, Linde and Ford's Premier Automotive Group.*

Reference was made to "*Rethinking Construction*" (11) (1998), more commonly known as the 'Egan Report', after the chairman Sir John Egan. Prepared by the 'Construction Task Force' for the Dept. for Trade and Industry, its scope focused on improving the quality and efficiency of UK Construction sector. In a summary statement, the Rethinking Construction Report noted that:

> *"…the Task Force wishes to emphasise that we are not inviting UK Construction to look at what it does already and do it better: we are asking the industry and government to join with major clients to do it entirely differently. What we are proposing is a radical change in the way we build. We wish to see, within five years, the construction industry deliver its products to its customers in the same way as the best consumer-lead manufacturing and service industries. To achieve the dramatic increases in efficiency and quality that are both possible and necessary we must all rethink construction".*

But, post publication, the report recommendations were not properly implemented and momentum was lost, most likely due to a lack of a mandate. On recognising this lacuna, BIM Level 2 is now being widely adopted, and the government is demanding it! In July 2013 the Construction 2025 Strategy (12) indicated that:

> *"Government will mandate BIM for all centrally procurement Government contracts from 2016. Industry must therefore meet the challenge–only through the implementation of BIM will we be able to deliver more sustainable buildings, more quickly and more efficiently. BIM is also critical to the successful implementation of a wider offsite manufacturing strategy."*

The vision for 2025 is that the industry:

- Is known for its talented and diverse workforce.
- Is efficient and technologically advanced.
- Leads the world in low carbon and green construction exports.
- Drives growth across the entire economy.
- Has clear leadership from a construction leadership council.

In the process, the long-term targets shared by Industry and Government anticipate 33% lower costs, 50% faster delivery, 50% lower emissions, and 50% improvement in exports.

With the aim of BIM covering the full "Cradle to Grave" approach to buildings and infrastructure, within the design, build and operate framework, in explaining what it is two definitions, amongst many others, might be offered:

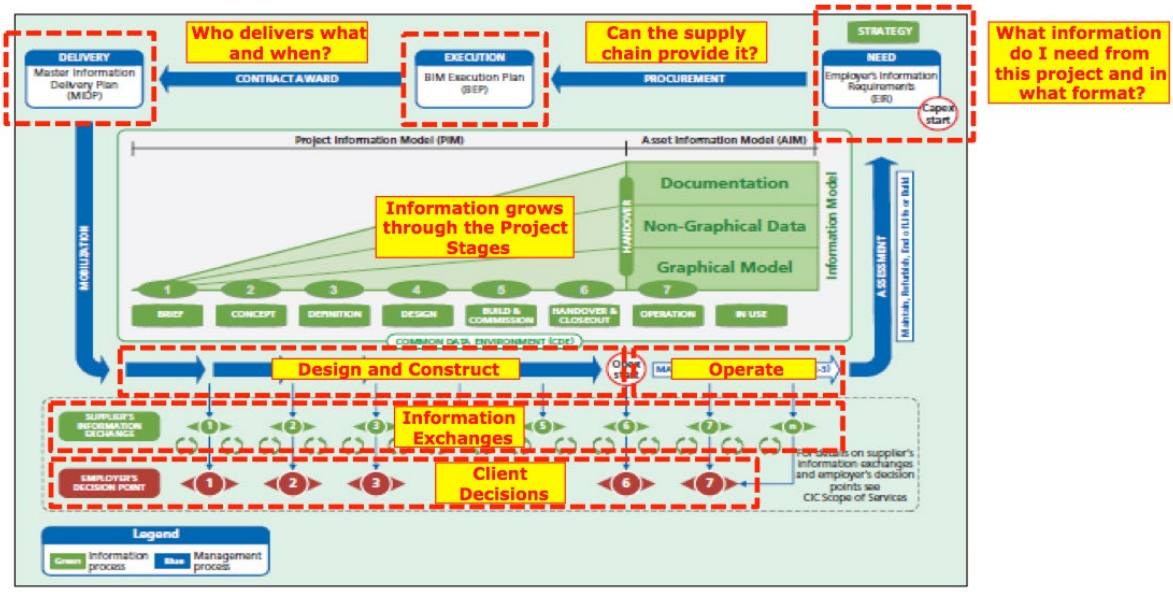
> *"Building Information Modelling is a set of technologies, processes and policies enabling multiple stakeholders to collaboratively design, construct and operate a facility" (Succar. B, 2013)*

> *"BIM is a technology-enabled collaborative information modelling and management process used in the whole lifecycle (planning, design, construction and operation management) of building, plant and infrastructure projects" (Ramboll Group, 2016)*

A summary of the BIM Level 2 requirements amount to:

- *Provision of an Employers Information Requirements (EIR) document with clear definition and decision points*
- *Provision of a Common Data Environment*
  Supplier and Supply chain capability assessment
- *Provision of a BIM Execution Plan (BEP) including the assigned roles, standards, methods and procedures and a master information delivery matrix aligned with the project programme*
- *Development of information models which reference, federate or exchange information with other models*
- *Compliance with the documents and standards listed in Pillars of BIM*

In considering what the BIM Level 2 Common Data Environment looks like, at its core is the Graphical Information block into which Non-Graphical information is exchanged, and MEP, Structural and Architectural information is fed. In gaining an insight into the related issues, the Information Delivery Cycle, as applied to Buildings and Infrastructure projects, can be annotated on *PAS 1192-2: 2013 Figure 2* as follows:



In the process, considerable responsibility is placed at the Client's door in the role they have to play in expanding what was traditionally recognised as the 'Project Brief'. This commitment is explicitly determined in considering the guidance on how to set up a BIM Project. In the

following process, where an entirely new set of operational acronyms needs to be readily understood, the steps are:

- The Employers Information Requirements (EIR) is prepared by the Client to outline the information and delivery requirements.
- The Client issues the EIR to prospective individuals or teams
- The individual or teams prepare a Pre-BIM Execution Plan (Pre-BEP)
- The Pre-BEP is the individuals response to how they would deliver the EIR
- This leads to the award of Contract and the appointment of the Team
- The Design Team prepares a Post-BIM Execution Plan (Post-BEP)
- The Post-BEP is a live project document containing all BIM protocols on how the Design Team will deliver the EIR

The Employers Information requirements (EIR) document consists of three standard categories – Technical; Management; and Commercial.

Under the Technical category the following need to be incorporated:

- Software platforms
- Data Exchange Format
- Co-ordinates
- Level of Detail
- Training

On Management, the following:

- Standards
- Roles and Responsibilities
- Planning the Work and Data Segregation
- Security
- Coordination and Clash Detection Process
- Collaboration Process
- Health and Safety and Construction Design
- Management
- Systems Performance
- Compliance Plan
- Delivery Strategy for Asset Information

Under Commercial:

- Data drops and project deliverables
- Clients Strategic Purpose
- Defined BIM/Project Deliverables
- BIM-specific competence assessment

Furthermore, with the Validation of Deliverables to the Client the (PAS 1192-2:2013) contents of post-contract BEP are listed under Management, Planning and Documentation, Standard Method and Procedure, and IT Solutions headings as follows:

Management:

- Roles, responsibilities and authorities;
- Major Project Milestones consistent with the project programme;
- Project information model deliverable strategy;
- Survey strategy including the use of point clouds, light detecting and ranging (LIDAR) or global navigation satellite systems (GNSS);
- Existing legacy data use;
- Approval of information;
- Project Information Model (PIM) authorisation process.

Planning and Documentation:

- Revised Project Implementation Plan (PIP) confirming the capability of the supply chain;
- Agreed project processes for collaboration and information modelling;
- Agreed matrix of responsibilities across the supply chain;
- Task Information Delivery Plan (TIDP);
- Master Information Delivery Plan (MIDP)

Standard Method and Procedure:

- Volume strategy;
- Project Information Model (PIM) origin and orientation;
- File naming convention;
- Layer naming convention;
- Agreed construction tolerances for all disciplines;
- Drawing Sheet templates;
- Annotation, dimensions, abbreviations and symbols

IT Solutions

- Software Versions;
- Exchange formats;
- Process and data management systems.

In the process it will be very easy to potentially achieve an excessive amount of information. It estimated that, in some cases, Excel's 250-column spreadsheet, each with 6 million lines, could be 'overwhelmed' with data.

Consequently, the need is to look pragmatically at BIM requirements.

Whilst there are perceived benefits in adopting BIM there are also risks and challenges to be faced, as listed below:

BIM Benefits	Risks and Challenges
Collaboration	Clearly defined and appropriate deliverables
Differentiation	Client expectations not aligned
Efficiency	Engineers' ability to interrogate models
Integration	Learning curve – slower initially
Quality	Appropriate hardware
Standardisation	More meetings
	Other consultants' capabilities
	More data and documents
	Changes typical design schedule
	Level and availability of modelling skills
	Tracking changes
	Understanding internal capabilities

In Summary:

The reasons to adopt BIM include:

- It is mandated on all Government funded (Public Sector) projects in the UK from April 2016 and (where Appropriate) in Scotland from April 2017.
- Private sector clients have also recognised the benefits and are asking for BIM to be used on their projects too.
- Well-planned BIM brings efficiencies.
- Well-planned BIM reduces errors

Good BIM requires:

- Understanding of the end use of the asset (*begin with the end in mind*).
- Early stage engagement with stakeholders (including the clients FM team).
- Clearly defined targets/aspirations for BIM and how this will be used to add value.
- Well-defined protocols describing the roles, responsibilities and deliverables for the project.

With regard to the Client:

- It is essential to fully understand and drive the EIR document, this is the design team is asked to deliver.
- Remember to allow sufficient time for the design team to plan, roles and responsibilities, understand their digital requirements, input into BEP's etc.
- New roles and responsibilities are identified in PAS1192-2 and these need to be understood and appropriately allocated within the teams.
- It is important the design team only deliver what is required for each stage and not over produce.
- The post-contract BEP will be a live document throughout the life of the project and will be used to validate their deliverables and how they align with the EIR.

With regard to the design Team, BIM:

- Is about the effective management of project information.

- Impacts on all aspects of business process.
- Will require behavioural change across all levels of the business.
- Affects anyone involved in the design and delivery of projects.
- Is about optimising the design, construction and operation of the asset.
- Will enable the reduction of waste resulting in more sustainable solutions.
- Is all about delivering better buildings and infrastructure

But, within the BIM Common Data Environment – how to collect heritage data is a challenge.

Tower of London © Ingval Maxwell: DSC01081a

3 Demystifying BIM Level 2

Report based on the presentation by Edonis Jesus, BIM Lead Lendlease Consulting

The issue of poor performance in terms of productivity has been regularly identified within the UK's construction industry over the past few decades. In the 1990's several reports were produced, with a view to drive up efficiency and eliminate industry waste. Of these, the most relevant were those produced by Latham, Egan and the Strategic Forum for Construction:

- Published in 1994, the Latham Report *'Constructing the team'* (13) warned of industry inefficiencies caused by industry fragmentation, and promoted partnering and collaboration to improve efficiencies.

- The Egan Report, *'Rethinking Construction'* (11), published in 1998 promulgated the view that performance could be improved through the elimination of waste, being a non-added- value activity within the construction process.

- The Strategic Forum for Construction report, published 2002, under the title *'Accelerating change' (14),* underlined the potential importance of information technology in achieving greater integration.

Primarily through inactivity in addressing the concerns, all of these combined intentions and report recommendations could be deemed to have failed to impact on the industry. In consequence, and following the global financial crisis of 2008, the UK Government decided to tackle the issue of poor performance, reduce capital and operational costs, and mitigate the impact of carbon from both the construction and operation aspects of the built environment. To do so, in 2011, it published the *Government Construction Strategy* (15). This report detailed a programme of measures to significantly reduce capital costs, and the carbon burden by 20%. Measures to be adopted include:

- Greater use of value engineering and lean procurement initiatives
- Use of 'Soft landings' seeking to reduce the hidden costs of adapting completed spaces to suit specific end user needs
- Increased use of standardisation to generate efficiency and procurement savings
- Building Information Modelling (BIM)

Within the Government Strategy, BIM is identified as:

> *A 'collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets. BIM embeds key product and asset data and a 3 dimensional computer model that can be used for effective management of information throughout a project lifecycle – from earliest concept through to operation'*

Determining that BIM Level 2 must be adopted for all centrally procured Government contracts from April 2016, (2017 in Scotland) the BIM programme objectives and highlights include need for:

- Reduced project risks; time, cost, quality, and safety
- Reduced project waste; material and efforts

- Increased certainty of outcomes
- Improved communications
- Increased visibility of the design and delivery processes
- Better outcomes

Through delivery efficiency, the aim is to work towards 'The Day the Waste Ended!"

CIC BIM Protocol

BIM Protocol (16) has been commissioned by CIC as part of its response to the UK Government BIM Strategy. Published in 2013, the Protocol has been drafted for use on all common construction contracts and supports BIM working at Level 2. In explaining how the Protocol works it is stated in the documents' Para 3,1 that:

> *The primary objective of the Protocol is to enable the production of Building Information Models at defined stages of a project. The Protocol is aligned with Government BIM Strategy, and incorporates provisions, which support the production of deliverables for 'data drops' at defined project stages. The Protocol also provides for the appointment of an 'Information Manager'.*
>
> *A further objective of the Protocol is that its use will support the adoption of effective collaborative working practices in Project Teams. The encouragement of the adoption of common standards or working methods under PAS 1192-2 are examples of best practice that can be made an explicit contractual requirement under the Protocol.*
>
> *All parties involved in the use, production or delivery of Models on the Project (the "Project Team Members") are required to have a BIM Protocol appended to their contracts. This will ensure that all parties producing and delivering Models adopt any common standards or ways of working described in the Protocol and that all parties using the Models have a clear right to do so. The responsibility for ensuring that Protocols are in place is with the Employer named in each agreement.*

Digital Plan of Work (DPoW)

A digital plan of work enables an employer to define the deliverables required at each stage of a construction project – from developing the strategy through to managing the asset. The content from the plan of work develops over time, as more information is known about the project. It should be made available to all project participants so that they know who must deliver what information and when. The digital project lifecycle is graphically defined in the PAS 1192-2 Mervyn Richards diagram.

The following definitions apply to BIM Levels 0 – 3:

- Level 0: Unmanaged CAD probably 2D, With paper as the most likely data exchange mechanism

- Level 1: Managed CAD in 2 or 3D format with a collaboration tool providing a common data environment, Commercial data managed by standalone cost packages with no integration
- Level 2: Managed 3D environment held in separate disciplines with attached data. Commercial data managed by a CDE. The approach may utilise 4D Programme data and 5D cost elements
- Level 3: Fully open process and data integration enabled by IFC or similar. Managed by a collaborative model server. Could be regarded as iBIM (integrated BIM) potentially employing concurrent engineering processes

Achieving BIM Level 2

Achieving Level 2 is distinguished by collaborative working about how the information is exchanged between different parties. This is informed by the British Standard BS 1192 in four parts, and related Publicly Available Specification PAS parts Two, Three and Five documentation, which promulgates the view that information created and exchanged should follow the described Standards and Protocols in:

- *BS1192:2007 Collaborative production of architectural, engineering and construction information – Code of practice* (17)
- *PAS1192:2 Specification for information management for the capital/delivery phase of construction projects using building information modelling* (18)
- *PAS1192:3 Specification for information management for the operational phase of assets using building information modelling* (19)
- *BS1192:4 Collaborative production of information Part 4: Fulfilling employer's information exchange requirements using COBie – Code of practice* (20)

- *BS7000-4 Design Management Systems: Guide to managing design in construction* (21)
- *BS 8541-6:2015 Standards for library objects for architecture, engineering and construction* (22)

Uniclass2015

Uniclass2015 (23) is a unified classification for the UK industry covering all construction sectors. It contains consistent tables classifying items of all scale. As part of the BIM Toolkit project, Uniclass allows project information to be structured to a recognised standard. This original 1997 version has been heavily revised, to make it more suitable for use with modern construction industry practice, and to make it compatible with BIM now and in the future. As a key deliverable of the BIM Toolkit project, NBS have worked with experts from across the industry to develop the new classification system. This builds on previous versions and developments of Uniclass, significantly extends the scope and responds to industry feedback to the draft tables CPI published in 2013.

London: © Ingval Maxwell: DSC01264a

With the aim of adopting a collaborative approach to reduce an estimated 30% of construction waste, BIM is one part of the overall improvement strategy. Other measures to be adopted include:

- Greater use of value engineering and lean procurement initiatives

- Use of Soft landings; which seek to reduce the hidden costs of adapting completed spaces to suit specific end-user needs
- Increased use of standardisation to generate efficiency and procurement savings

Within tight time constraints, by 3 October 2016 all centrally funded Government Departments needed to have *"the capability to electronically validate BIM information delivered from the supply chain"* and to be *"making progressively more use of supply chain data for key business activities".* Whilst a number of Departments are already adopting BIM, Local Authorities are not covered by the BIM mandate although many are falling in line. Similarly, although London Underground is not directly subject to the mandate on using Level 2 BIM, it does receive government funding and has therefore chosen to pursue BIM as a priority. As a result, Level 2 BIM has been available for use on their projects by April 2016 through taking a stepped approach towards achieving it by ensuring that new projects achieve Level 1.

