Glasgow Caledonian University

SFT BIM Pathfinder Project

School of Engineering and Built Environment

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Glossary of Terms

AIR	Asset Information Requirements
BIM	Building Information Modelling
BEP	BIM Execution Plan
CDE	Common Data Environment
EIR	Employer's Information Requirements
LOD	Level of Definition
LOI	Level of Information
OIR	Organisation Information Requirements
PLQ	Plain Language Question
MIDP	Master Information Delivery Plan
L2 BIM	Level 2 BIM

Acknowledgements

The authors would like to acknowledge the support and guidance provided by several members of the four pathfinder projects for providing valuable data and information on key aspects of these projects. Several interviews and discussion sessions were held with key members of all the project teams over a prolonged period. In particular, the support provided by Mr. Brian Currie of Lothian Health Board, Dr Vajira Premadasa of HES, Mr. Andrew Walker of Morgan Sindall and Ms Elena Baeza and Juan Manuel Velazquez of Ferrovial are gratefully acknowledged. Without their support, this report would not have been possible.

Executive Summary

As is well publicised now, the Scottish Government has the objective of Level 2 BIM adoption on all relevant projects where appropriate from April 2017. This report and associated research has been commissioned to support in the development of guidance to support the public sector in the adoption of BIM.

This report provides insights into four *pathfinder* projects from within Scotland through research, engagement, interviews and surveys. The report provides interesting and useful findings on key benefits and challenges of implementing BIM in projects. All *pathfinders* demonstrated that although none of them may have been fully compliant with Level 2 BIM, even by adopting BIM processes and technologies at a lower level (and making gradual progression to higher levels), there were major benefits to be had compared to traditional non BIM-based approaches.

Projects

Each *pathfinder* project was identified carefully to assess different aspects of BIM-enabled asset procurement lifecycle. The projects included a multi-use city-centre development in Aberdeen (P1), a large hospital new build in Edinburgh (P2), a motorway improvement project in Coatbridge (P3) and the retrofitting of a key heritage structure in Edinburgh (P4). Respectively, these projects demonstrate a private-sector led BIM-based Capex reduction (P1), the use of Common Data Environment (CDE) in a large new build project (P2), a very direct comparison between traditional and BIM technology based design (P3) and retrofitting a unique, existing heritage building to manage opex and the ensuing organisational issues in developing a business case for BIM (P4).

Benefits & Challenges

Across the 4 pathfinder projects, the key benefits and challenges were identified as follows:-

Benefits	**Challenges**
More effective co-ordination and clash detection saving substantial amounts	Lack of Coherent Client BIM Strategy
Hugely reduced re-design effort	Lack of Appropriate Contractual protocols
Decreased supplier costs	Scarcity of properly trained BIM resources particularly in BIM Workflows
Better outcomes for Clients	Lack of mature Data Sets in construction industry
Cost savings in O&M for Clients	
Better engagement from site personnel	
More effective options appraisal potentially saving substantial sums	

It is clear that despite some challenges, the potential benefits as demonstrated by these *pathfinders* outweigh them quite substantially. In addition, the pathfinder projects have offered the opportunity for unique comparisons (i.e. M8/M73/M74 Improvements) where BIM working could be compared to traditional design methods for the same project. This provided a credible and robust evidence base for identifying the benefits. The key quantitative benefits evidenced from across the pathfinders include:-

1. Traditional working and design was 5 times longer than BIM enabled projects.
2. BIM projects can reduce waste on site by between 60-70%
3. BIM projects can reduce post contract (RFI's/TQ) change by 80%

Recommendations

This research of BIM pathfinder projects has allowed analysis of the implementation, application and lessons from BIM within live projects. In linking this learning to the work of the BIM Delivery group for Scotland and associated future guidance, we would provide the following recommendations. All future Scottish Government guidance should support; -

1. Clearly defined employer's BIM requirements are essential and ensuring these requirements are embedded into the contract. Any guidance and support should focus authorities in developing organisational information requirements.
2. There are key challenges in relation to training and upskilling and any future guidance should ensure best in class resources are available to support training and upskilling.
3. The guidance should address our key steps for Level 2 BIM Implementation as set out on page 81.
4. Examples of good practice should be shared and evidenced to support collaboration and sharing of best practice as outlined on page 55.
5. The guidance should address the perceived obstacles as brought to light by the survey outlined on page 57.

Through addressing the recommendations above within forthcoming guidance, this will support the public sector and Industry as BIM is implemented within future contracts. A key lesson has been the need for suitable skills and resources and this will continue to grow as projects strive towards BIM Level 2 going forward.

Background and Introduction

1.1 Background and Introduction

1.1.1 Supporting Scottish Government

A review of Scottish Public Sector Procurement in Construction carried out in October 2013 proposed that:

"BIM will be introduced in central government with a view to encouraging adoption across the public sector. The objective should be that, where appropriate, projects across the public sector adopt BIM level 2 by April 2017."

The recommendation was endorsed by Scottish Ministers and supported by 5 supplementary BIM recommendations. A BIM implementation Plan supporting the recommendations has been created by the Scottish BIM Delivery Group set up by the Scottish Futures Trust.

1.1.2 Minimum standard

The Scottish Government has mandated Level 2 BIM maturity as a minimum standard in all its projects from April 2017. Level 2 BIM maturity can be described as:

"A series of domain (e.g. architectural, structural, services) and collaborative federated models, consisting of both 3D geometrical and non-graphical data, prepared by different parties during the project life-cycle within the context of a common data environment."

It is hoped that all Scottish public sector procurers will provide defined, validated outputs via digital data transactions using proprietary information exchanges between various systems in a structured and reusable form.

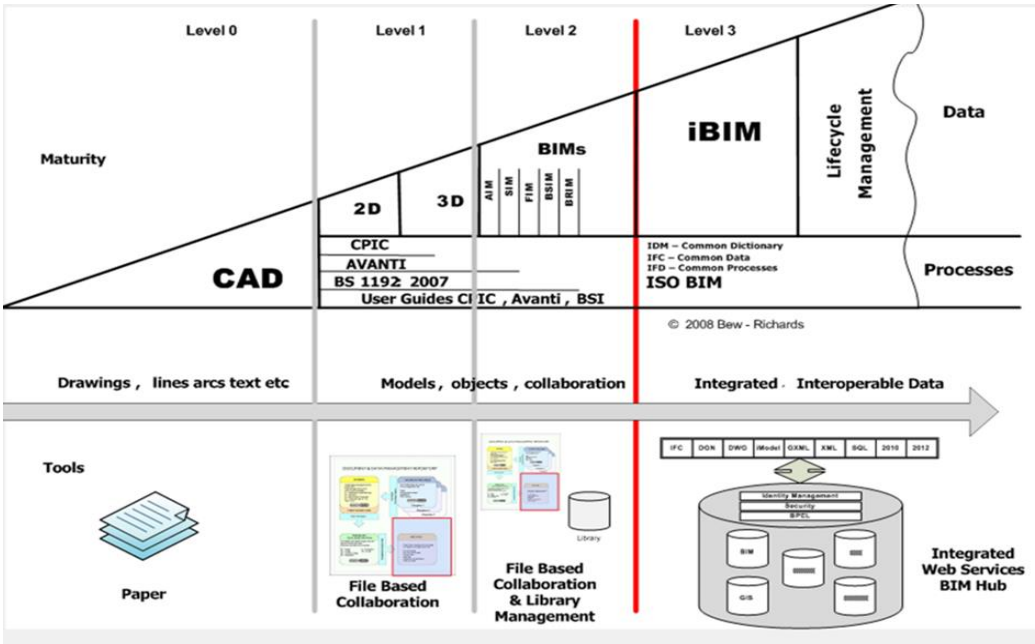

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Figure 1 BIM Maturity Levels