The BIM Level 2 process involves:

- Agreement on Standards and Process to be used
- BIM Protocol and Model Production Delivery Table included in appointment contracts
- Provision of Employers Information Requirements (EIR) document
- Provision of a Pre-Contract BIM Execution Plan and Project Implementation Plan
- Assessment of suppliers BIM capability before appointment
- Appointment of project Information Manager
- Provision of a Common Data Environment (CDE)
- Development of Post-Contract BIM Execution Plan
- Development of Task Information Delivery Plans (TIDP)
- Development of Master Information Delivery Plans (MIDP)
- Production of the Project Information Model
- Production of the Asset Information Model
- Compliance check against BIM documents and standards

Reflecting on the difference between new build and heritage assets the Venice Charter (24) (1964) notes that the *'Understanding of any component of heritage is beyond understanding the physical characteristics of existing building, because each individual heritage object is a message from the past, and it remains as living witnesses of the age's tradition'.*

However, arguments for the use of BIM in the historic environment might include benefits from:

- Support activities to the understanding of the historic built environment
- Digital representation of historic structures
- Support CRM assessments and decision making
- Assist archaeological/structural analysis
- Enhance building performance
- Support the management of Heritage Information
- Improve communication with the public
- Demonstrate safe methods of working, logistics planning and movement
- Support conservation, restoration, rehabilitation, repair and maintenance activities

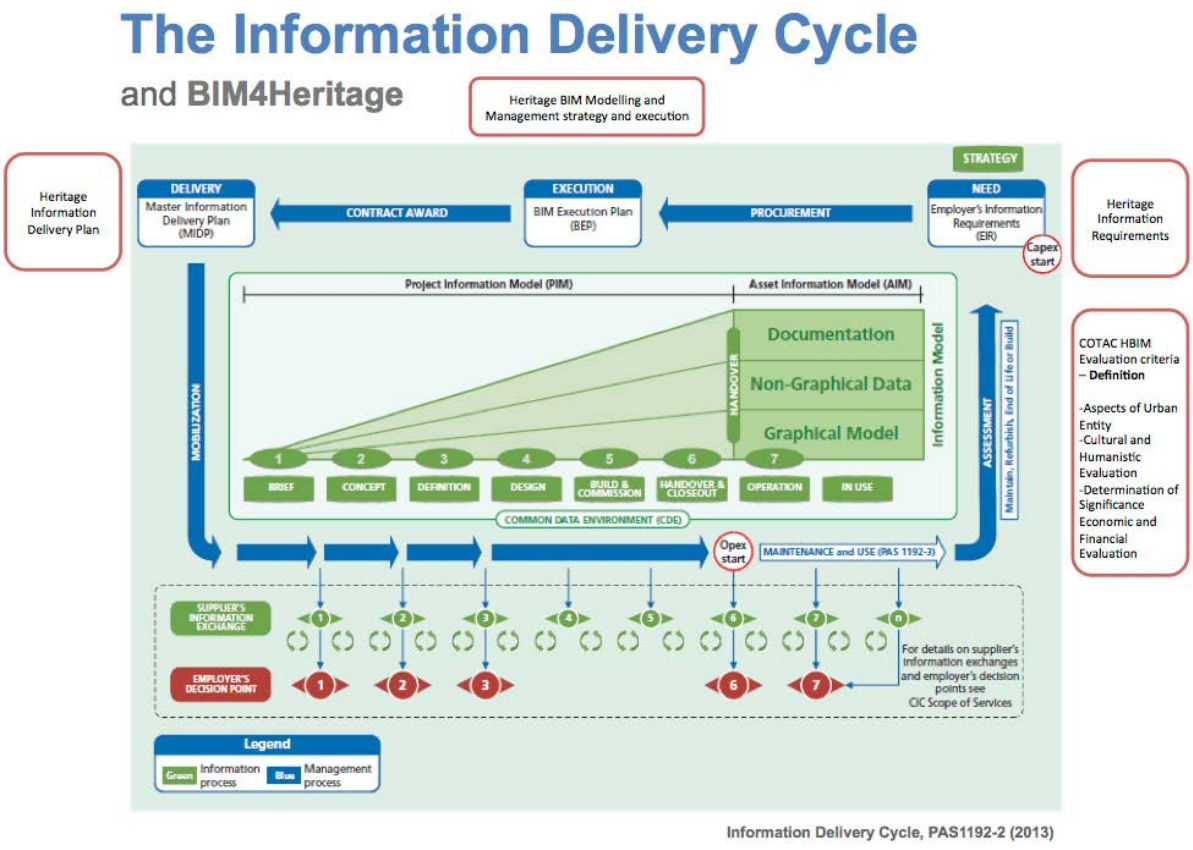
- Capture knowledge

But, in developing these, there are challenges too, including:

- Cost (data capture, data processing)
- Data Processing (3D Modelling) time
- 3D Model accuracy
- Potential of BIM application to the Historic Environment not fully explored – interfaces of BIM in relation to conservation and heritage science processes not yet identified
- Lack of research
- Lack of published case studies

In addressing some of these issues, in 2015 Historic England published its revised *'Metric Survey Specifications for Cultural Heritage'* (25), which includes a section on standard specification for the supply of building information modelling (BIM).

Other considerations, such as COTAC's two 2016 '*BIM4C Integrating HBIM Framework Report'* on *'Part 1: Conservation Parameters'* (2) and *'Part 2: Conservation Influences'* (3) are starting to look at the issues in more detail. In consequence these are being considered in the context of the PAS1192-2 Information Delivery Cycle diagram, as below:



Information Delivery Cycle, PAS1192-2 (2013)

BIM4Heritage Group

But, much more needs to be done. In consequence a BIM4Heritage Group (26) has been initiated within the BIM4Communities, and is currently working to refine its intentions and remit. The vision of the Group is to provide a forum for organisations and industry professionals to share knowledge and lessons learnt on BIM applied to historic structures. Its purpose is to promote the learning, awareness and understanding of BIM within the conservation and heritage sector of the built environment, and to influence and integrate this with wider industry needs. This will involve a range of disciplines and conservators who have the current stewardship of the existing building stock; it will also aim to enable industry to understand the importance of information relating to conservation requirements.

Discussion Q&A Issues and Points:

- Behavioural changes are required throughout the entire cycle
- Appointing an 'Information Manager' is critical to the contract, but the clients still needs to validate the information, therefore they need the capability to do so
- The future will involve developing predictive analysis
- The key is being able to facilitate altering the information
- Clients must own and manage the data appropriately and avoid leaving it with the suppliers.
- Little thought has been given to supply chain needs as yet
- Use of 'open standard' software to allow exchanges of information
- Existing information could be built on to create core asset material so the Facility Management team will become more efficient
- Software is getting cheaper

- The client employs the 'Information Manager' therefore does the 'BIM Manager' take on the role of three people?
- Who is coordinating the BIM manager?
- Need to implement BIM software – Revit, Bentley or other competing interests?
- Software availability – who oversees making it work for the historic environment?
- Clashes management: how to bring different models together to avoid clashes?
- The 'Iceberg' of information needs require considerable support for the clients, so what training is to be given and what advice is available?
- How to make the 'asset model' a usable model to hand over to the clients? Is this likely to be led by software delivery?
- What are the benefits and how to convince clients?
- How to adopt Naming Conventions in historic construction?
- How to future-proof the information that might be gathered?

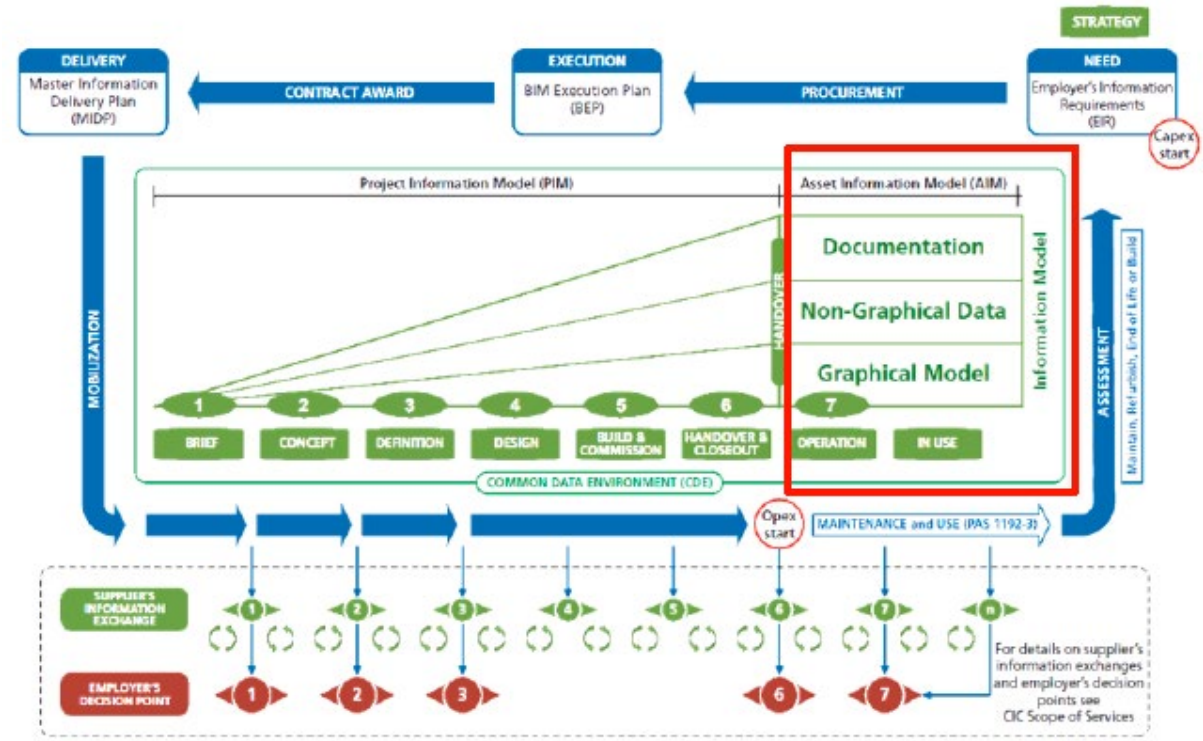
4 Capability of Information Capture

Report based on the presentation by Carl Brookes, Ramboll UK Team Director Advanced Engineering and Geomatics

In introducing the topic, the question was raised as to where existing heritage assets, and the BIM4Heritage initiative fit in to BIM, and how measurement and monitoring, 3D laser scanning, photography and photogrammetry, and benchmarking might assist in providing an answer. The reality being there is no hand over data and no nicely set up model, but there is a lot of data that needs to be collected through archival research etc. and then represented spatially through GIS or models.

It is acknowledged that the benefits of the 'new-build' process are being increasingly recognized, and whist the challenges influencing uptake may relate to the 'Capex' investment, 'Opex' receives the greatest benefits, as the handover of Project Information Model (PIM) becomes the Asset Information Model (AIM)

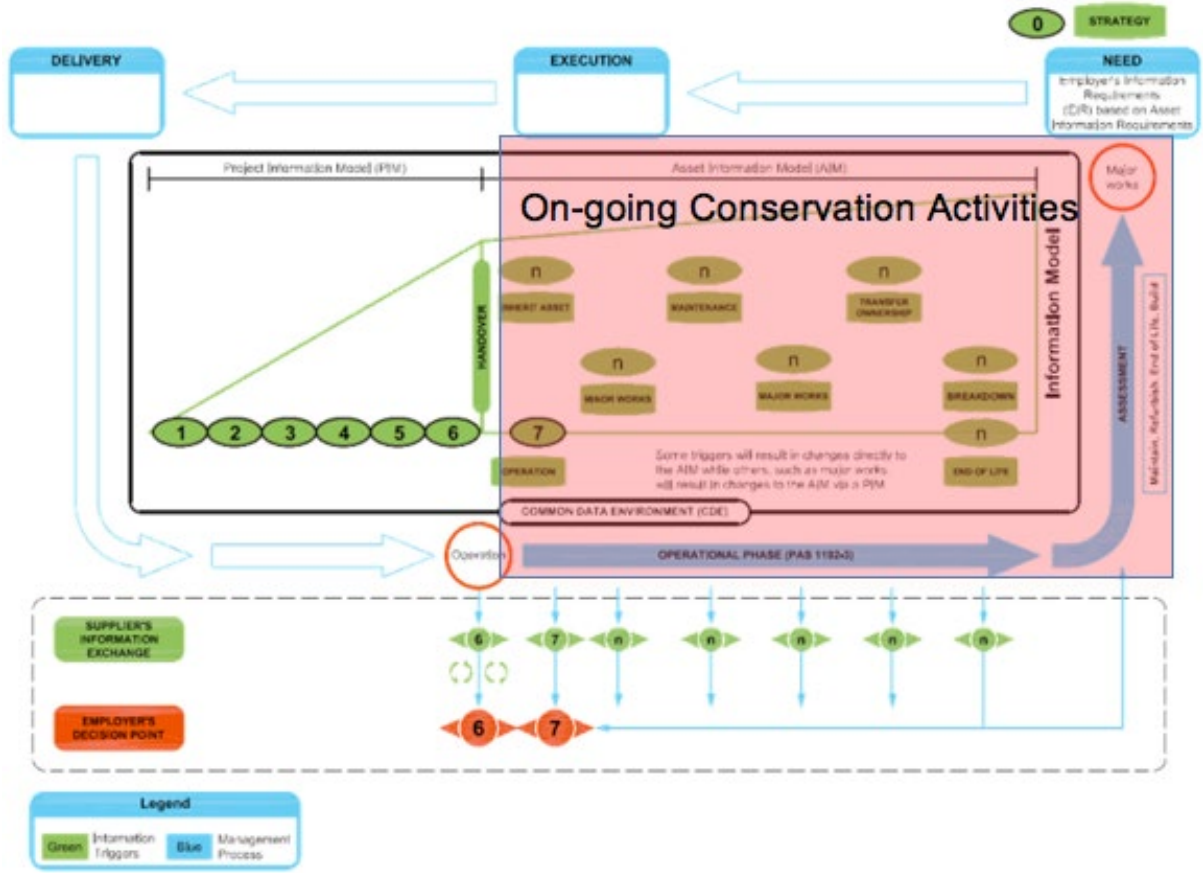
> *Note:*
> *CAPEX start represents one of two states, either where a project begins with no pre-existing information or where a project begins based on the assessment of pre-existing information from an asset portfolio.*
>
> *OPEX deals with the operational phase, focusing on use and maintenance of the Asset Information Model for Facilities Management.*



The above diagram is reproduced from PAS 1192-2:2013 - Specification for information management for the capital/delivery phase of construction projects using building

information modelling (18), with a highlit box to indicate where heritage issues might better fit. But there is much pre-existing information beyond the stage 7 Operation and Use elements that need to be also taken into account. Consequently, on existing and heritage sites, the benefits of BIM are currently less clear. There is no handover Asset Information Model (AIM) and existing information is likely to be in a combination of forms, reports, sketches, 2D CAD etc. in addition to relevant considerations as to significance, value and legislative parameters that also need to be accommodated.

Should an Asset Database, such as Tribal K2, be used with the intention of improving efficiencies and achieving maximum returns on investment to stay competitive and improve service delivery, it is likely to be predominantly orientated towards the post-handover stage of a 'new-build' project. Consequently, some sort of more relevant spatial framework and/or model will need to be developed and produced.



The above diagram, reproduced from *PAS 1192-3:2014 Specification for information management for the operational phase of assets using building information modelling* (19), with an overlay, indicates where significant on-going conservation activities can be anticipated once the full status, physical condition and conservation parameters are also understood

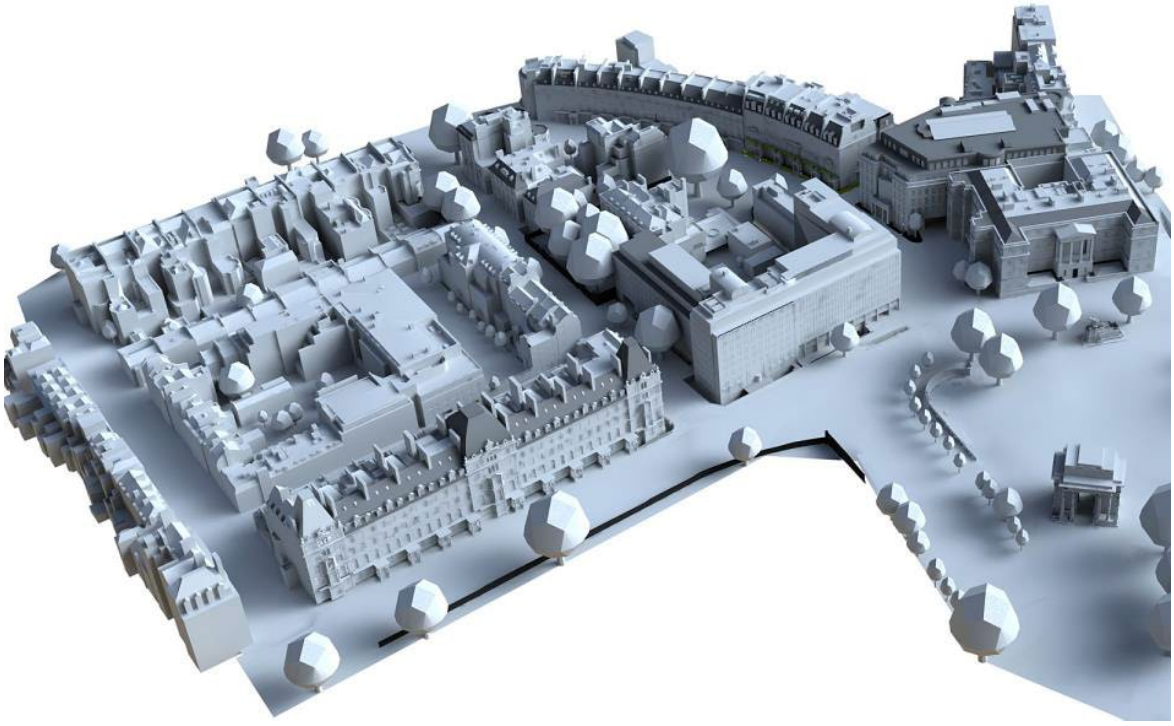
At the heart of these will inevitably be the need to gain a detailed survey understanding of the asset. The scale and scope of that will to a great degree be determined by the need and the fitness for purpose of the gathered information.

The following examples illustrate possible degree of considerations, and the benefits and challenges of using modern technologies, to achieve the required results.

Measurement And Monitoring: 3D Laser Scanning Examples and Possibilities

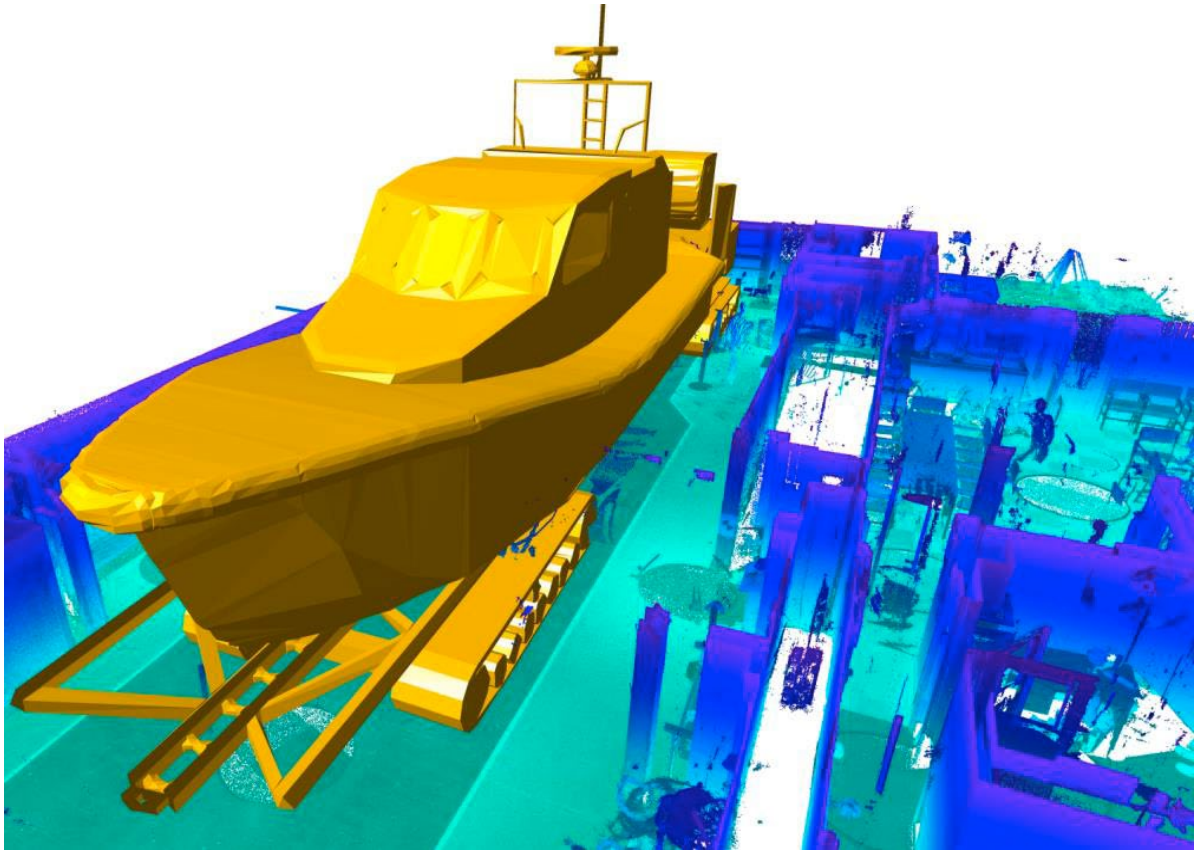
Laser Aided Modelling (LAM®) 3D Architectural Arrangements as a feed into BIM 3D models, using automatic recognition of specific elements to convert the cloud into objects.

Point Cloud RGB, Illustration: Ramboll

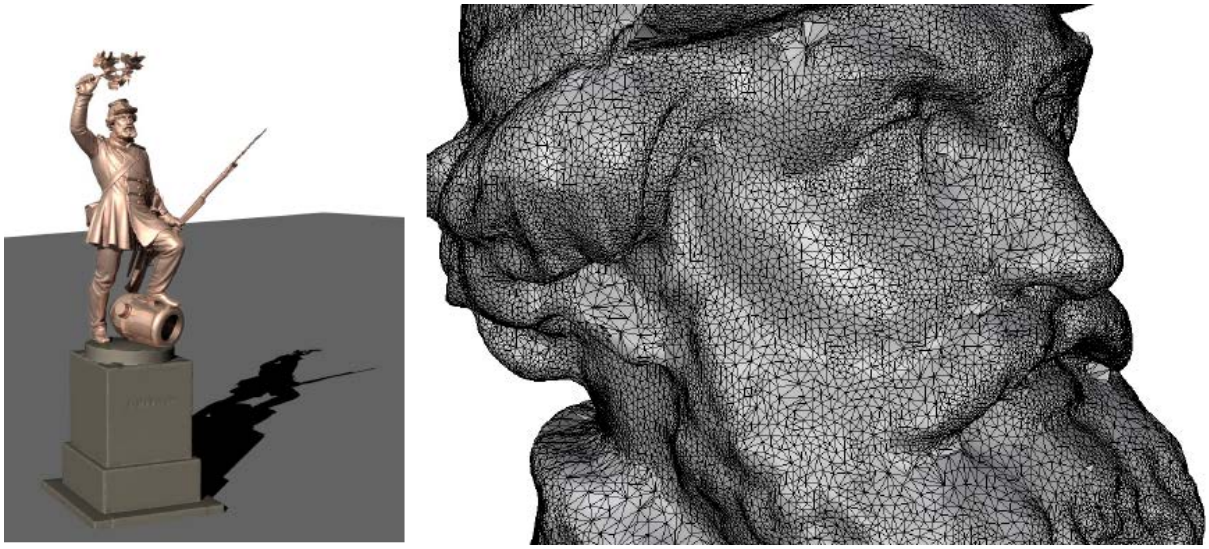


3D Geometry model, Illustration: Ramboll

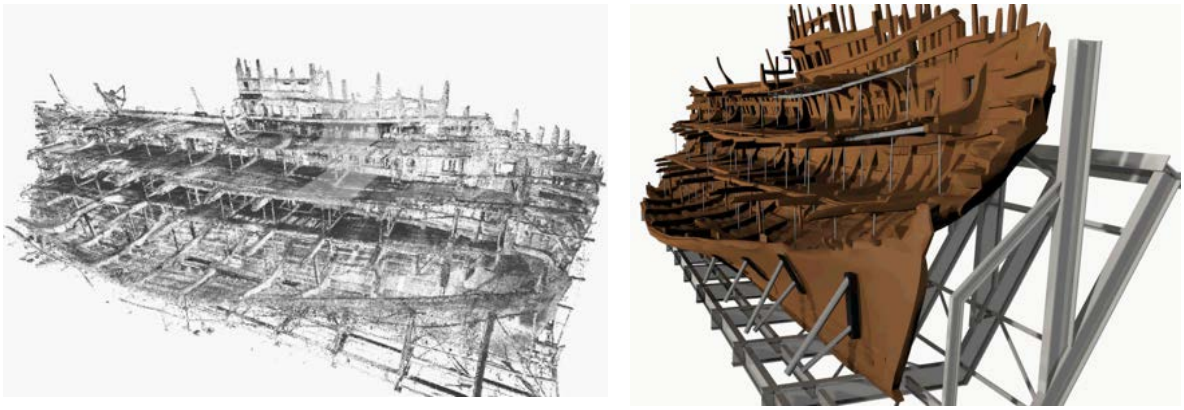
Laser Aided Modelling (LAM®) 3D Structural Arrangements: Extracting Steel Sections Illustration: Ramboll



Laser Aided Modelling (LAM®) Simple Clash Detection, checking proposals against existing environment (Can this RNLI lifeboat fit into the building?). Illustration: Ramboll

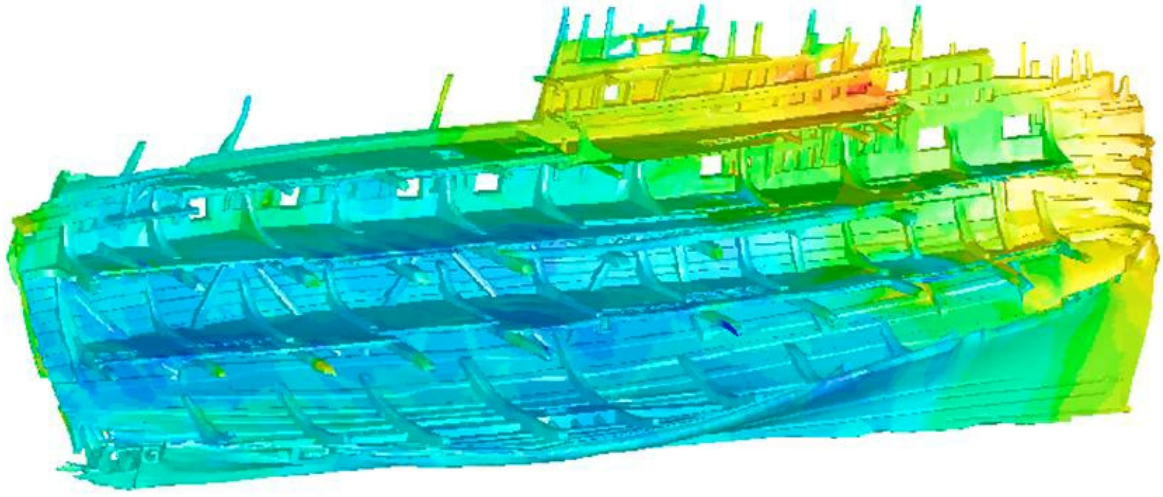


Laser Aided Modelling (LAM®) to feed into BIM3D model. Detailed Forms: Generated with a VR Mesh. Illustration: Ramboll



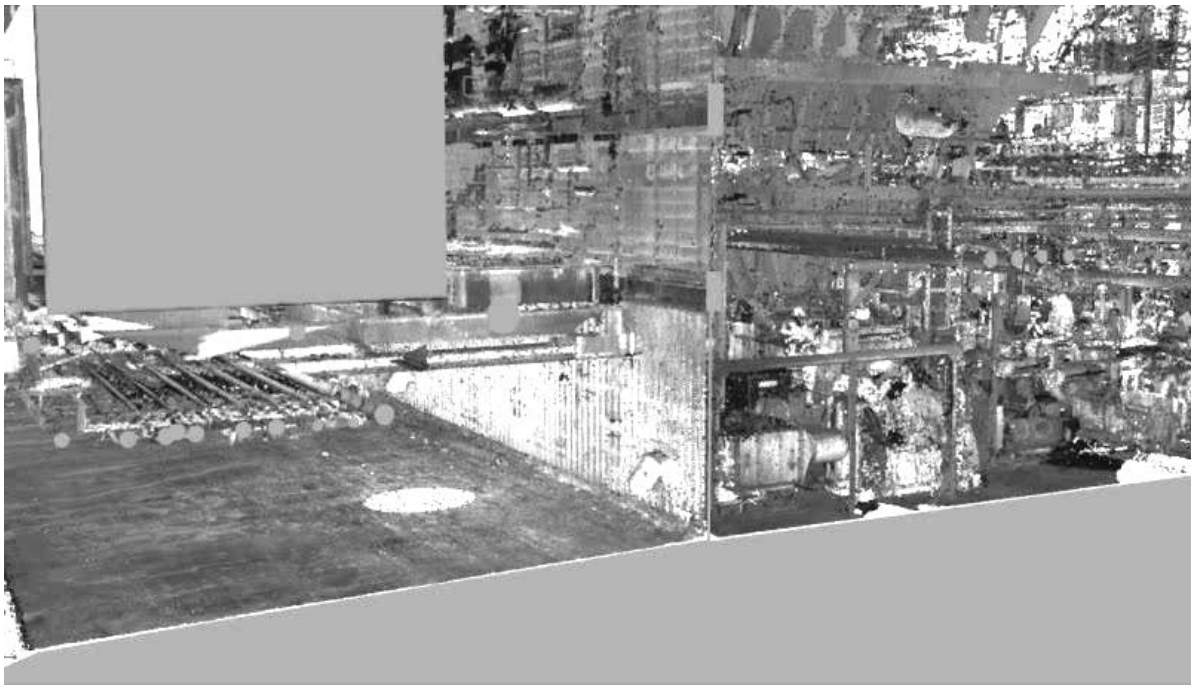
3D laser scanned point cloud Geometry Model

Laser Aided Modelling® For use in analysis: Mary Rose Hull



3d Model used by other disciplines - numerical simulation of atmosphere using CDF Illustration: Ramboll

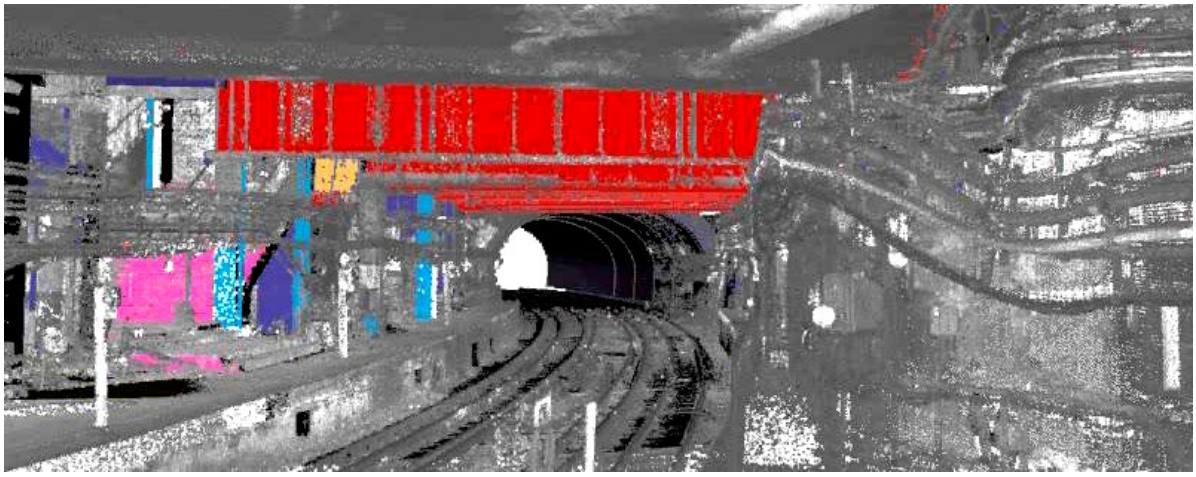
Point Cloud to Revit Models: Illustrations: Ramboll



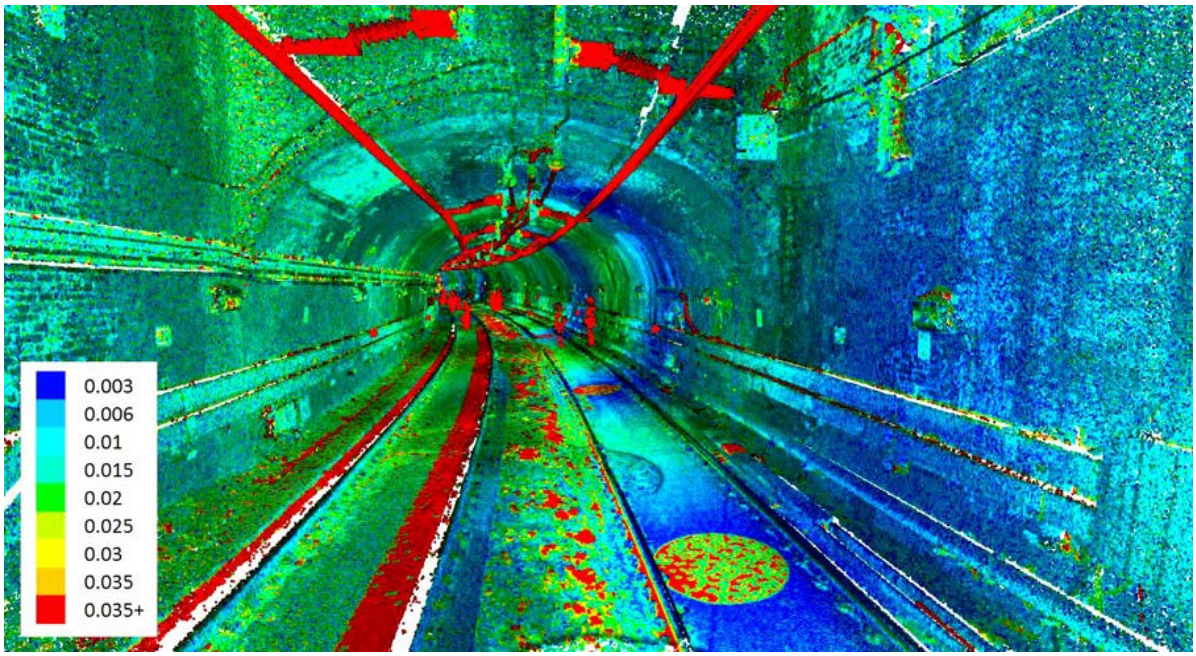
Conventional process: Existing environment scanned, modelled, and new equipment designed and accurately fitted. Reduces risk of expensive snags during construction.