1.1.3 Supporting processes, tools and guides

Over the last four years, the BSI has published a series of guidance documents and standards. Various British Standard Level 2 BIM processes, associated tools and guides that will be configured to suit the needs of a particular project are summarised in the diagram below:

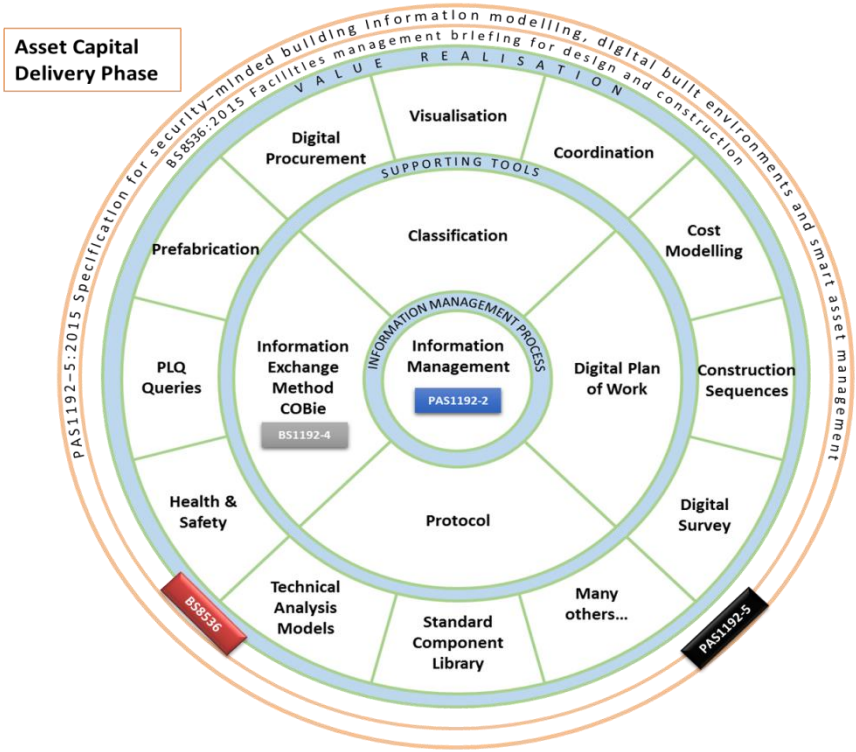


Figure 2 Information management Processes, Tools and Value Realisation

1.2 Pathfinder Projects

As part of the BIM implementation plan, Scottish Futures Trust monitored a number of BIM pathfinder projects to capture lessons and inform future guidance. This forms part of Horizon 3 of the BIM Implementation Plan.

The key objective was to capture lessons in how BIM is implemented on a project and the benefits that are realised. The lessons informed the new Scottish BIM guidance Portal for Scotland.

For each project, the objective was to identify and monitor a specific area with regards to BIM implementation and capture lessons learned. This was achieved through an initial readiness meeting with the BIM Pathfinder Delivery Group.

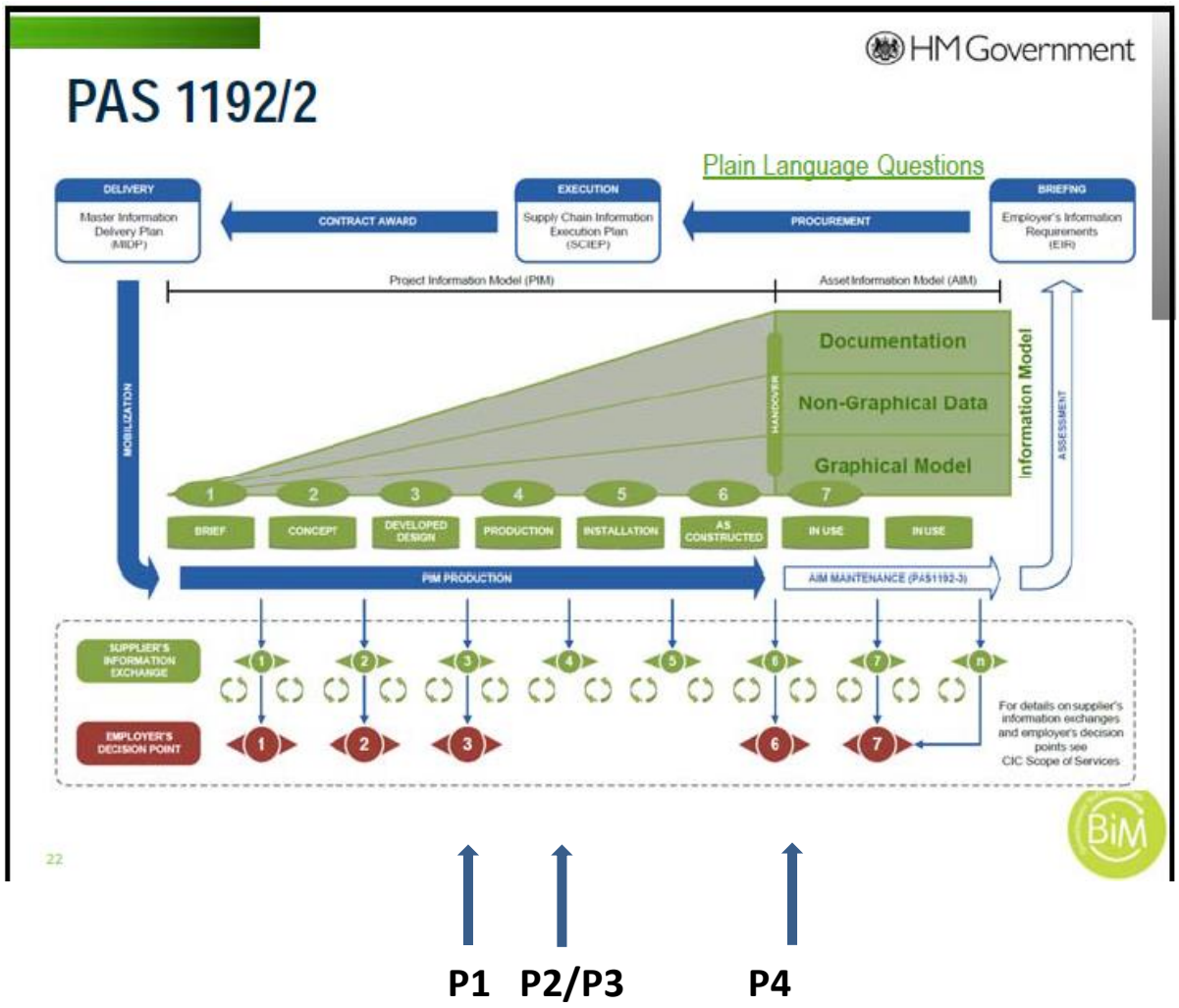


Figure 3 Stages of Pathfinder Projects against Information Delivery Lifecycle (PAS1192: Part 2)

The four pathfinder projects (P1, P2, P3 and P4) were chosen carefully so they provide useful information on different stages (or data drop points) of the overall information delivery lifecycle shown above taken from PAS1192: Part 2. It was not possible to follow a single project throughout the entire lifecycle simply because of time constraints.

Pathfinder Project Descriptions

Pathfinder Project Nr 1

Marischal Square Project, Aberdeen (P1)

An Exemplar in Private Sector-Led BIM Implementation for Capex Reduction

Figure 4a Marischal Square Development Schematic

Figure 4b Marischal Square Development Schematic

2.1 Introduction and Background

It should be acknowledged that Morgan Sindall made a decision to start their Level 2 BIM journey as early as the UK BIM Task Group's launch of the initiative. After assessing their internal training needs, they decided to carry out a pilot project pro-actively by implementing BIM in the Marischal Square project in Aberdeen.