Point cloud applications within Hybrid CAD:

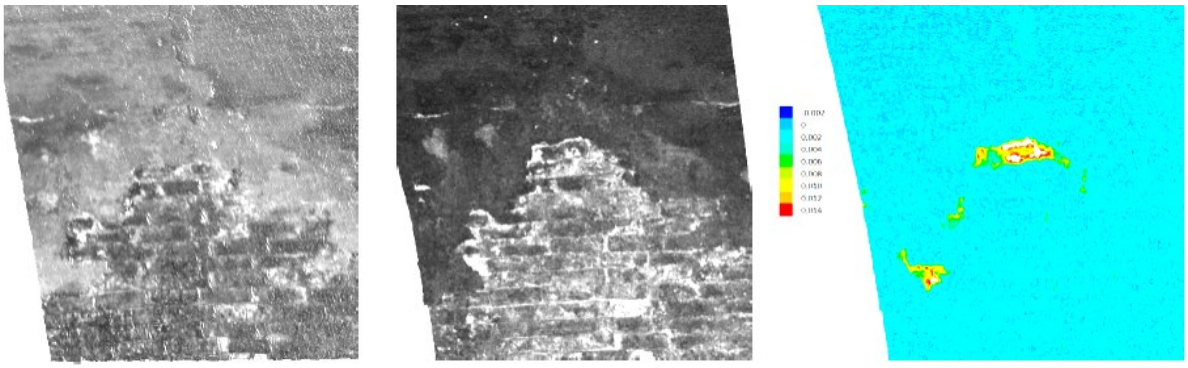
Planning tunnel strengthening: process using hybrid environment to avoid modelling.
For heritage assets it's better to use hybrid space with point cloud of original structure and add new structure: working with the point cloud without burden of CAD'ing.



BIM: Existing and Proposed: Illustration: Ramboll



Monitoring through comparing Point Clouds to determine major changes:
Illustration: Ramboll



Monitoring through comparing Point Clouds to determine minor changes in condition
Illustrations: Ramboll

Digital Photogrammetry Verses 3D Scanning

Cost benefits with better access being possible through the use of UAVs and UGVs. But, approach is generally not as accurate, and some survey controls are required to effect scaling.

Meshing can show aberrations resulting in unrealistic representations (such as warped imagery, as below), and there is also poor performance when trying to 'see 'through vegetation.

Illustrations: Ramboll

Landscape Modelling: UAV and digital photogrammetry can result in reasonably acceptable detailed information (such as the representation of recorded storage pallets, enlarged and extracted from the centre of the image below)

Illustrations: Ramboll

Benchmarking: Point Clouds from Different Measurement Technologies

Unmanned Aerial Vehicles (UAV)
UAV's serve as flying sensing platforms to give precise measurements, and are able to reach remote spots to inspect facades and structures. They minimise the need for scaffolding and/or lifting platforms offering photogrammetry, facade surveys and facade equalization. Combined with terrestrial laser scanning, a UAV operation can be extremely effective.

Lightweight Revolving Laser-scanner
Trials with the latest lightweight revolving laser-scanner, such as the ZEB REVO, can be handheld, pole-mounted, or attached to a mobile platform such as a vehicle or UAV. They can record more than 40,000 points/second. The resulting 3D Point Cloud can be used to create 2D layouts or 3D models in industry standard CAD and point cloud post-processing software.

Global Positioning System (GPS)
GPS is a satellite-based navigation system made up of a network of 24 satellites. Placed into orbit by the U.S. Department of Defense they were originally intended for military use. In the 1980's the system was made available for civilian applications. GPS works 24 hours a day, anywhere and in any weather conditions. There are no subscription fees or setup charges. GPS is an important tool for estate management

Indoor Positioning Systems (IPS)
IPS's are emerging that allow notes, photos etc. to be automatically linked from, for example, a field tablet, back to BIM.

Inertial Measurement Units (IMU)
3D motion tracking IMU's are based on known origin, timing and accelerometers. They are a self-contained system that measures linear and angular motion usually with a triad of gyroscopes and triad of accelerometers. An IMU can be used either by being gimballed or in a strap-down position.

Simultaneous Localization and Mapping (SLAM)
Robotic Simultaneous Localization and Mapping addresses the issue of updating or constructing a map of an unknown environment while simultaneously keeping a locational track of the mapping source within it. SLAM algorithms are tailored to available resources, and are not aimed at perfection, but at operational compliance such as that employed in self-driving cars, unmanned aerial vehicles, autonomous underwater vehicles, planetary rovers, newly emerging domestic robots. Some systems claim an accuracy of 0.2m.

Spheroidal Photography and GIS Interface
Although cylindrical panoramic photography of some kind or other has existed for over a century, panoramic image stitching software, using a graphical user interface as a panorama tool, has developed considerably in recent years. It economically offers detailed and accurate surveyed information for use with modest equipment and hardware. Fully spherical 360° x 180° images are created through inbuilt high quality tone mapping and exposure fusion algorithms.

Trueview software
Autodesk's DWG Trueview free download software provides an easy and cost-effective way of viewing files created by leading Computer Aided Design software such as industry standard AutoCAD. Although lacking any real editing capability, it is a fully stand-alone application that not only allows the opening of files but the taking of accurate measurements as well as tools to change various options including zoom frame shadow etc. The altered files can be saved and shared in standard formats including DWG.

Discussion Q&A Issues and Points:

The cloud point is only a record of surface information.

- How to create a 'virtual opening up' behind the surface?
- How to interpret decay and degradation of materials?
- How to interpret the different materials?
- The key is how to determine the loss of fabric

Link with ultrasound and ground penetrating radar with c100mm accuracy could assist.

What are the asset benefits for a parochial church council?
When will it be available for more widespread use?

There could be benefits in having regular inspections, and using these to predict future movement and plan for maintenance.

- But, it's just a tool that needs to be interpreted.

Small practices will have a skills gap in using the information.
Some understanding of 'maths' is required to be effective and skilled.

- You need a PC that can cope with big data sets.
- You need to have a server to access info.

Cheaper software and plug-ins are available, but this still requires skilled people to work with the point clouds and 3D.

Expertise is emerging from the gaming community, and is now working through to the professions and industry.

There is potential but this has yet to be developed further.

Could be useful to:

- Record services at they go in so that when covered up their position is known.
- Archaeological detail at different stages of a 'dig'

5 BIM4Heritage: The Conservation Conundrum – Where BIM Empowers the Conservation Process

Report based on the presentation by Ingval Maxwell OBE, Chairman Council on Training in Architectural Conservation

The construction industry in the UK has essentially split into two parts. The hitherto referred to 'mainstream' industry essentially deals with the conception, design, construction and performance of modern buildings. Generally speaking they are hermetically sealed relying on moisture and air extraction with mechanical or passive stack ventilation systems to keep the interiors comfortable. By contrast, the conservation repair and maintenance sector (CRM) relies upon an understanding of the history, various pre-existing constructional techniques, and intrinsic breathability, where moisture transfer is dissipated through the structure by inherent natural ventilation routes. This fundamental difference creates the 'conservation conundrum' as far as BIM is concerned.

The Council on Training and Architectural Conservation (COTAC) initially started their considerations regarding the application of BIM in 2011, leading to a conference in November 2012 under the title *"Past Caring? BIM and the Refurbishment of Older Buildings"* (27). In taking this initial approach, the conference started to address what building information modelling meant in relationship to conservation needs and facilities management. In trying to get this understanding, it took into account lessons learned from the *'Maintain Our Heritage'* (28) experiment scheme in Bath, the Dutch '*Monumentenwacht'* (29) project from the Netherlands, and how the process might be informed by the results of the UK's various *'National House Condition Surveys'* (30).

Recognising that surveying would be a key part of that developmental need, an initial consideration of digital documentation in the historic environment was offered, and the benefits of the *'European Union Cultural Heritage Identity Card'* (31) research project were also addressed. The underlying aim was to find out how information on the physical condition of buildings could be used to determine integrated and sustainable ways for the maintenance, refurbishment and management of the holistic historic estate.

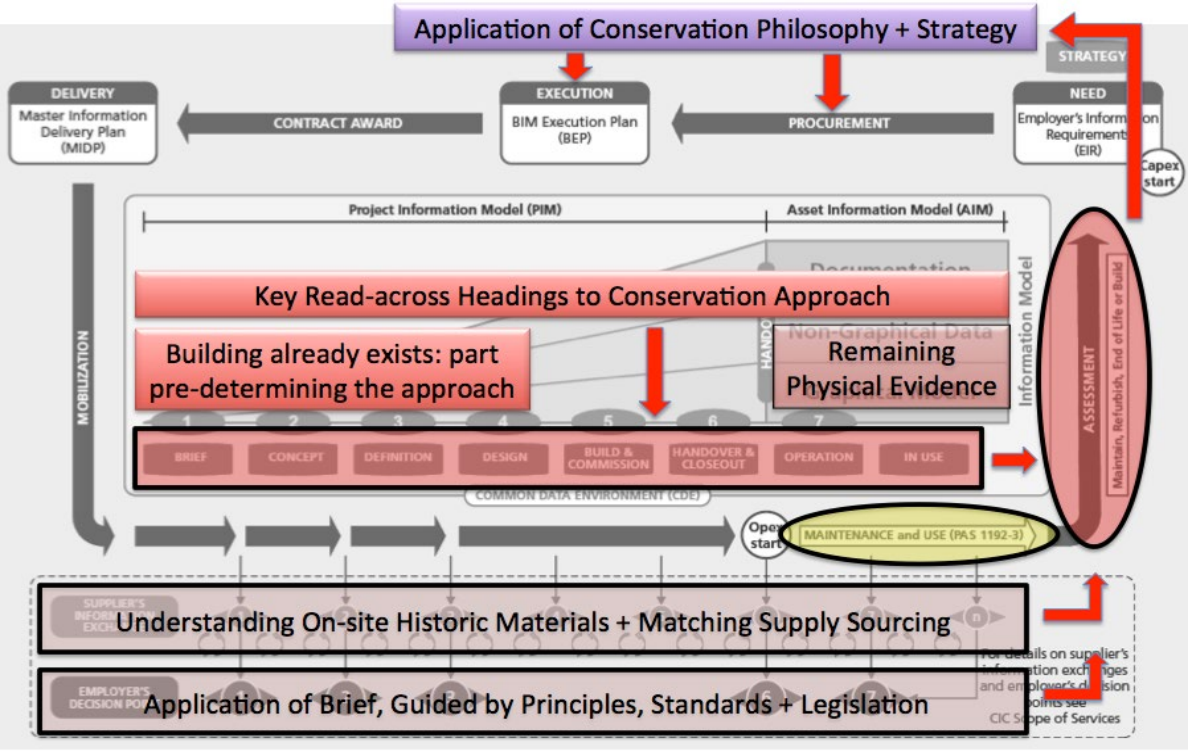
Building upon the preliminary awareness regarding digital documentation, COTAC's 2013 Conference *'A Digital Future for Traditional Buildings'* (32) led to the production of the report in 2014 headed *'Integrating Digital Technologies in Support of Historic Building Information Modelling: BIM for Conservation'* (9). As an Annex to this report, a Survey Monkey Questionnaire analysis into 'BIM Education and Training Needs: March 2014' was also incorporated.

COTAC's 2014 Annual Conference entitled *"Fire and Flood in the Built Environment: Keeping the Threat at Bay"* (33) resulted in a similarly titled report being produced in 2015 in two parts to deal with 'Fire ' and 'Flood'. These built upon the information and advice that speakers freely offered during the conference programme, their related presentations, and discussion outcomes. The overall aim was to link the emerging views on the impact of fire and flood to an emerging Building Information Modelling for Conservation (BIM4C) initiative.

The reports aspired to achieve this by identifying what issues needed to be considered in a Historic Building Information Modelling (HBIM) environment.
Spurred on by these initiatives, COTAC formed a Group of like-minded individuals concerned about the issue under the moniker *'BIM4Conservation'*. In consequence of the group's activities, two significant documents were produced under the heading '*COTAC BIM4C Integrating HBIM Framework Report'* with Part 1 dealing with '*Conservation Parameters'* (2) and Part 2 dealing with *'Conservation Influences'* (3), both being published on-line in 2016.

Again, this approach endorsed COTAC's 2014 report findings that surveying what remained in-situ was an essential prerequisite to understanding the needs of the existing built heritage in any BIM consideration. At the same time the 2016 reports widened the conservation perspective to offer a more comprehensive strategy in the consideration of how that might best be delivered and integrated.

In a preliminary attempt to create a recognisable read-across to the new-build BIM considerations, these developments informed the application of conservation philosophy and strategy as an overlay on the Mervyn Richards PAS 1192-2:2013 'Information Delivery Cycle' diagram, as illustrated below:



Conservation Approach Overlaid on: PAS 1192-2:2013 Information Delivery Cycle Illustration © Mervyn Richards

Here, it was acknowledged that key read-across headings to conservation existed in the identified eight steps of *'Brief; Concept; Definition; Design; Build and Commission; Handover and Closeout; Operation and In Use'*. But, fundamentally, this necessitated a greater emphasis being placed on the substance of the 'Assessment' area of the diagram where

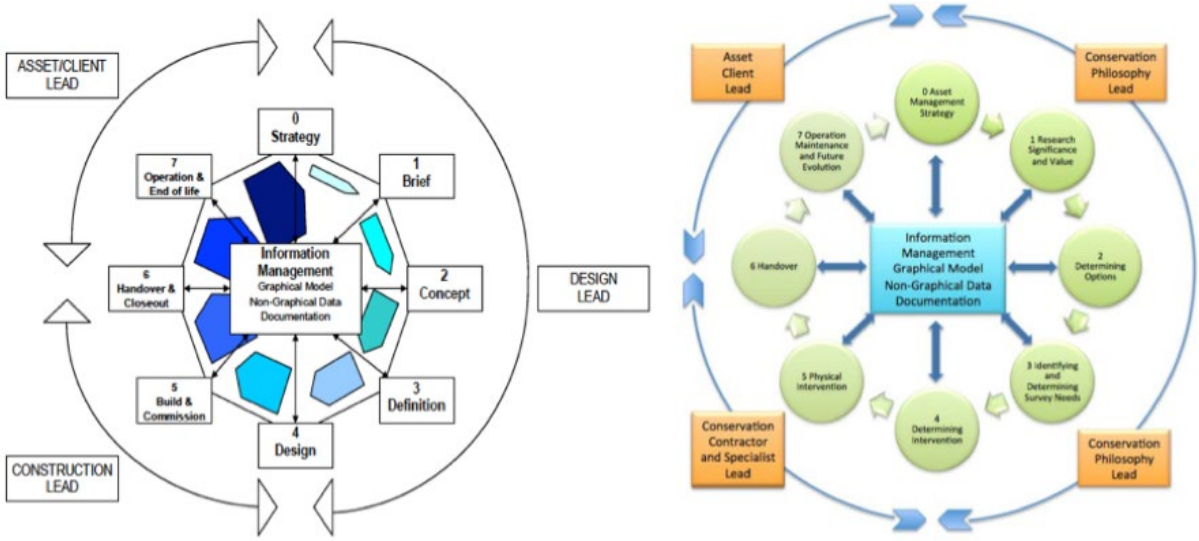
'Maintenance, Refurbish, End of Life or Build' greatly simplifies the complexity of the CRM sector.

COTAC's BIM4C thesis challenged this simplicity by noting that remaining physical evidence from buildings and structures that already exist to a greater extent pre-determines the more comprehensive and detailed approach that needs to be substituted.

Furthermore, in determining a more relevant CRM read-across to the *'Supplier's Information Exchange'* and the *'Employer's Decision Point'* diagrammatic strips of data interactions, existing historic and traditionally constructed buildings respectively require a more detailed 'Understanding of the on-site performance of previously adopted historic materials, together with an in-depth recognition of where matching supply sourcing might be obtained' (if at all). This needs to be considered together with the employer's awareness and acceptance on the 'Application of a brief guided by recognised conservation principles, standards and relevant legislation' that could be imposed at any point across the eight core 'Common Data Environment' parameters. Fundamentally, such a range of influences needs to be fully appreciated at the outset 'Assessment' stage of the remaining physical evidence.

This challenge, basically determines that a BIM approach to the CRM process essentially starts by requiring a greater consideration being given at Stage 7 (Operation) of the existing building, rather than the diagrammatic Stage 1's identification of the 'Brief'. The basic criteria being that a Employer (Client) need to better understand what physically remains, and what the restrictions and constraints might be, before any detailed briefing or conceptual work can be contemplated in adapting, changing, conserving or restoring it.