Marischal Square will deliver a vibrant new mixed-use quarter for Aberdeen and include offices with associated car parking, hotel, retail, cafés, restaurants and civic space, along with public access, landscaping and public realm improvements around a site once dominated by the former council headquarters building, St. Nicholas House.

The development will be a keystone of the council's city centre master plan proposals, providing a new civic space for Aberdeen and creating an enhanced setting for both Provost Skene's House and Marischal College. The new development will comprise:-

1. two office buildings providing 173,500 sq ft of Grade A office space with secure parking
2. seven restaurants and café bars occupying 28,000 sq ft of ground floor space;
3. a 126-room Residence Inn by Marriott providing long stay luxury accommodation for business and leisure travellers;
4. modern civic space around a rejuvenated Provost Skene's House museum;
5. high quality elevations of granite and glass enclosing a development with high levels of sustainability – the offices will be BREEAM 'Excellent' and EPC 'A' ratings; and
6. a new area of useable public space between Marischal College and the new buildings.

The development is scheduled for completion in July 2017.

The project is being developed by Muse who are a national developer with regional operations in Manchester, London, Leeds and Glasgow

Four years ago, Morgan Sindall Construction (MS) was very much at the formative stages of their BIM development and had formed a Core group to lead the implementation of BIM into the business over a 5 year period. This limited the opportunities for BIM in respect of projects. Although MS had a portfolio of projects to further their own knowledge, they felt Marischal Square presented an ideal opportunity to further their BIM offering.

There was no BIM brief on the project and certainly no EIRs coming from the client. However, as MS were involved from the inception of the project right through to handover it was their considered opinion that it would be the ideal environment to push BIM.

2.2 BIM Adoption Scope

As previously mentioned, there were no EIRs or BIM brief in place for this project and it was left to the MS BIM Core Group to determine what could be realistically achieved through this project without detriment to 'known' methods of project delivery. As BIM was at the cutting edge of development, the business recognised that BIM would run parallel to the 'flat world' or traditional methodology until such time as confidence was achieved by the MS team.

After much deliberation and importantly, understanding the capabilities of all the stakeholders involved in the project, MS elected to undertake 3d, 4d & 5d implementation for the project. 6D was considered but, as the properties would eventually be let to tenants that MS did not have access to at this time, they elected not to write a pre-emptive brief for the 6d element.

Additionally, as part of their overall BIM development, they had invested in a product called VICO, which was a software that had considerable traction in USA and promised to combine 3d/4d & 5d under one umbrella. The premise of this software was that any change made to the model environment would be reflected in outputs on both 4d planning and 5d costs, thus making it a very powerful tool for making true 'Value Engineering' decisions.

There was no client BIM information Manager in place so MS drew on the services of Morgan Sindall Professional Services (MSPS) who supply this service to Morgan Sindall businesses and external clients.

Over and above the BIM brief, MS set up a number of KPIs that they could measure the success of BIM. These were KPIs that they currently used in a traditional approach, thus permitting direct measurement between the two methodologies:

1. Cash forecasting/profile
    a. Planned versus actual
2. Number of clashes/conflicts
    a. Should be less than normally experienced due to BIM Information manager involvement and QAR
    b. Less rework – industry norm is 20/30%
3. Number of RFIs generated
    a. RFI is reactive and cost the industry circa £1k each
    b. Expectation on this project should be minimal
4. Waste off site
    a. Less rework
    b. More prefabrication
    c. Less skips
5. Training
    a. Level of competence of project staff on completion
    b. Level of confidence of project staff at completion
    c. Review of training programme

6. Controlled completion programme
    a. No 'rush' at the end
    b. Handover as currently planned

2.2.1 Engagement of the Project Team in BIM Implementation

The primary design team for Marischal Square project consisted of:

1. Halliday Fraser Munro Architects, Aberdeen
2. Fairhurst Engineers, Aberdeen
3. Atelier 10 Services Design, Glasgow

Very much like Morgan Sindall, the design teams had looked at using BIM in their respective organisations but had not yet ventured into full 3d/4d &5d BIM delivery. However, they were all unanimous in realising the potential benefits in proceeding with BIM implementation to further their own learning and understanding.

A great deal of time was spent through the early stages to ensure the entire design team understood expectations and capabilities. MSPS, in their BIM Information Manager, role extended their appointment to teach and mentor the BIM stakeholders throughout the project.

2.2.2 Supply Chain Involvement

Similar to the development of the design teams, the supply chain also demonstrated varying degrees of BIM capability. Although the project is large, it is made up of many repetitive elements which had the advantage of few trades needing to be involved. These included:

1. Sub & superstructure
    a. Piling
    b. Post tensioned concrete
2. Building envelope
    a. Curtain walling
3. Building services
    a. Mechanical
    b. Plumbing
    c. Electrical

Probably the biggest benefit that has come from these three elements would be the integration of services throughout with the absolute minimum of clashes or rework.

2.3 Some Key BIM Benefits and Innovation

Beyond the use of all the dimensions (3D/4D/5D), the project is currently trialling model linked mobile site applications on tablets and smartphones to maximise the use of modelled information and smarter ways of working.

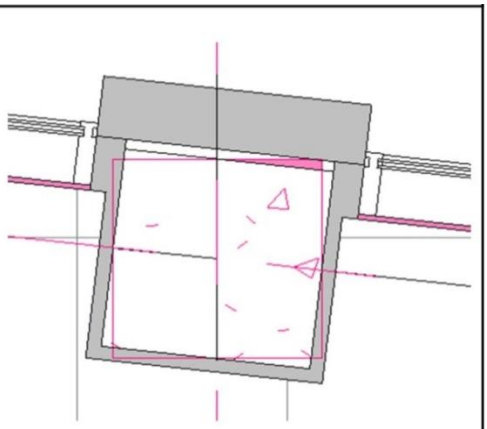
10	Impact	Incorrect drawings and setting out	
	Issue	Column misaligned (along gridline 2-01)	
	Proposal	Fairhurst to coordinate Revit model with current HFM model - (Office 2 only)	

Figure 5 Mis-aligned Columns Coordination in Design

Some of the major achievements in the journey are listed below:

1. The use of collaborative BIM elevated the designers' perceptions of BIM beyond 'Revit' 3 dimensional modelling;
2. Early 3D design of the services allowed more confidence (and consequently less risk) in placing the order;
3. Much improved and effective coordination between sub and superstructure and services;
4. Options appraisals was hugely more effective and as an important example, the fibre optic cables redesign potentially saved circa £90k;
5. 4d Planning achieved the following in a much more effective way:
    a. Greatly enhanced visualisations greatly helped in the design as well as construction stages
    b. Planned vs. actual Model comparison was very useful for demonstrating recovery or improvement, if required.
    c. Very useful in sub briefing and collaborative meetings