To better appreciate this, rolling the diagrammatic strip layout of the eight core 'Common Data Environment' parameters into a cyclical arrangement, more relevant 'read-across' prompts can be more clearly appreciated. In doing so a more explicit integration can be achieved, as follows:



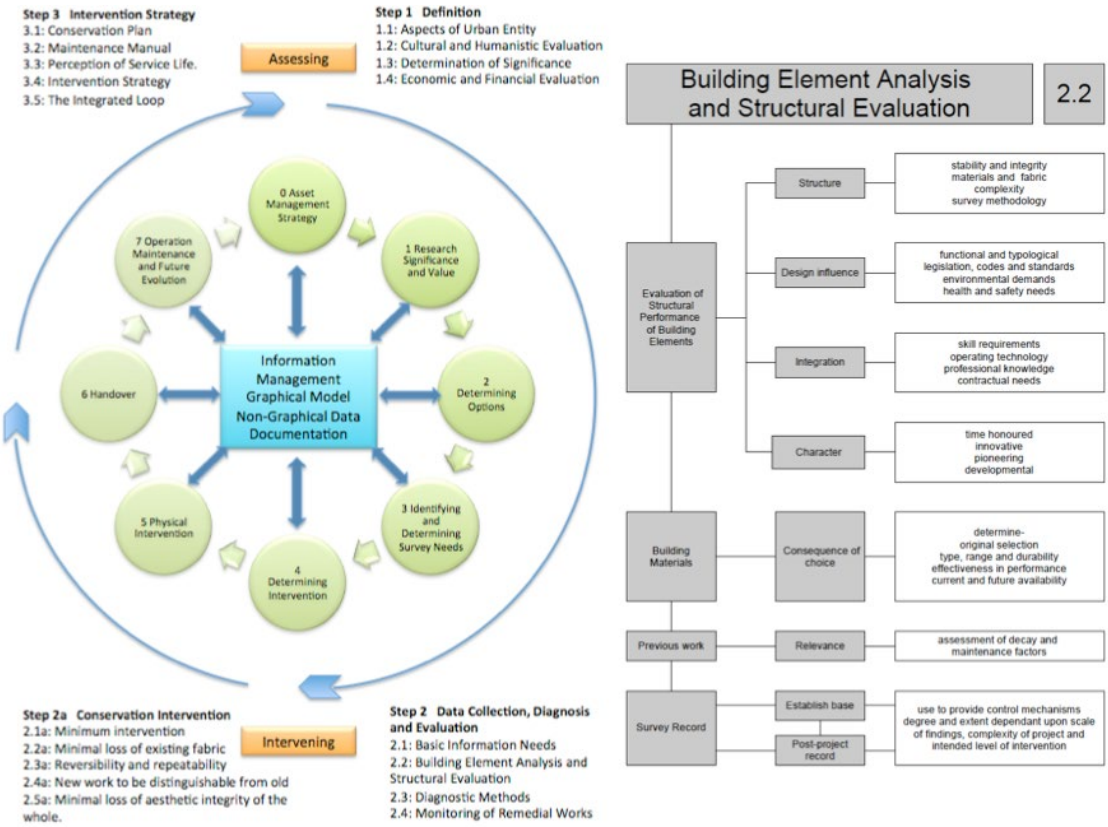
Although a *'Design Lead'*, progressing into *'Construction'* and '*Asset Client Lead'* approach is clearly relevant for new build schemes, a *'Conservation Philosophy Lead'* for the initial four

Stages is better suited towards 'Determining the Intervention' as the read-across equivalent to the new-build 'Design' Stage 4. This would entail placing a greater and essential emphasis on *'Researching Significance and Value; Determining Possible Options; and 'Identifying and Determining Survey Needs'* as the equivalent read-across to the *'Brief; Concept, and Definition'* Stages 1-3.

Thereafter, the *'Construction Lead'* would be best be overlaid by a *'Conservation Contractor and Specialist Lead'* whereas *'Build and Commission'* would read-across to *'Physical Intervention',* whilst the '*Asset Client Lead'* needs of '*Handover'* and *'Operation'* would remain the same in intent, with the difference being that the historic asset would more than likely require a substitute heading of '*Future Evolution'* for '*End of Life'*.

What COTAC's BIM4C Groups' work entailed was adopting the cyclical approach to assist in achieving a greater understanding of what the relevant CRM issues might be applied within a BIM scenario. Consequently, its two key reports offered similarly styled diagrams that applied the 14 *'ICOMOS Guidelines on Education and Training in the Conservation of Monuments Ensembles and Sites'* (34), the advice contained in *'BS 7913:2013 British Standards Guide to the Conservation of Historic Buildings'* (35) whilst suggesting a variety of other parameters, including *'Historic England Conservation Principles'* (36).

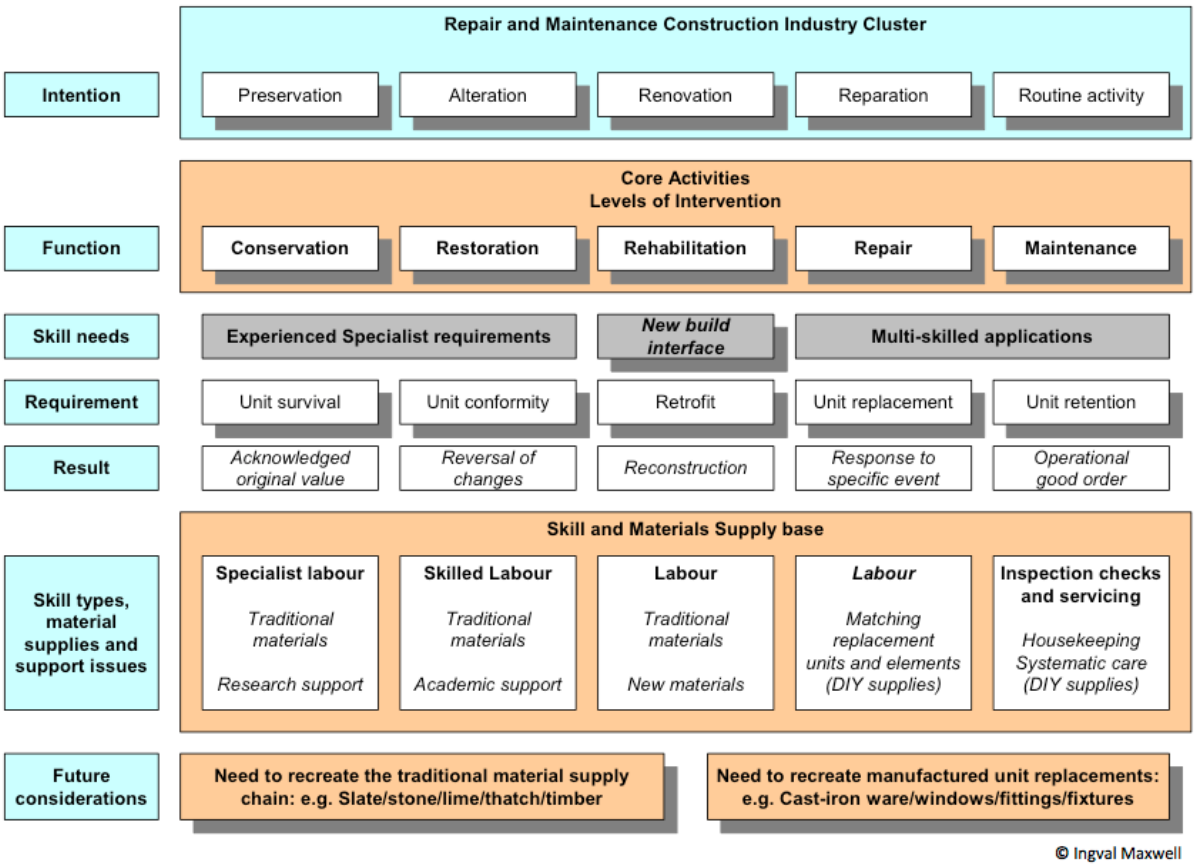
In greater part these were explored in Part 2 of the COTAC HBIM Reports, where 18 tables were presented under the headline topics of '*Definition'; 'Data Collection, Diagnosis and Evaluation'; Conservation Intervention' and 'Intervention Strategy'*. It was possible to fit these variously sequenced findings around the cyclical process, with the examples table *'2.2 Building Element Analysis and Structural Evaluation'* illustrated as below:



This approach inevitably created a greater weight on the need to specify the value and significance of the historic asset, and indicated how Conservation Plans, Maintenance Manuals, Quinquennial Inspections and Life-cycle Performance issues, could be better accommodated.

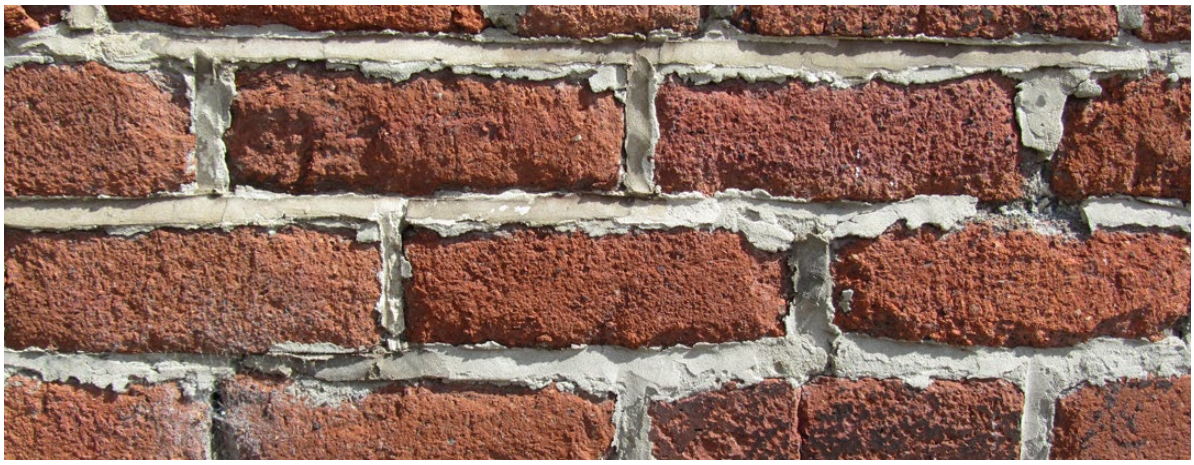
Given the longevity of the built heritage, what the COTAC BIM4C approach was identifying was that there have clearly been a number of iterations in the use of the built heritage in the past where structures have gone through a repetitive series of cyclical applications. Essentially, the emerging hypothesis was that the cyclical arrangement should be considered as a series of overlapping 'use-themed' spirals into which, with each particular turn of the screw, the variety of related conservation issues could be inserted. At each iteration these might include current statutory requirements and perceived value and significance, the current physical state, conservation principles, physical survey data, researched information, risk assessment information, environmental and economic and technical constraints, to be currently read in conjunction with the guidance set out by ICOMOS and BS 7913:2013.

But, the conservation process is far from straightforward, taking into account that each intention could well include any combination of preservation, alteration, renovation, reparation and routine activities in any one project. The read-across functions to these in terms of core activities and levels of intervention might be described as conservation, restoration, rehabilitation, repair and maintenance, as set out in the table below where the associated skill needs and types, aimed for results, support activities and issues are set out:



With a central renovation and rehabilitation theme being the new-build interface leading to retrofit and reconstruction results, on the repair and maintenance side there is an argument to suggest that multi-skilled applications would be necessary, whilst on the conservation and restoration side experienced specialist requirements would be required. Regarding skills and materials, increasingly skilled and specialist labour will be required to support the latter, whilst more basic labour and specialised unit labour may be sufficient for the latter. But, it can be so easy to get the end result wrong. Resulting work can significantly change the aesthetic and future performance at the most basic level if the analysis, specification and site controls are ineffective, even in the 'simple' task of repointing brickwork, as below. Accommodating challenges such as this in a BIM Common Data Environment will demand rigour and a sensitive understanding.

© Ingval Maxwell: IMG_0617a



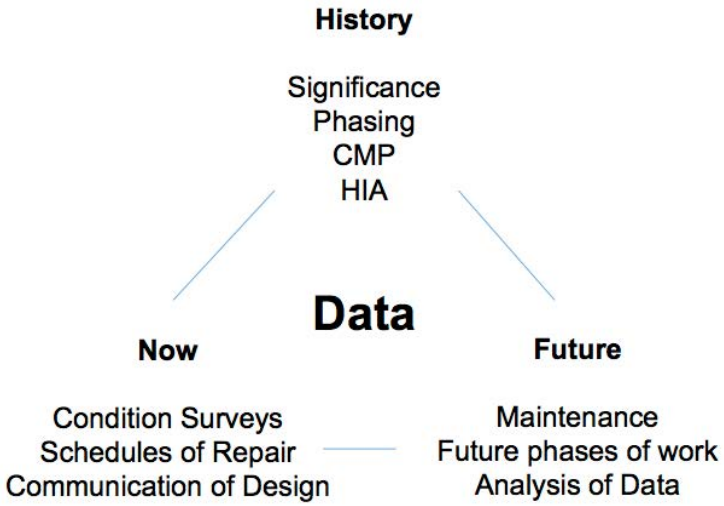
© Ingval Maxwell: IMG_1876a

But, the additional challenge with the repair and maintenance of existing buildings will be where to source existing elements if they needed to be replaced which, in turn, could occasion the need to recreate manufactured units and replacements from an earlier age. On the other hand, given deterioration of existing structures and traditional materials used in their construction, an equally difficult problem exists in identifying where matching material supply sources can be found (if at all). In essence, both issues will be extremely difficult to overcome, resulting in the need for compromise in decision-making. Here, a better understanding of the philosophy and ethics of conservation, coupled with an awareness of significance and value as guided by legislation, will be key determining factors in what information will also be required to be put into a BIM Common Data Environment.

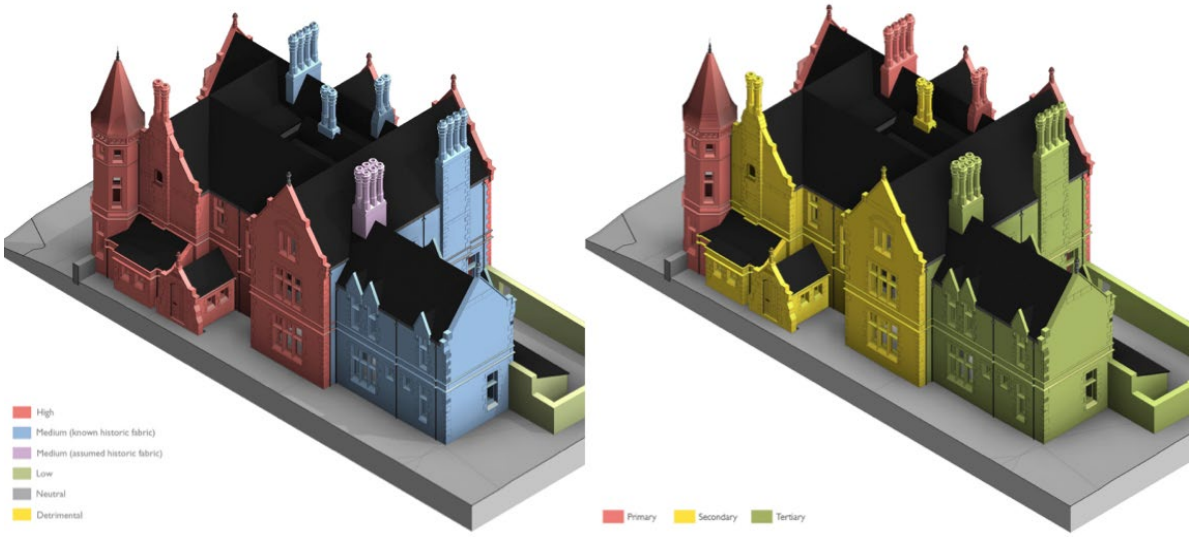
6 Case study methodology: Linking History, Now and the Future, Surrounding the Data

Report based on the presentation by Andrew Dobson, Associate, Purcell

The methodology behind the Palace of Westminster Elizabeth Tower (Big Ben) project was explored, noting the real benefits of having a BIM model as a way of 'pulling' all relevant information together. In setting out the approach, the data gathering inputs both historic and current information, along with future plans. Diagrammatically, the central data bank was determined in terms of the surrounding input sources, under the headline topics of History, Now and the Future:

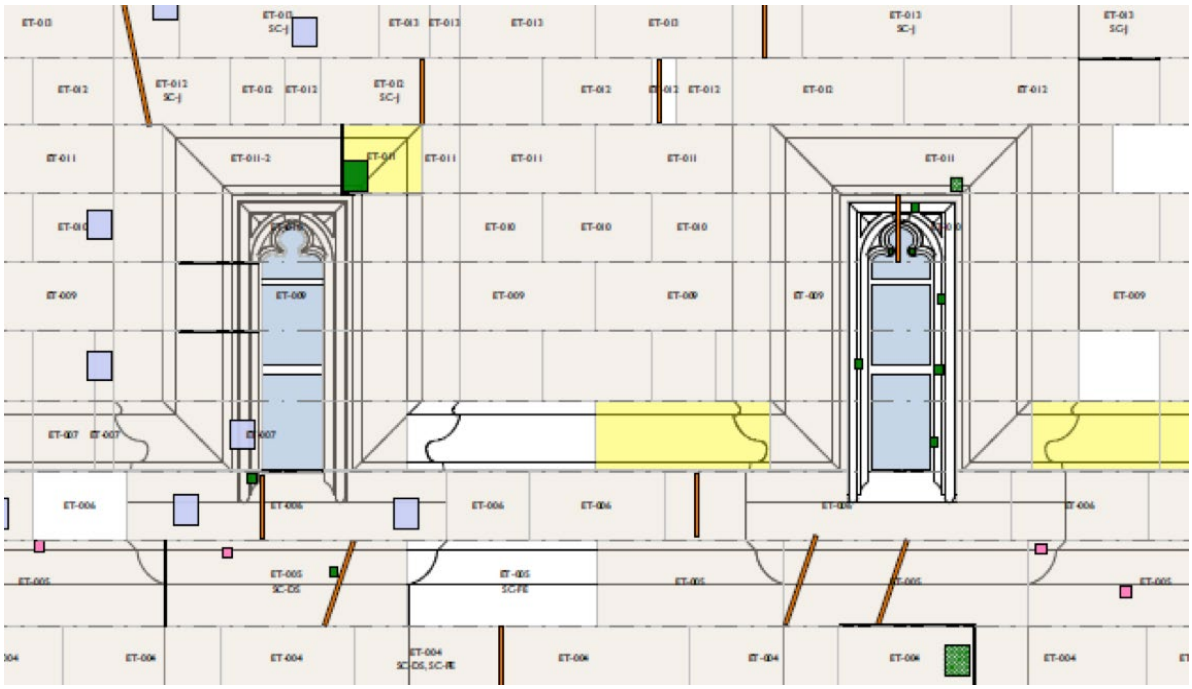


To provide an effective baseline including the historic development data is significant in that the information it provides informs on dated phasing, structural changes, specification details of the original construction and related changes. As colour coded in the example below, this can offer an immediate appreciation of the development and value of the structure and its component parts by explicitly illustrating its historic development and significance:

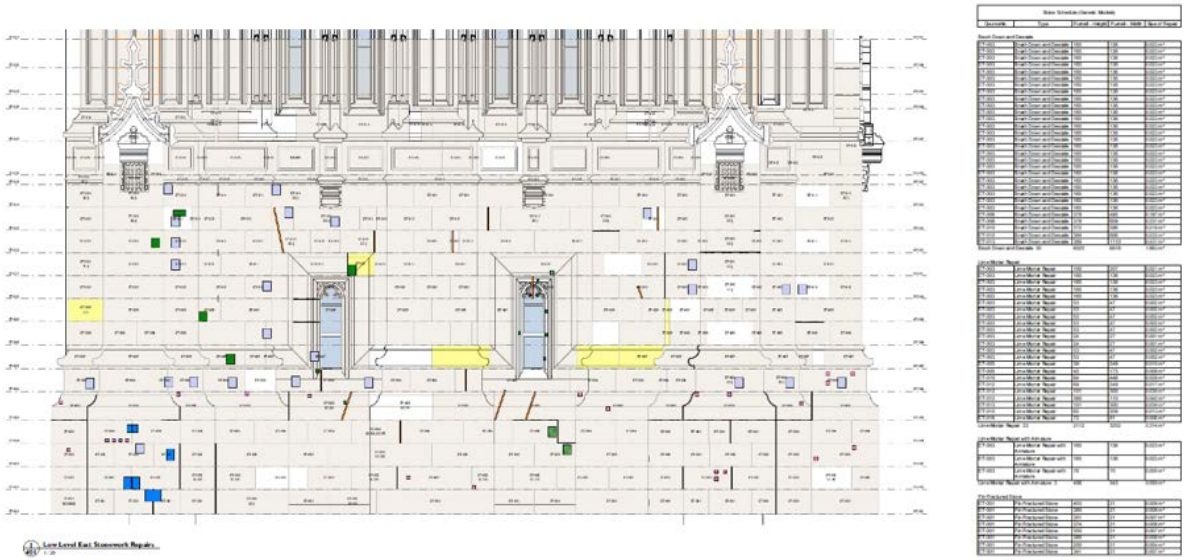


Illustrations: Purcell

Regarding conservation and maintenance plan information, conditions prevailing on the day are equally important, as is noting any schedule of pending repairs. Including intended future plans can assist in providing a comprehensive analysis of need.



Identifying the extent of stonework repairs through incorporating site inspection and performance analysis information over digitised laser scanned or photogrammetric survey data can satisfy a number of needs.



Illustrations: Purcell

Through being overlaid on survey drawings with an attached schedule of repair, BIM combined schedule and drawings information can be easily exported e.g.to Excel. This allows other parties to use the information outwith a Revit environment that can be manipulated on site through use of an electronic tablet. The aim is to create a consistent system and approach for the benefit of all site users.

Illustration: Purcell

Within the framework of a detailed survey, that core BIM information can also readily provides a mechanism to communicated design proposals, as above, with the proposed conversion of a pottery site to a conference centre as a community design project.

Discussion Q&A Issues and Points:

Is there a standard available to attach a BIM module to a schedule?

- Create a set of properties on site and attach to elements on the BIM model as a set of properties.

Cathedrals involve lots of data: how can this be realistically loaded to be accessible and useful?

- The way ahead is draw ‘a line in time’ to go forward from, and there are systems that allow the making of connections between legacy historic data and BIM models.

7 BIM Sensitive Analysis: Developing 3D Models Of Historic Assets for Simulation and Assessment: BIM Level 1: Ramboll Case Studies

Report based on the presentation by Carl Brookes, Ramboll UK Team Director Advanced Engineering and Geomatics

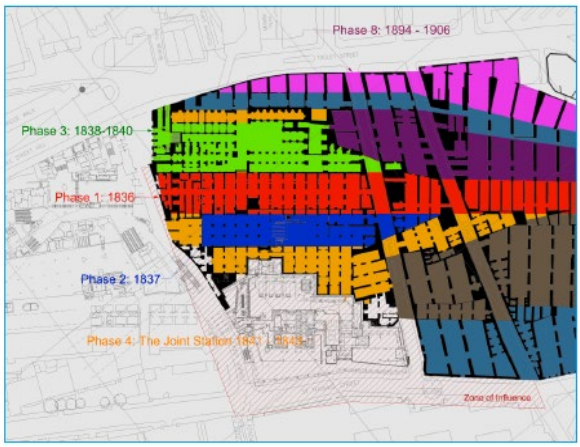
The presentation explored the issues and technologies requiring BIM Level 1 resources through some of Ramboll's previous project examples:

- The influence of the construction of the Shard of Glass on London Bridge Station
- Strength assessment of The Iron Bridge
- Improving the earthquake resistance of a Historic Masonry Chimney in Baku
- Simulation and monitoring of Masonry Vaults at Leeds Station

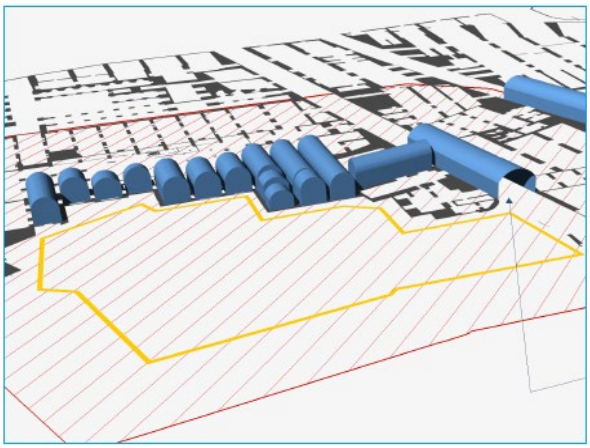
London Bridge Station: Influence Of The Construction Of The Shard Of Glass

The 72-storey Shard London Bridge, with an additional 15 roof radiator floors, was constructed on the site of a 1970's office block bordering London Bridge Station (37). In order to assess the environmental performance of the design, the plans were subject to a pre-assessment using the Building Research Establishment Environmental Assessment Method (BREEAM), which provided authoritative guidelines for minimising the adverse effects of buildings on global and local environments, and for promoting a healthy and comfortable indoor environment. The results were very positive.

It was also necessary to understand the influence of the London Bridge Station on the construction of the Shard



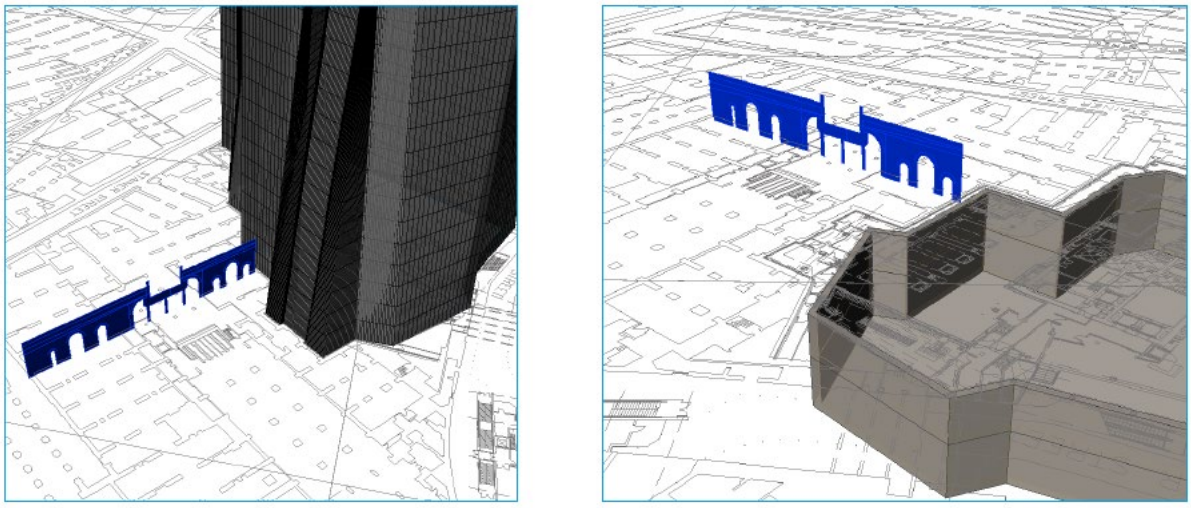
Construction phases and joints



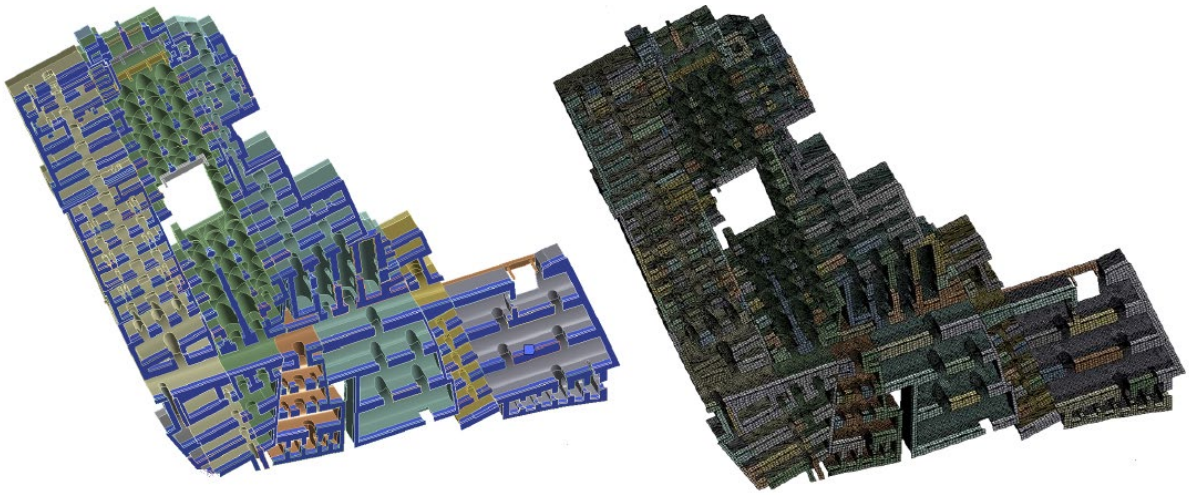
Very limited geometry available

Illustrations: Ramboll

Structural arrangements from record information various phases of construction were identified over the period 1836 - 1906 and related the extent of the Shards' zone of influence. Structural movement from the records anticipated ground level fluctuations and involved noting construction joints where movement could take place.



Deconstruction, the extent of the considerable required excavation required for the Shard's construction.

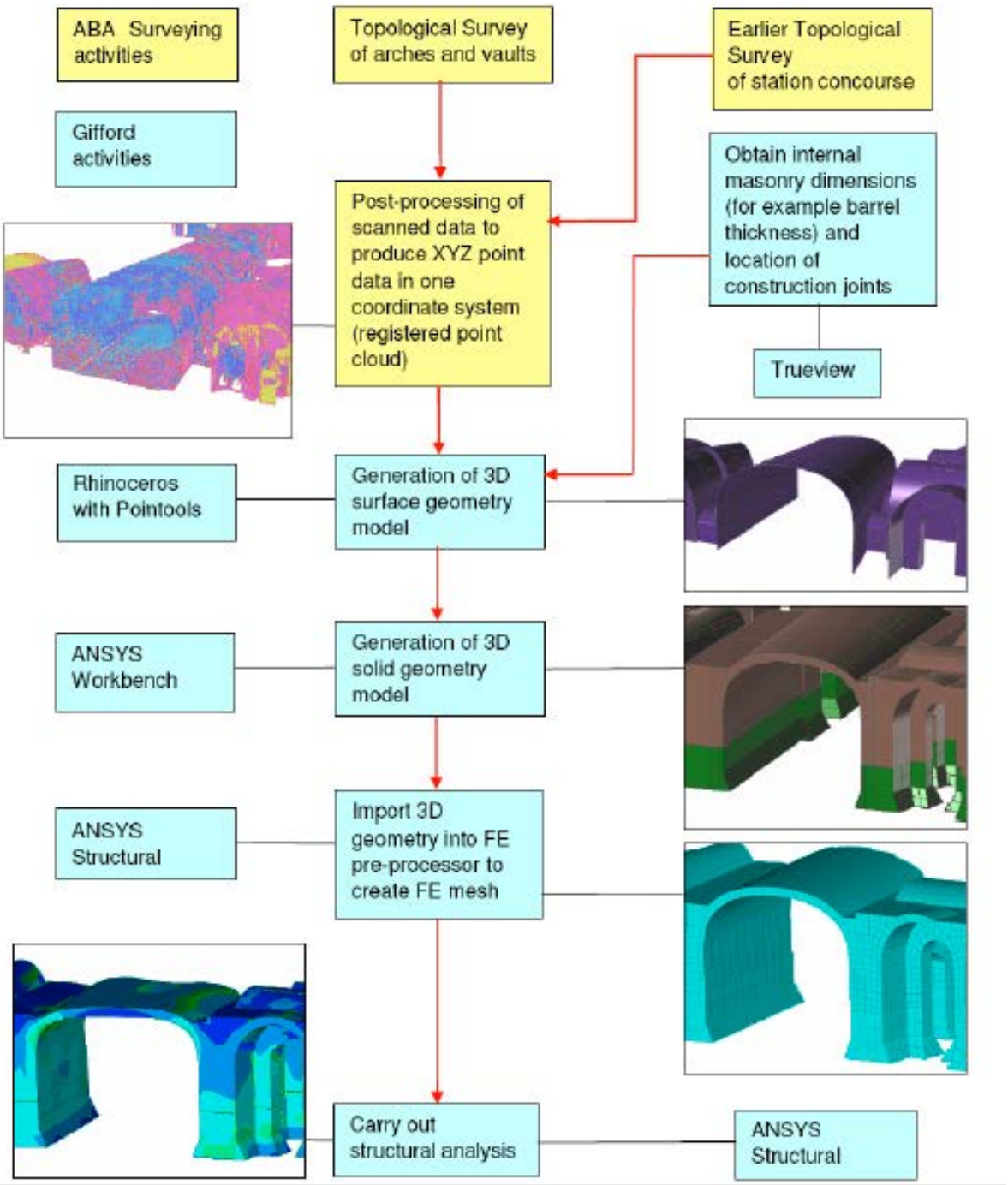


Illustrations: Ramboll

3D Geometry and Finite Element Model. The survey of the vaults became a resource for analytical approach to assess displacement strains in the modelling process. The typical results of the geometry model allowed stress comparisons to de-risk the process.

The Modelling process, approach, and tools involved, as charted below, involved creating:

- The Point Cloud
- Surface Model (LAM)
- Solid model
- Finite Element mesh
- Structural Analyse results (ground movement)



Illustrations: Ramboll

Ironbridge: Risk and Strength Assessment

The Ironbridge project involved:

- Laser survey and geometry modelling
- Archive research and summary
- Structural assets analysis, simulation and strength assessment
- Revealing areas of failure

Opened in 1781 the River Severn's Iron Bridge was the first arch bridge to be made of cast iron. Although celebrated due to its use of this new material, the detailed design utilized carpentry mortise and tenon, and dovetailed jointing techniques (38).

Built with five cast iron ribs spanning 30.6 metres (100 ft.) it has almost 1,700 individual components, the heaviest weighing 5.5 tons (5.6 t). These were individually cast to fit with each other, rather than being of standard sizes. Consequently, discrepancies of up to several centimetres exist between 'identical' components.

The situation was compounded by the Gorge narrowing (by half a metre over time) and the effect of compression on the bridge elements.

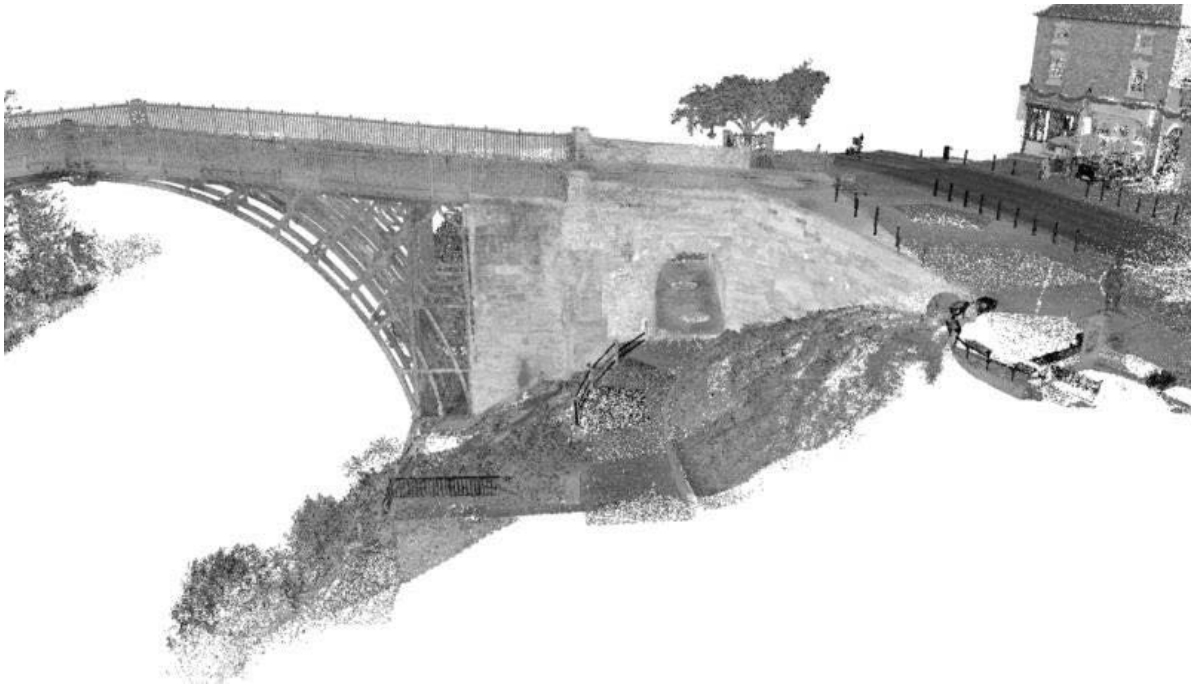
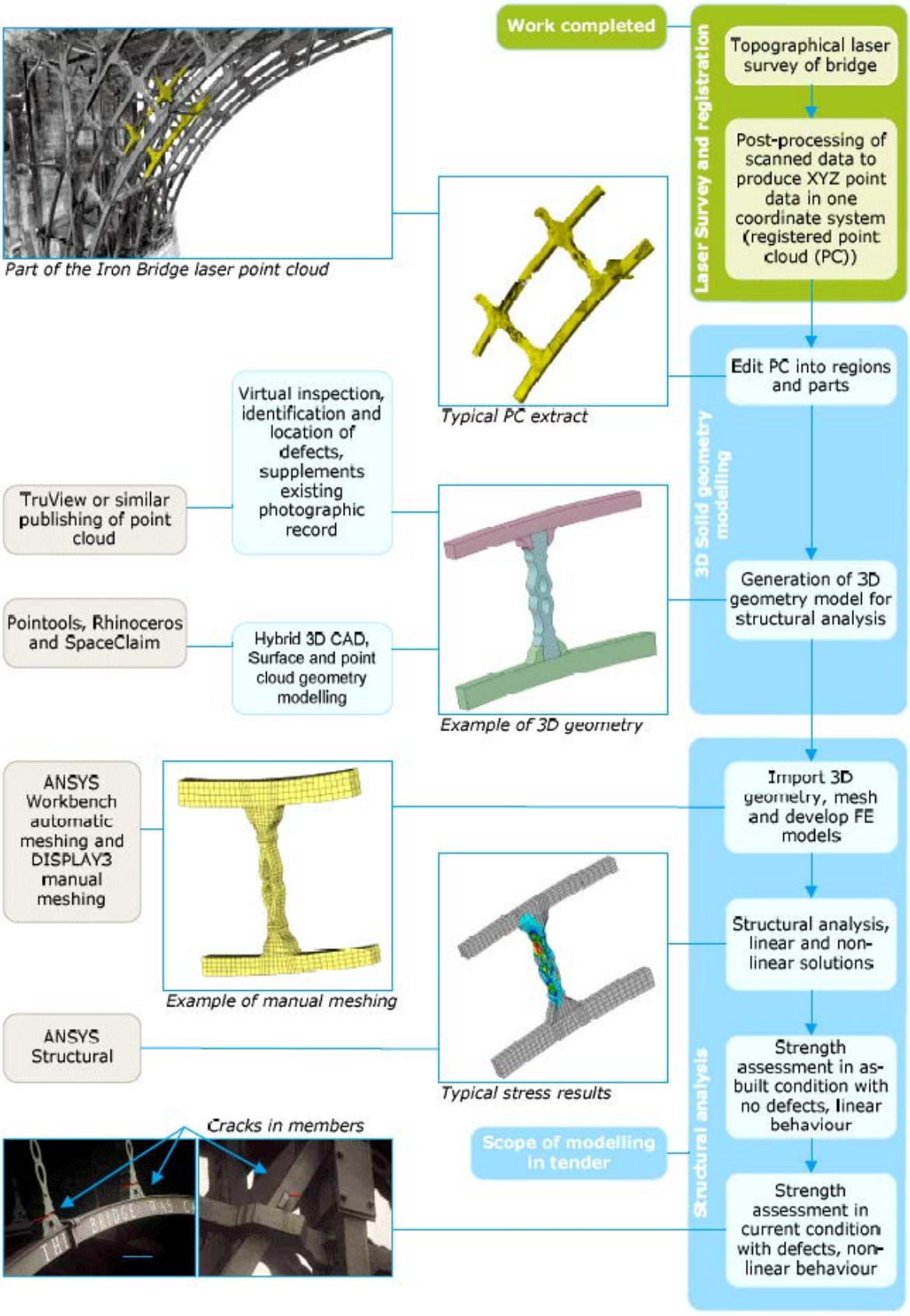


Illustration: Ramboll

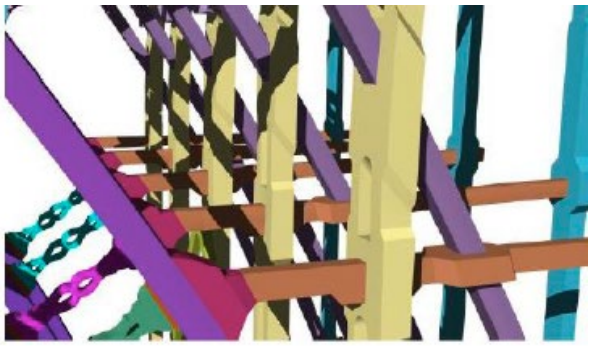
To fully understand these issues, laser scanning enabled an accurate representation of the built environment, with precise measurements, to create an accurate 3D geometry model. This was used as a resource for desktop inspection and investigation by providing the basis of geometric and analysis models that can be viewed from any direction.

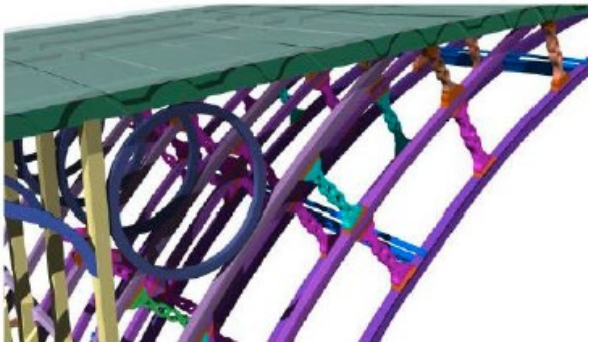
LAM® process Software included:

- Rhinoceros
- Pointools plugin and edit
- In-house software
- Display 3 and NISA2
- ANSYS Mechanical


Work completed
Laser Survey and registration
Topographical laser survey of bridge
Post-processing of scanned data to produce XYZ point data in one coordinate system (registered point cloud (PC))
Part of the Iron Bridge laser point cloud
Typical PC extract
3D Solid geometry modelling
Edit PC into regions and parts
Virtual inspection, identification and location of defects, supplements existing photographic record
TruView or similar publishing of point cloud
Pointools, Rhinoceros and SpaceClaim
Hybrid 3D CAD, Surface and point cloud geometry modelling
Example of 3D geometry
Generation of 3D geometry model for structural analysis
ANSYS Workbench automatic meshing and DISPLAY3 manual meshing
Example of manual meshing
Import 3D geometry, mesh and develop FE models
Structural analysis, linear and non-linear solutions
ANSYS Structural
Typical stress results
Strength assessment in as-built condition with no defects, linear behaviour
Cracks in members
Scope of modelling in tender
Strength assessment in current condition with defects, non-linear behaviour
Structural analysis

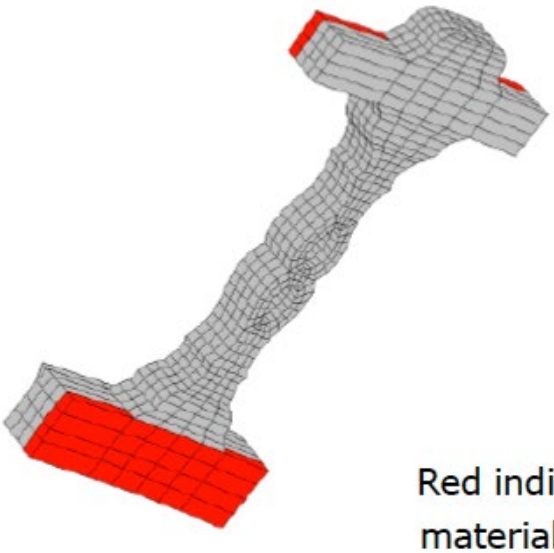
The generated visualisation of the modelling process allowed researched analysis in detail of the radial links and their variants.



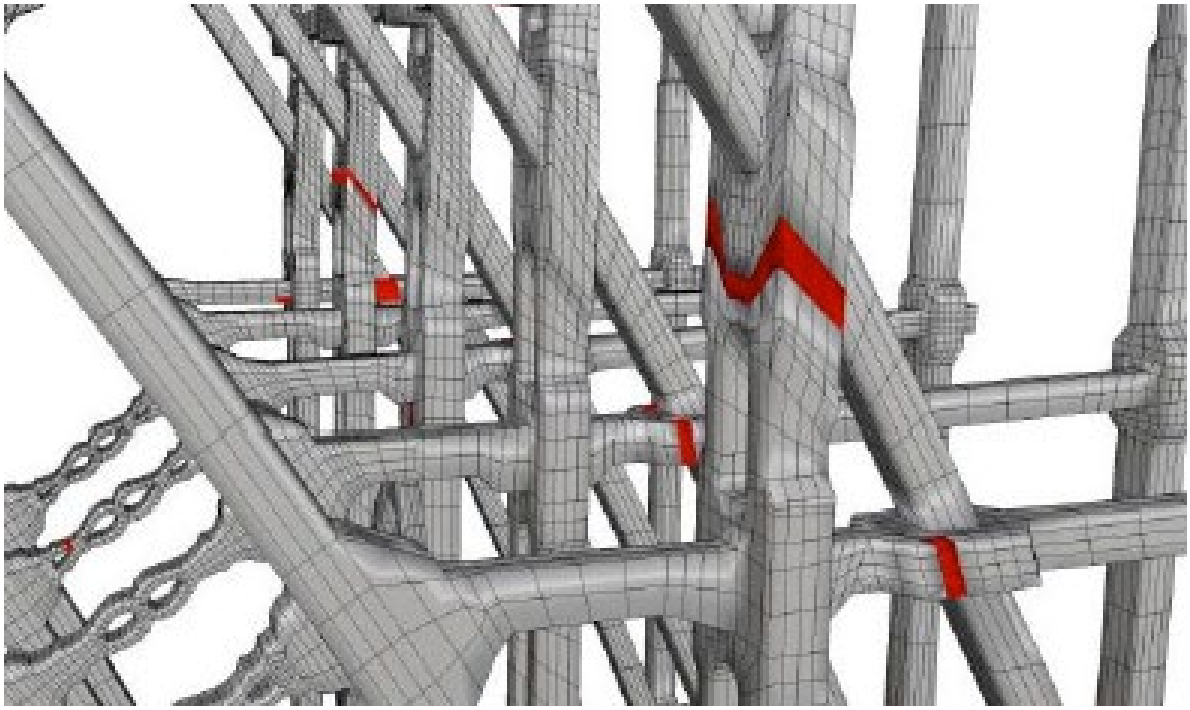


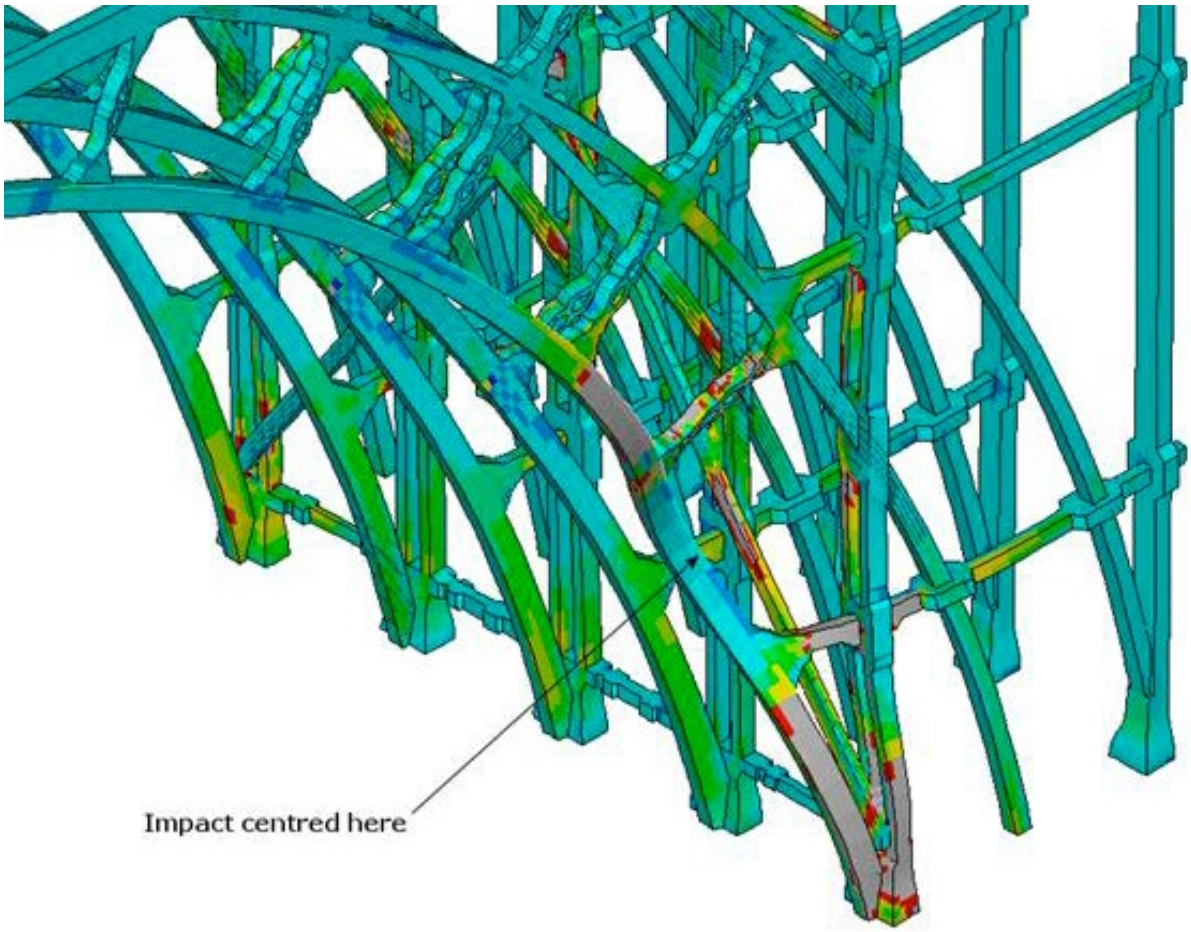
Illustrations: Ramboll

The detailed structural analysis also offered an understanding of inherent aberrations. The finite element model revealed the position of defects in the deck and the structural elements. Such an analysis exposed broken joints, bracketed connections to support the deck, clamped decorative rings and joints, discontinuous deck plates, soft material surfaces, and existing cracks:



Illustrations: Ramboll



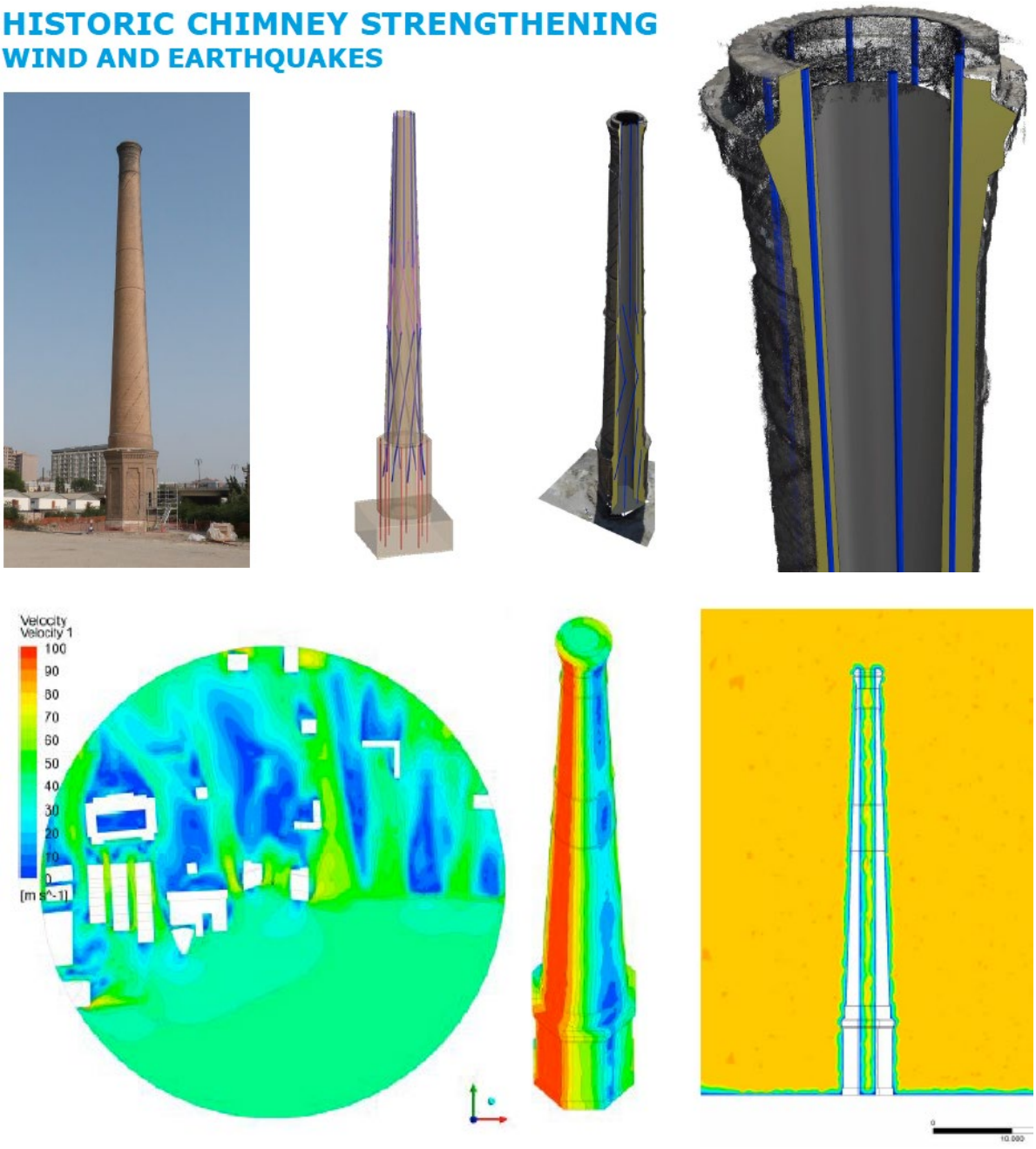


Illustrations: Ramboll

With identified risks from a possible collision by a boat, to flood risk and floating debris, the surveyed details allowed calculations of induced stresses under such impact conditions.