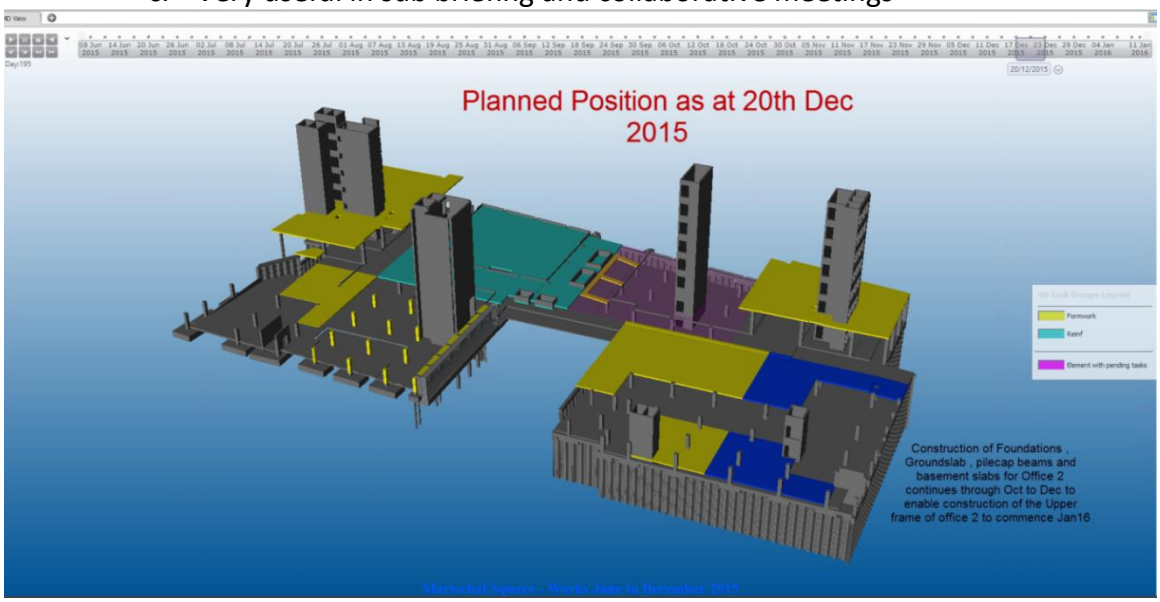


Figure 6a Comparison of Planned & Actual (July 2015)

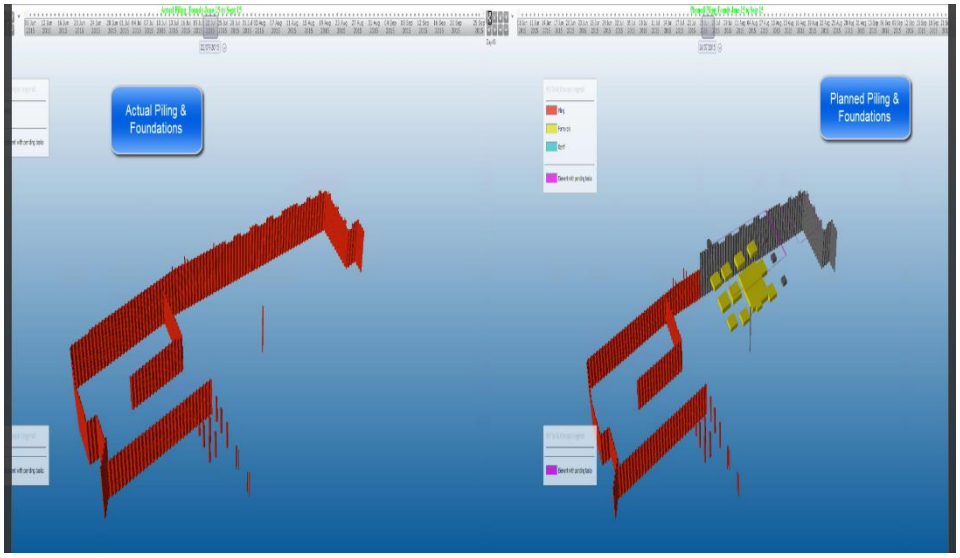


Figure 6b Comparison of Planned & Actual (July 2015)

6. Field BIM which is currently under trial has proved extremely effective in:
    a. Inspection and test plans, backed up with GA's, design detail drawings, non-conformance report and the ability to attach pictures.
    b. All site specific permits with the ability for these to be signed for by MS and subcontractors
    c. All site safety inspections with the ability to attach pictures
    d. Daily diaries
    e. Snagging
7. On health and safety, the field BIM trial has also helped in briefing using the smart board technology that allows sub-contractor engagement much more effectively.
8. Some other successes noted so far are as follows:
    a. All Design Team Information generated from their 3D model
    b. Use of the federated model in meetings and reviews
    c. Limited rework issues experienced so far
    d. M&E Installation Model federated within Design Model

2.4 Some Key Lessons Learnt and Discussion

The experience of BIM implementation so far has led to several areas which require more thought and planning in future projects. These are:

1. Some of the technology used in the project involved a lot of work and rework to get right.
2. BIM was being run, initially, as a parallel exercise meaning additional works were required to service both streams of development.
3. Full commitment of the project team at an early stage is required.
4. Scope of the BIM implementation needs to be decided and agreed early on in the process.

Finally, it is important to point out that whilst the project is not yet complete, the success of the BIM elements can be measured twofold:

1. BIM knowledge has increased exponentially for Morgan Sindall and the design stakeholders. They have all benefitted from the experience (good and bad) and are better placed for any future BIM projects that come their way. There are still lessons learned being coordinated and these will be made available towards the end of the project. The team have pushed some new boundaries and had particular success in the application of Field BIM techniques which is probably the most positive feedback they get from site personnel.
2. The return on investment is harder to measure as BIM is very often about the things you don't do (waste, rework etc.). The measurable KPIs set for the project have not all been reached as they only become tangible and measureable at handover. However, some very positive conclusions can be drawn out of:
    a. RFIs – well down and around 40 in number during the post-contract stage – for a project of this size this would normally be measured in several hundred;
    b. QAR (Quality Audit reports)/Clash – it is clear that the pre-emptive design coordination works through federation has greatly reduced rework or error on site. There are hundreds of clashes that featured in the model environment that have not found their way to site and, to date, there are only four areas of minor rework required to some minor services that have had to be undertaken on site.
    c. Waste – measured in terms of skips off site. It has been difficult to draw on an exact parallel for Marischal Square that was completed pre-BIM but MS were able to draw on projects with a similar nature or project spend. Overall, to date, it looks to be running 60/70% less than its predecessors which has to be regarded, out with the cost of handling waste materials, as a major triumph for environmental control.

Overall, this project is being regarded as a successful frontrunner project by MS. It is generally felt that despite some initial difficulties, this project demonstrates tangible and measurable returns for the investment.

Pathfinder Project Nr 2

The Royal Hospital for Children & Young People (P2)

Benefits and Challenges in CDE-driven Collaborative Project Delivery

3.1 Introduction and Background

At the outset, it should be acknowledged that NHS Scotland is clearly at the forefront of Level 2 BIM adoption among all NHS organisations in the UK. NHS Scotland initiated its Level 2 BIM journey by developing a comprehensive BIM strategy not long after the launch of Level 2 BIM initiative.

The Royal Edinburgh for Children & Young People (RHCYP) project will re-provide the services from the Royal Hospital for Sick Children, Child and Adolescent Mental Health Service (CAMHS) and the Department of Clinical Neurosciences (DCN) in a single facility adjoining the Royal Infirmary of Edinburgh at Little France.

This project addresses the re-provision of all acute hospital departments from the RHSC, the CAMHS inpatients and day care services and the DCN to Little France.

The RHCYP and DCN will be managed separately from the existing RIE building and its PFI contract arrangements. Facilities management (FM), access and delivery arrangements, and the procurement and provision of energy and medical gases will be independent of the RIE.

The project is the first acute hospital facility procured under the Scottish government's Non Profit Distributing (NPD) model.

3.1.1 Key Building Facts

- 1800 rooms within the full facility
- Building footprint of 13850 square meters
- Number of floors – 6 (7 including helipad)
- Number of operating theatres – 10
- Number of stair and lift cores – 10
- Number of door sets – 2500
- Number of windows – 700
- Number of lifts – 18
- Number of hospital departments – 62
- Number of node rooms – 28
- Number of server rooms – 1

3.1.2 The Building in Numbers

- Four months of piling in excess of 750 large diameter, rotary bored (fully cased) piles
- Over 30,000 cubic meters of bulk evacuation
- 8 meter deep evacuations
- 25000 cubic meters of concrete required
- Concrete frame – steel reinforcement totalling over 4000 tonnes
- 165 kms of cabling throughout
- In excess of 110 km of pipework
- 20 kms of ductwork

Figure 7 The Royal Hospital for Children & Young People

The building will redevelop and relocate services from the Royal Hospital for Sick Children, Child and Adolescent Mental Health Service and the Department of Clinical Neurosciences in a single building, construction cost is estimated to be £150 million, adjoining the Royal Infirmary of Edinburgh at Little France. Construction works started in February 2015 and the new building, which will adjoin the Royal Infirmary of Edinburgh via adult and children Emergency Departments, will be handed over to NHS Lothian (NHSL) in autumn 2017 and is anticipated to open in spring of 2018.

3.1.3 Project Consortium

IHS Lothian Ltd. (IHSL) is a consortium of companies who were selected as preferred bidder to design, build, finance and maintain the new building in March 2014. The project consortium consists of four companies. These are Multiplex Construction Europe with HLM Architects who will design and build the new facility, Bouygues E&S who will provide Hard FM (facilities management) in the new building.

Figure 8 Royal Hospital for Children & Young People Images of Progress

3.2 BIM Adoption

The adoption of BIM within this project represented a frontrunner project within Scotland. The procurement for the project commenced in late 2012 and at this stage, BIM adoption was at its earliest stages. In addition, the procurement route as a non-profit distribution (NPD) model offered further challenges in how each level of the supply change defined and manged their specific information requirements.

Under NPD, NHSL have contracted with a consortium, IHSL, to design, build and maintain the facility for a 25 year period. This has meant that unlike traditional procurement arrangements, the private sector consortium have an active interest in defining operational information requirements for the new facility as well as the construction information requirements. For NHSL they too have an interest in operational information requirements relevant to the scope of their responsibility (i.e. soft FM services) and handover data at the end of the concession period. For their part, at the Invitation to Participate in Dialogue (ITPD) stage, NHSL asked the bidders to prepare a BIM execution plan (BEP) for review by, and agreement with, the Board and IHSL did respond with a BEP. NHSL also made stipulations for handback by stating that , "On the Expiry Date, Project Co shall:

- Hand over ownership of the BIM model to the Board;
- Fully update the BIM Model to reflect all changes during the Operational Term including specification details, operation and maintenance requirements and residual design life of all components and assemblies of the Facilities:
- Agree the format of on-going maintenance and replacement information with the Board; and
- Provide training in the operation of software relating to the BIM model to the Board."

Therefore, the level of ambition to adopt BIM and overcome the challenges of being an early adopter and tailoring the information requirements to reflect the procurement process should be acknowledged.

However, the RHCYP contract had no client EIRs in place or indeed any other element of Level 2 BIM processes except BIM Execution Plan, as mentioned above, which was extensively used by the main contractors. The main contractor, Multiplex, in line with their current standard practice, decided to adopt BIM wherever appropriate. The main activities where BIM appears to have been used were the design coordination and data exchange through a common data environment. Multiplex have fairly mature BIM processes in place and the company now uses BIM as standard practice on all projects. A number of their supply chain organisations generally buy into the BIM approach but in case of the RHCYP project a number of them did not really engage in the BIM processes. A major reason mentioned for the lack of engagement in the process was the intellectual property rights (IPR) issues as there were no BIM protocols (as mandated by formal level 2 BIM guidance documents) in place. Interestingly, Bouyguyes (FM contractors) drove most of the changes

in the BIM Execution Plan (BEP) and the IRs (Information Requirements). However, some of these were questioned by Multiplex as the design implications of these IRs were significant. So, as is clear, although this project could not be classified as a fully Level 2 BIM compliant, there are clearly elements of Level 2 BIM that have been implemented by the project team. This is highly encouraging and tends to suggest that the supply chain (or parts of it) can clearly see the benefits of adopting BIM.

3.2.1 Some Key Lessons and Benefits of BIM Adoption

As is clear from the above discussion, there were several elements of Level 2 BIM which were implemented in this *Pathfinder.* However, as it lacked a holistic approach to Level 2 BIM implementation, there were several lessons that can be drawn from this project. For a start, a lack of set of EIRs meant that there were no structured information requirements in place from the client's perspective. Besides, there was evidence that even major suppliers were unwilling to share information due to a lack of legal protection of their IPR. On the technical front, a proper CDE was used in this project. However, an important lesson that arose in this project was that the size of model files often put unprecedented strain on the CDE thereby not actually producing the kind of benefits one would normally expect from using a CDE. Splitting the model files was potentially a solution but even that presented a number of challenges in terms of the best possible way of addressing what is a well-known technical challenge.

Some other challenges were evident in this project in relation to BIM adoption. The outsourced FM provider also presented challenges in terms of retrospective information requirements specification. Finally, the project would have benefited from implementing greater resources to manage, validate and deliver their BIM Level 2 requirements. Especially at the early stages of the project where a fully developed set of EIR's aligned to their specific information needs would have supported full BIM Level 2 implementation. So, the key lesson is that an unstructured, partial implementation of Level 2 BIM is not likely to result in major benefits to the client organisation although this project demonstrated that there were *pockets* of benefits that members of the supply chain realised internally within their organisations.

Interestingly, this project demonstrates some unexpected benefits too. For example, the BEP template has been used to train and educate the M&E contractors who are now using it as a standard practice having realised its benefits. Each discipline now uses the BEP template and owns its part in the document.

Pathfinder Project Nr 3

M8/M73/M74 Improvement (P3)

A Unique Comparison of Traditional CAD approach with 3D BIM

4.1 Introduction and Background

It should be acknowledged at the outset that Ferrovial appear to be taking a lead in Level 2 BIM adoption in the infrastructure sector and they are doing this often without any contractual obligations. This pathfinder project is one such example where they were not contractually obliged to adopt BIM and yet they did, which only signifies their progressive outlook and vision for the future.

The c. £600M M8/M73/M74 Motorway Improvements Project is a major transport infrastructure scheme. It completes the M8 motorway link between the cities of Glasgow and Edinburgh and provides key upgrades to sections of the M73 and M74. Ferrovial, Lagan, Amey and RPS are collectively responsible for the design, construction, commissioning and operation and maintenance of the project on behalf of the Scottish Roads Partnership. The design for this project is being undertaken by Amey and RPS, with design staff principally located in Galway, Dublin, Cork and Belfast. Ferrovial Lagan JV (the constructor) are based on the project site in Motherwell, with Amey O&M close by on site in Motherwell as well. The scheme comprises a new 12km dual three-lane M8 motorway section between Baillieston and Newhouse and upgrades to 16km of the existing motorway network. The upgrades include widening for additional lanes and significant new works and alterations to existing motorway interchanges at Raith (M74/A725) and Baillieston (M8/M73).

Figure 9 M8/M73/M74 Motorway Improvement – Raith Interchange

The Raith Interchange is one of the largest interchanges on the project. Works here include the construction of a new 600m long and 12m deep underpass, construction of a realigned Raith Roundabout, three new bridges, two new pedestrian footbridges, pier protection at two existing bridge structures, five signalised junctions and numerous other off-line works such as flood alleviation storage ponds. The junction remains open to traffic during the construction works.

In this project, Amey and Ferrovial Lagan Joint Venture (FLJV) have a mutual objective to develop capability in Building Information Modelling (BIM) in the infrastructure sector. This objective is shared by RPS, the design sub-consultants on the M8/M73/M74 Motorway Improvements Project. The design and construction of the M8 Upgrade has already commenced using conventional 2D design techniques and content management platforms. Due to construction programme pressures, a change in strategy to adopt BIM as the core approach for the design and construction of the entire project was deemed unrealistic. Therefore, it was decided that there was potential to develop a 3D model of the Raith Interchange section of the M8 Upgrade using BIM techniques and processes. It was intended that the Raith Interchange model would be developed in parallel with the 2D design process. The design of the Raith Interchange was assigned to RPS under the existing consultancy contract.