Chimney Strengthening Against Wind and Earthquake, Baku

A demolition-threatened historic chimney in the Azerbaijan capital of Baku (39) will become the central focus of a multi-million pound new shopping complex. The work will involve a patented anchor system to secure the structure by drilling into the chimney from the top and feeding 24 meters of anchors into the chimney walls to secure it. The assessment involved wind and earthquake analysis, with the point cloud detail showing where to retrofit the reinforcement. The survey was carried out by an UAV with external controls.



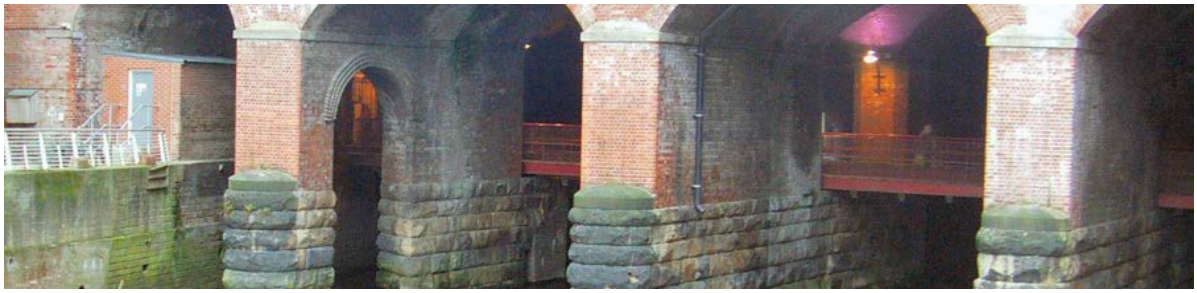
Illustrations: Ramboll

Modelling microclimate wind loading in a simulated environment involved a discipline transformation from common survey results, with the geometry also allowing very accurate setting out, false work and anchor alignments.

Leeds New Station

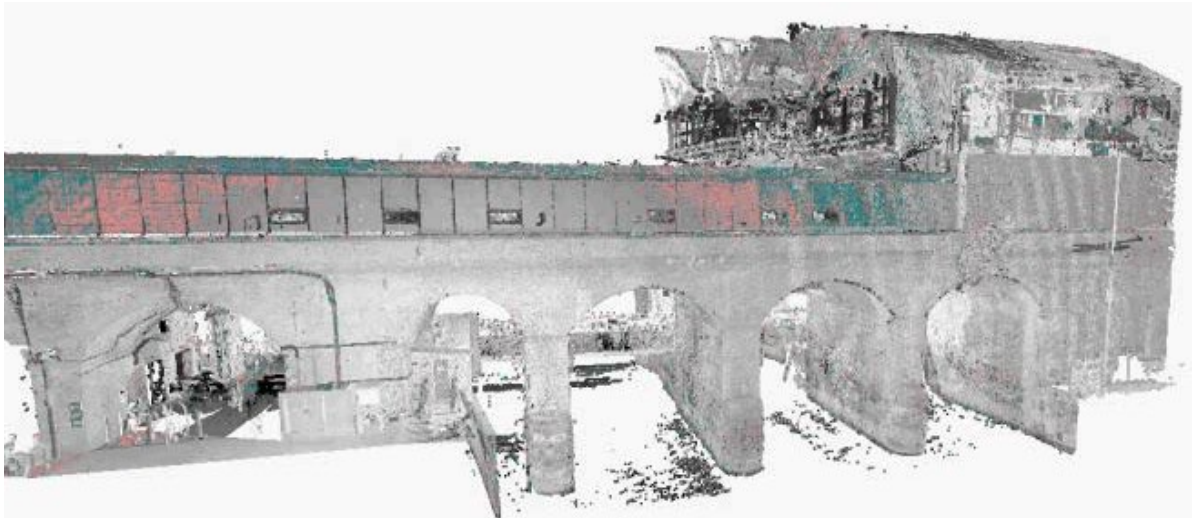
Leeds New Station is a listed structure with numerous underlying masonry vaults (40). A review in late 2015 recommended that pending new HS2 platforms be added to the existing station. These would attach to the southern part of the existing building, and span the river in a North-South alignment to create an overall 'T' plan footprint. Although not directly linking the rail lines, the arrangement will allow a common concourse for easy city interchange between the high speed and normal rail services.

Top effect a simulation and monitoring of the masonry vaults, a 3D laser point cloud was created of the external surfaces to assist in determining if the structural loading of the new station arrangements could be accommodated on them.



Illustrations: Ramboll

2D information from 3D data was easy to produce to allow the calculations - offering hybrid drawings of point cloud existing information and new build construction.



Illustrations: Ramboll

Barrel vault core drilled information was inserted into the databank, and resulting scaled drawings were inserted into the BIM model.

Illustrations: Ramboll

Discussion Q&A Issues and Points:

There is a need to:

- Assess and clarify what is 'fitness for purpose'
- Check the relevance of what was anticipated and what was achieved: BIM could enable this

With Building Services, modelling starts with a baseline against which future impacts are considered. The aim is to assist in offering and accepting 'comfort' in the proposals.

8 Beyond the Clouds – Beyond the Usual, Reading Beyond the Visible Surface, Future Proofing the Captured Information, and What is Around the Corner?

Report based on the presentation by Ingval Maxwell OBE, Chairman, Council on Training in Architectural Conservation

With any historic building there will be evidence incorporated in the structure from use, changes and incidents that have occurred during the building's past history. Although developments in modern surveying technologies can greatly assist it will frequently require a careful eye when carrying out that work to ensure that the nuances are properly identified. In terms of significance and inherent value their contribution to a better understanding of the structure should not be underestimated. Over time such changes can present a complex picture that can often be challenging in the extreme to successfully unravel the evidential physical data to fully understand it.

Norwich: © Ingval Maxwell: IMG_2984aa

Whilst this may present problems enough on the surface, a greater issue can exists in determining what underlies that surface in terms of substructure, hidden fabric, structural discontinuity, earlier decorative schemes and voids. The potential range of latent unknowns takes the BIM 'Assessment' needs down the route of archaeological investigation where the surface may have to be stripped away (with appropriate approvals) to get a fuller understanding of how the fabric is actually functioning. Such an approach can provide opportunities but, to achieve it, there is the related issue regarding an appreciation of the historic timescale that created it.

Record drawings, and illustrative building construction manuals from the 19th century, can go some way to suggest what might exist beyond the visible surface, But, when these sources are not available there is no alternative other than actual on-site investigation. In part, this

may be supported by the use of techniques such as penetrating radar and thermography but it can be difficult to achieve this with relevant precision.

© Ingval Maxwell: Temperature and water performance contours

With regard to finishes and fabrics a greater appreciation of thermographic contours or, for that matter, through excessive wetting surface patterns as a result of a maintenance failure, can create more complex conditions to deal with and interpret effectively. Here, the correlation of what is happening to the materials in the in-depth environment, such as the disaggregation of decorative wall painting or triggered dry-rot fungus, needs to be fully appreciated to determine the right courses of action, and this can easily require pre and mid-project stripping out to understand effectively and obtain relevant data.


© Ingval Maxwell: IMG_3398a

Whilst COTAC's conference on Digital Documentation illustrated that there was a real value in emerging systems that were appropriate for BIM's Common Data Environment needs, it also highlight the need to consider 'fitness for purpose' on what the intended survey approach might revealed. This could range from the application of laser surveying technology for town planning purposes to clients' presentational fly-through materials and other interpretive techniques.

However, the future well-being of any historic fabric finish involves knowing what is actually happening on the surface and immediately behind it. As digital surveying techniques have developed so too have the appreciation of the speed and quality of information that can be gathered, the concern over increasing costs that could be involved, the memory hungry database, and applicability across the range of current hardware that professionals, clients and others might be using. Therein lies the conundrum – how might these disparate issues be seamlessly welded to ensure an appropriate level of a workable uptake?

Aberlemno: © Ingval Maxwell

As technology has been developing, the initial close-range mesh detailing has not been as significantly robust as the more recent applications in gaining an effective off-site understanding of the real physical condition of surfaces. With a rougher triangulated mesh representation of the detailed surface emerging from the former approach, and greater point cloud intensity offered through the latter, this raises the question as to whether or not such initial surveys may have to be repeated and superseded. In the future, determining a 'fitness for purpose' approach from the outset will be essential to obtain the right level of recorded survey detail whilst not risking abortive work, effort and expense.

Glasgow: © Ingval Maxwell: DSC00972a

History has given us physical representations from the past that have been painted on plaster, carved in stone, and left on parchment and paper. Despite the significant developments in digital surveying technologies, how can we be assured that the longevity of the digital information that is collected now will have relevance over the future life of a historic building?

Such a structure may have already lasted for 100 to 300 years or more, and could easily have another 100 to 300 years life expectancy ahead of it. Can the emerging systems and the intentions underlying the BIM structure and its Common Data Environment approach readily accommodate that degree of longevity?

9 Concluding Discussion

What's your 10 Year Plan?

Speakers were invited to offer suggestions as to what the next decade might bring in the development of BIM with respect to the needs of the built heritage. Issues raied included:

- Analysing information, simulations, integrated design aspects, design for comfort, predicted operational costs
- Machine learning
- 'Deep mining' using search engines to find the data
- The Cloud will help with BIM organisation and data storage through creating a 'BIMlight' approach for clients with no 'on-costs'
- Organising and collaborating for Level 3
- Accepting and resolving the industry imbalance in understanding traditional building constructions
- Addressing the lost skills base with virtual training possibilities

Audience Comments

Regarding the Church of England property portfolio, and a range of other similar low commercial value properties, BIM will not translate easily to clients who require no ongoing costs, the longevity of systems, and effective maintenance with wider links to other purposes such as virtual visits, interpretation, and other admin uses. There is a need to show how it can support client's long-term aims.

There is a need to spend time working with specialists heritage contractors who need to understand what is wanted and how to do it. How does BIM relate to the skill and justification for what is actually to be done to the building? The message needs to get out to contractors. Contractors need to understand what is required of them and respond accordingly. What is BIM going to do to assist in the justification for this?

Some barriers to BIM being adopted in the heritage sector are due to resources and scale issues where properties generally have smaller accumulations of data. In addition, the skill to manipulate the data is a barrier to its adoption, warranting 'a BIM that is easy to use'.

Can some comfort be taken from the 'Cloud' as this requires no money to invest in software, and could a 'BIM light' Cloud approch for clients help bring all parts of industry together.

Is a challenge for BIM and practitioners the need to have professional indemnity insurance, and how are any PI issues resolved in a conflict situation?

A number of other relevant issues were raised from the floor, including:

From the Client's point of View:

- Keep it simple.
- We will need to use another language for Clients
- Legacy is an important issue.

- Concerns about accessibility to the data in the future?
- How could the “Cloud” be introduced to building owners with no funds?
- BIM has been driven by new build, but its use for asset management is more relevant to heritage
- In the heritage sector we should focus on Asset Information Model (AIM)
- Potential uses for ongoing maintenance need to be illustrated.
- Need to show real beneficial use in future maintenance, not just for projects

Considering the technology:

- BIM is 10% technology; 20% process and 70% behavioural
- Behavioural issues are hard to address, handling the software is easy.
- Can BIM aid digital construction?
- What might 3D Printing address?
- How responsive is BIM to change, as there is an essential need to plan for change in heritage buildings
- Linking data to physical position in a building, built on over time, throught process needs to be recorded
- Can the data be democratised through the web.

On resourcing:

- The scale of resources for historic projects tends to be small, and are a barrier to BIM being adopted.
- Historic building work has many uncertainties, there is a need for BIM which can adapt and is fast to use.
- Precious sites need detailed analysis whilst other projects could use simpler models

10 Web-based References

Listed as noted in the various numbered report sections, the following URL's were accessed and correct on 5 January 2017

1 Overview and Context

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5: PAS 1192-3 Specification for information management for the operational phase of assets using building information modelling
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2 BIM De-bunked: The Current state of play

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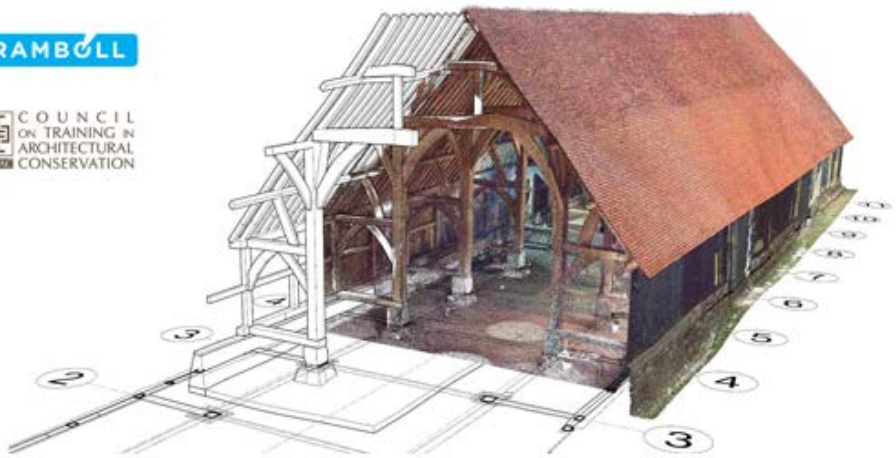
11 Annex: Conference Invitation and Programme



BIM4HERITAGE – WHERE WE ARE AND WHERE WE ARE GOING

Your invitation to Ramboll and COTAC's BIM4Heritage conference

Ramboll, 240 Blackfriars Road, London, SE1 8NW
Friday 9th December 2016, **10.00am - 4.00pm** RSVP here

Dear Ingval Maxwell ,

Ramboll and COTAC are delighted to invite you to their conference, 'BIM4Heritage - Where we are now and where we are going'.

At this warts and all event, we will provide an honest appraisal of the use of BIM within heritage buildings and environments. The conference will provide guidance on how BIM can be used for heritage conservation and repair and maintenance processes. We will review the risks and opportunities concerning the adoption of BIM and explore the increasingly advanced applications of BIM.

OUR PROGRAMME

The conference runs from 10.00am – 4.00pm and the programme will include:

- **BIM de-bunked** – BIM Level 2 in the historic environment is put under the spotlight with a review of current state of play and issues facing the industry
- **Capabilities of information capture** – The pros and cons of information capture and the issues surrounding the decisions on what level of BIM you need
- **The Conservation Conundrum** – How heritage practitioners and estate managers can use BIM to enhance conservation work, including factors that may influence the process
- **BIM sensitive analysis** – Where BIM tools feed complex analysis to allow detailed assessments that maximise conservation and minimise intrusion
- **Beyond the clouds** – Reading beyond the visible surface. Future proofing the information captured and what is around the corner.

Speakers include: Andrew Dobson, Purcell; Carl Brookes, Ramboll; Edonis Jesus, Lendlease; Graham Stewart, Ramboll; Ingval Maxwell, COTAC; Lewis Guy, Ramboll.