Figure 10 M8/M73/M74 Motorway Improvement – Raith Interchange (2016)

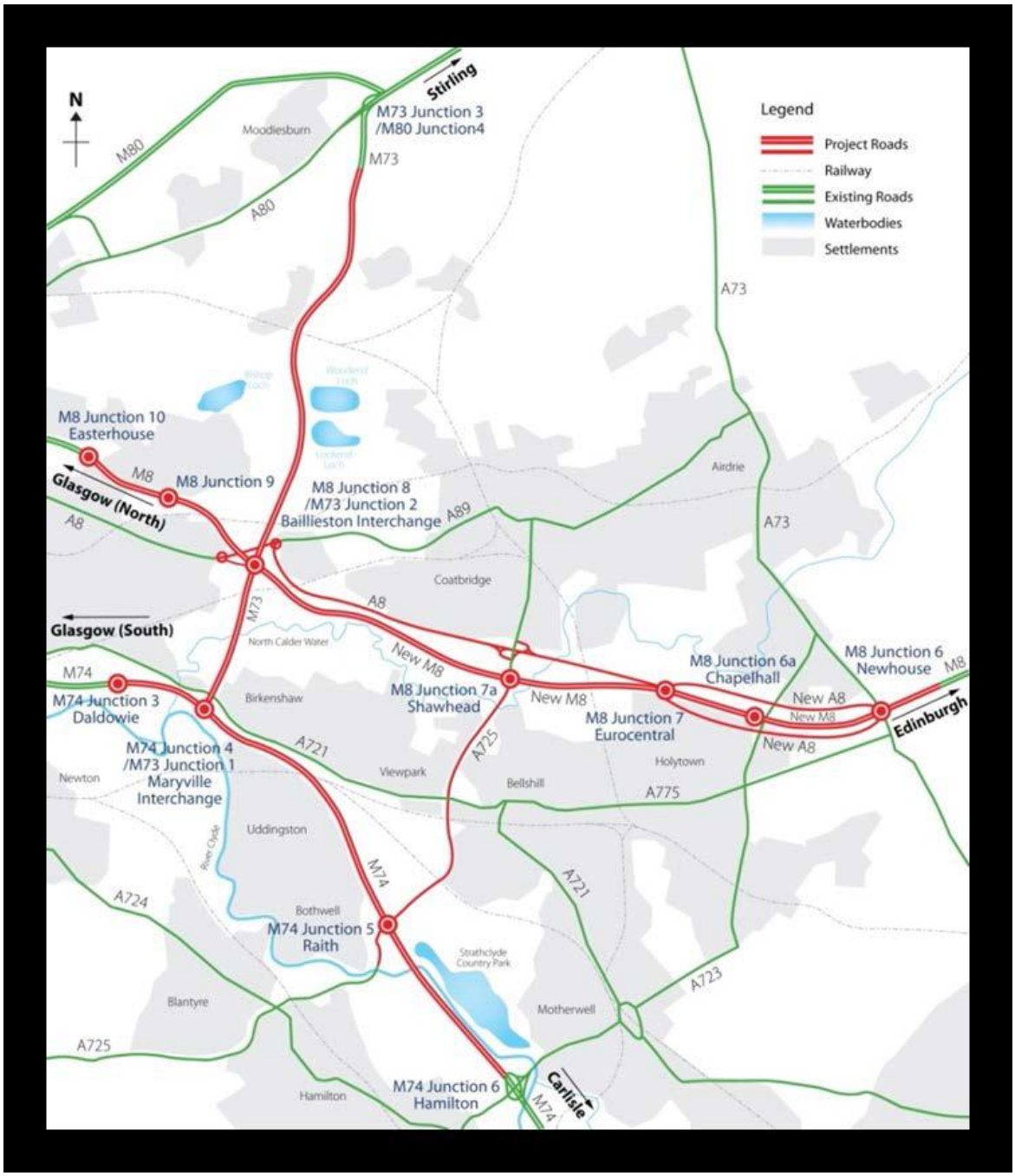


Figure 11 M8/M73/M74 Motorway Improvement Location

During the preparation of parallel approaches, it became clear to both Amey and RPS that the delivery of the BIM activity should be achieved collaboratively in order to:

1. Minimise the co-ordination risk between teams, establishing a collaborative framework, guided by the principles in BS11000.
    a. Minimise the potential for operational and contractual conflict e.g. disputes around the transfer format between 2D/3D activities.

b. Maximise the experience and resource pool that can be applied to the BIM activity, including sharing the lessons learnt on other similar projects delivered by RPS and Amey.
c. Drive greater efficiencies in joint working for both the Client and consultants.

4.2 BIM Implementation Scope

The 3D modelling of the Raith Interchange was implemented in line with the FLJV requirements and scope as mentioned below.

1. Development of Level 2 BIM models up to 'for construction'* status level of detail for:
   a. Alignment
   b. Structures
   c. Culverts
   d. Drainage

2. Enabling the integration of BIM models produced by FLJV, namely models for:
   a. Utilities
   b. Sign
   c. Traffic management
   d. Temporary works

3. For various practical reasons, a number of disciplines, mentioned below, were excluded from being modelled using 3D BIM:

   a. Traffic signs and road markings
   b. Pavements and geotechnical details
   c. Road restraint systems / safety barrier
   d. Traffic signals
   e. Fencing (inc. gates)
   f. Earthworks
   g. Soft landscaping

4. Amey/RPS will undertake the role of Model Manager for the duration of the BIM development activity (28 weeks). The responsibilities of the Model Manager will include:

   a. Co-ordination and monitoring of the production of models for each discipline
   b. Managing the integration of the models for each discipline from the Amey/RPS and FLJV teams

c. Arbitration between the individual disciplines where there is conflict between disciplines, escalating significant issues
d. Liaison with the existing Project Design Coordinator (responsible for the main project permanent works design - RPS)
e. Reporting to the FLJV M8 BIM Manager

5. Amey/RPS will facilitate managed access to the models during their development and in final stage (subject to agreed access protocols). Amey/RPS will manage the content shared within the common data environment (CDE) using the standards set out in the BEP.
6. On completion of the BIM model and agreed iterations, the Amey/RPS Model Manager will transfer control of the model to FLJV.
7. Notwithstanding the above, formal ownership of the BIM model during development and subsequently will remain vested in FLJV. Amey/RPS jointly and separately will be permitted to use the model during development and in its final state for training purposes and as evidence of capability for tendering and similar activities.
8. Use of the model for commercial gain by Amey/RPS, jointly or separately, will only be with the prior written consent of FLJV, but that consent will not be unreasonably withheld.
9. FLJV will undertake the role of BIM Contract Manager for the duration of the project. The responsibilities of the BIM Contract Manager will include the following:

a. Establish and agree a BIM Execution Plan
b. Agree BIM software selection
c. Coordinate BIM use on project, determine Schedule of use, sharing activities, quality control, modelling responsibilities and document in BIM Execution Plan.
d. Authorize user access rights
e. Communicate with all levels of management on BIM
f. Identify training needs for company personnel and appropriate courses.

4.2.1 Some key benefits of BIM Adoption

A unique characteristic of this *pathfinder* was that the project team decided to use the traditional CAD-based design and a BIM-based one in parallel for the Raith Interchange section of the project. This proved a fascinating test bed for the team as well as other interested parties to make a direct comparison between CAD and BIM-based design.

As is clear from the earlier sections, the adoption of BIM in this project was largely focussed around the design activities. However, some aspects of Level 2 BIM were also implemented like the BIM Execution Plan (BEP) which was used to manage the use of BIM and data sharing and exchange on the project through a CDE**.** 4Projects was used as the CDE and information was shared with all the different departments of the project, e.g. construction

team, H&S, QAQC, environmental, traffic management and utilities. The client team also had access to the CDE.

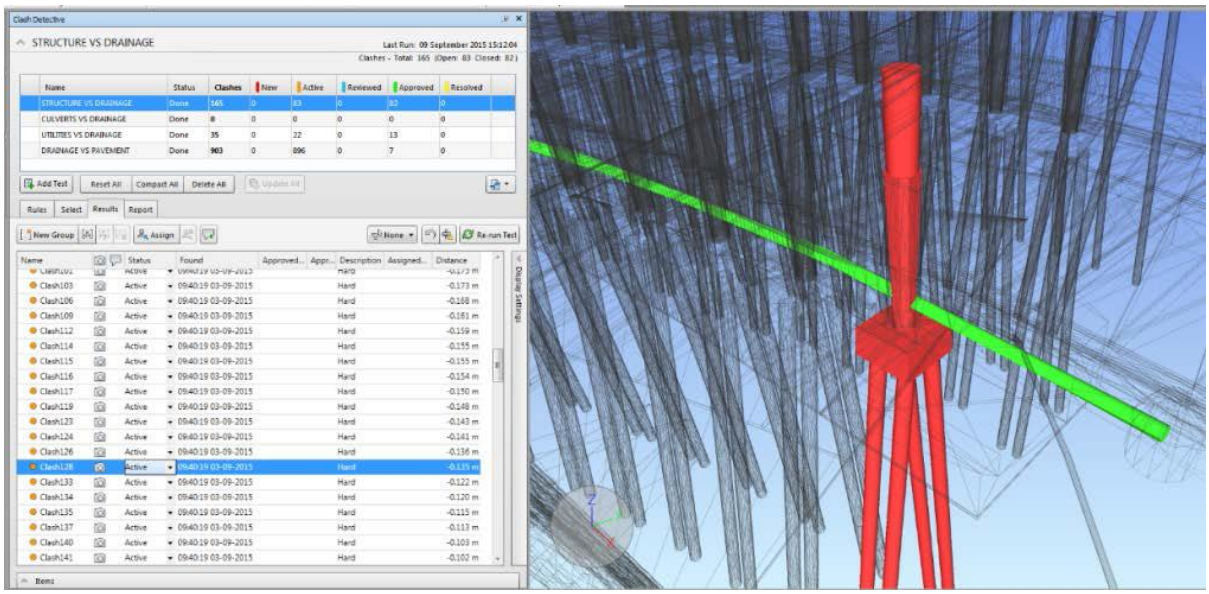


Figure 12 Risk Management and Clash Detection on the M8/M73/M74 Project

The appointment of FLJV BIM Contract Manager can be likened to the role of Information Manager as envisaged in Level 2 BIM Protocol.

There were several other benefits that have accrued from the adoption of BIM in this project. The main benefits can be classified in the following categories:

1. Improved Coordination,
2. Faster and easier Clash Detection; and
3. Substantial Efficiency gains in Design Change management

There was evidence of other intangible benefits as well. For example, the use of 4D and 5D models helped optimize construction programming besides being a powerful visualization & communication tool which enabled the identification of problems in advance of construction and also helped extract material quantities much more efficiently. The project team found that the use of BIM and CDE made it easier to control the paperwork. It also helped keeping all stakeholders in the loop regarding what was the current state of the design or works.

The following table provides a very powerful comparison of the CAD and BIM-based approaches in terms of the effort required for the same design activities. The overall comparison makes a compelling case for the adoption of BIM.

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USE OF BIM SOFTWARE VS. TRADITIONAL

		TIME (hours)	
DATE	DESIGN ITEM ANALYSED	BIM (AUTODESK)	TRADITIONAL (TCP)
05/03/2015	Raith A725 SB Access Track design review	1	8
05/03/2015	Raith Temporary alignment TW25-26 design review	1	4
06/03/2015	Raith Temporary alignment TW27-28 design review and propose alternatives	1	4
06/03/2015	Raith Temporary alignment TW07-08 Rev I design review	0.5	4
06/03/2015	Raith Temporary alignment TW09-10 Part1 & Part3 design review	0.5	3
06/03/2015	Develop new access track proposal	1	4
19/03/2015	Generate cross section at Raith Roundabout including alignment, utilities and drainage	1	4
19/03/2015	Checking new design received with Raith North phasing TW	2	8
20/03/2015	Generating S105 Cross section showing beams and diaphragms	1.5	5
20/03/2015	Checking clashes between new alignment and existing drainage and ITS in M74 SB offlisp	0.5	8
25/03/2015	Generating cross sections at S201B abutments for construction sequence	0.5	8
26/03/2015	Raith Temporary alignment Raith North roundabout design review and proposing other alternatives	2	8
06/04/2015	Raith Temporary alignment TW01-02 design review	2	8
06/04/2015	Raith Temporary alignment TW07-08 Rev J design review	0.5	4
	TOTAL (hrs.)	15	80
		RATIO	1 h. vs 5 hrs.

Figure 13 Comparisons between CAD and BIM on the M8/M73/M74 Project

Pathfinder Project Nr 4

Edinburgh Castle – Main Palace Retrofit (P4)

Development of a Business Case for BIM Investment & Operational Benefits

5.1 Introduction and Background

Historic Environment Scotland (HES) appear to be taking the lead in the adoption of Level 2 BIM among similar organisations in the UK. HES started out on the Level 2 journey fairly early on and are quite unique in their approach to Level 2 BIM considering their role and mission. Historic Environment Scotland is a non-departmental public body (NDPB) that was formed in 2015 through the merger of its predecessor organisations, Historic Scotland and the Royal Commission for the Ancient and Historic Monuments of Scotland. The statutory role of HES is set out in a Scheme of Delegation between itself and the Scottish Minsters, which places an obligation on HES to care for and manage 345 Properties in Care (PICs). This includes some of Scotland's most iconic buildings, sites and monuments, including Edinburgh and Stirling Castles. In addition to its strategic role as the lead public body for Scotland's historic environment, HES also undertakes a range of research, educational, tourism and commercial activities.

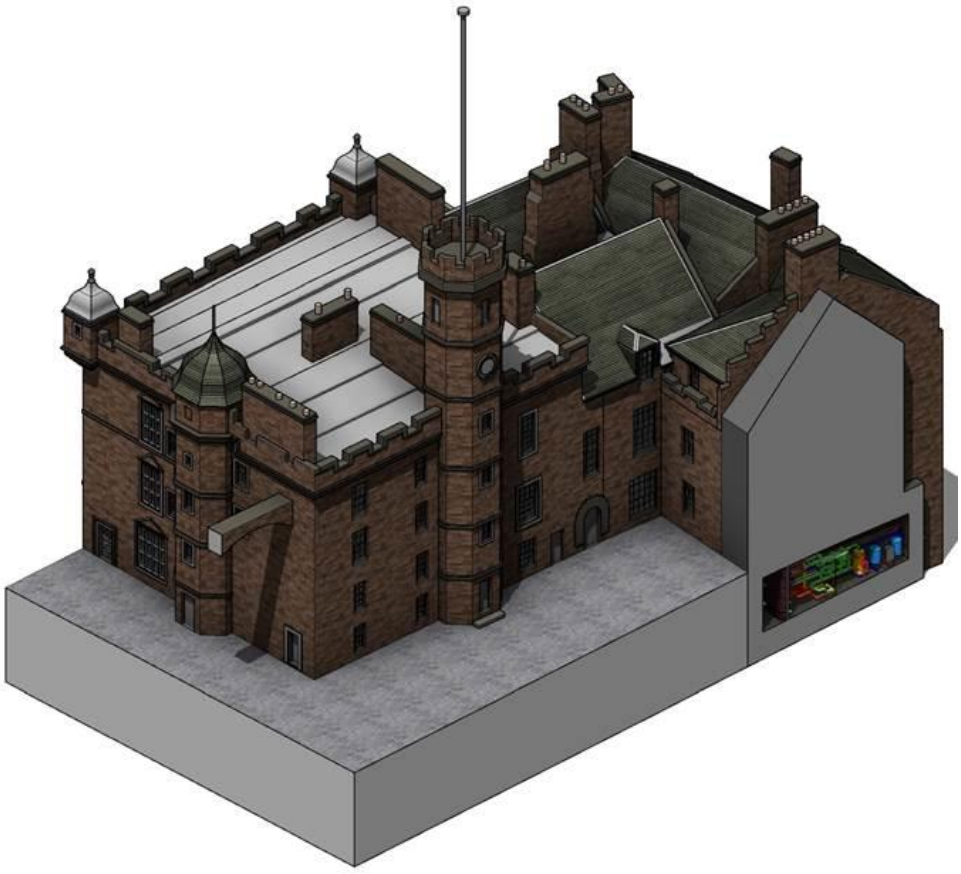


Figure 14a Laser Scanned Image of Edinburgh Castle Main Palace

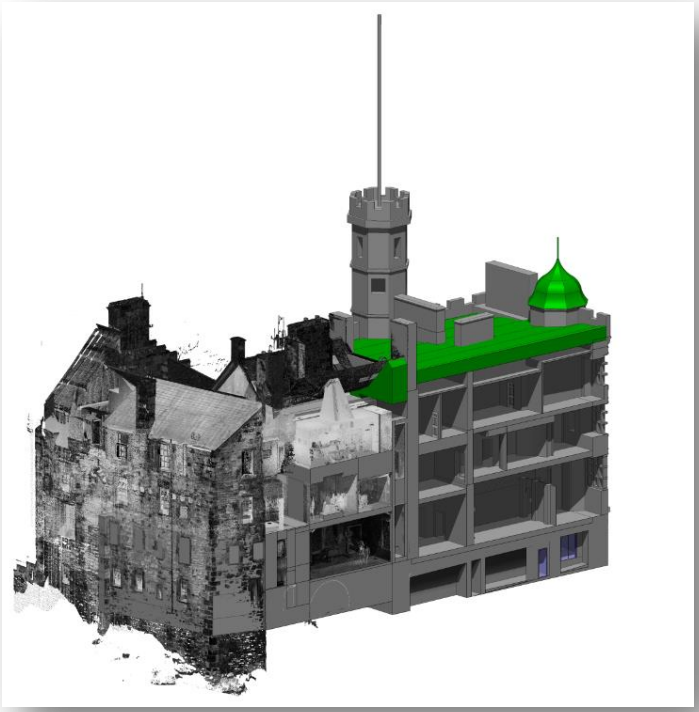


Figure 14b Laser Scanned Image of Edinburgh Castle Main Palace

Within HES, the Conservation Directorate is responsible for the practical management of the PICs and has built up considerable expertise in setting and promoting best practice standards, whilst also undertaking research into traditional skills, materials and sustainability. Latterly HES has developed a global reputation for the pioneering use of cutting-edge digital technologies to support and enhance its activities. Much of this work is undertaken within collaborative frameworks involving external stakeholders and partners. A significant activity in this area is HES's role as a key partner in the Scottish 10 Project consisting of the digital documentation of all of Scotland's World Heritage Sites and a selected group of World Heritage Sites overseas.

5.1.1 Drivers for using BIM

The principal driver for the use of BIM is the requirement for HES, as a public body, to show compliance with the Scottish Government's BIM Strategy by developing a series of readiness measures by the stated target date of April 2017. The implications of this requirement are being investigated through the delivery of a pilot HES BIM Project to trial the adoption of Level 2 BIM standards and processes, where appropriate (please see Project Details section).

The HES BIM Project objectives are to:

1. Inform the development of a full business case setting out HES's BIM strategy, including an assessment of benefits, lifecycle costs and resource requirements, in order to secure senior management approval for the use of BIM as an integral component in HES's organisational processes.
2. Support the delivery of statutory obligations under the Scheme of Delegation between HES and the Scottish Ministers by contributing to the replacement of inefficient, ad hoc working methods with standardised and reliable information management and reporting processes.
3. Develop skills and knowledge of BIM tools and processes across all levels of HES whilst developing expert client competencies to manage the procurement of information from external supply chains in an effective manner.
4. Coordinate with and contribute to other ongoing HES Conservation Directorate information management work streams (please see Project Details section).
5. Engage with partners and stakeholders to contribute to the development of the Scottish BIM guidance and wider industry practices relating to the application of BIM to existing built assets.
6. Improve access to high-quality asset information in order to improve the quality of decision-making and minimise the likelihood of abortive work, additional costs, disputes and potential reputational damage arising from the use of uncoordinated or unreliable information.
7. Future proof HES and enhance its reputation for using cutting-edge digital tools to care for and manage the historic environment.

5.1.2 Project details

The HES BIM Project is a subsidiary work stream within the overall Properties in Care Asset Management System (PICAMS) Project, which is currently in the early stages of development. PICAMS is conceived as a comprehensive digital asset management system which is intended to facilitate access to and improve interoperability between a number of existing information management systems and datasets managed by HES Conservation Directorate. Other related work streams within PICAMS include:

1. SIGMA pilot project, a collaborative initiative with the British Geological Survey to develop a GIS-based on-site digital condition monitoring and reporting tool for PICs.
2. Rae project, a Scottish Government ministerial commitment to digitally document all 345 PICs.

The key activity of the HES BIM project involves the production of a comprehensive asset information model (AIM) of the historic Palace Block at Edinburgh Castle on the basis of laser scan point cloud data, legacy information and on-site surveys. The project, which is

being delivered entirely with HES internal resources, is currently in progress and in line with the Scottish Government's BIM programme.

The Palace Block is a complex and highly significant building within Edinburgh Castle, a Scheduled Ancient Monument and central component of the Old and New Towns of Edinburgh World Heritage Site. The Palace, which has been in royal use since the 14th century, was the residence of Mary Queen of Scots in the 16th century and the birthplace of James VI in 1566. It has housed the Honours of Scotland since the 17th century and is now a major tourist attraction. HES and its predecessor organisations have been responsible for the care, maintenance and operation of the Castle complex, including the Palace, since 1906.

The HES BIM Project aims to establish a comprehensive information resource to support the operational management of the Palace Block, whilst also providing reliable information to underpin future capital projects. The scope of the HES BIM project involves the production of the following outputs:

1. As-existing Asset Information Model (AIM) of the Palace Block in line with the agreed Asset Information Requirements (AIR). The AIM will consist of:
    a. 3D models (architectural, structural and services) reflecting the existing physical conditions of the Palace Block.
    b. Asset attribute information to support the identified uses of the AIM.
2. Common Data Environment (CDE) strategy with appropriate data structures, templates and standards.
3. Information outputs as required to meet the identified uses of the AIM
4. Analytical post-project evaluation to inform a full business case for the adoption of BIM at organisational level.

A future aspiration of the HES BIM Project is to develop an as-completed AIM of the Engine Shed, a capital project sponsored by HES to redevelop and extend a formerly derelict industrial building in Stirling to provide accommodation for Conservation Directorate's Science and Outreach Teams. The project, which has a construction cost of £5m, is currently being delivered with the involvement of an external supply chain. It is due to be handed over to HES in early 2017, and it is planned to commence developing the Engine Shed AIM thereafter, potentially tying in with the Soft Landings element of the capital project. Although the Engine Shed AIM does not form part of the pathfinder, the lessons learnt will be incorporated into the full business case for organisational BIM adoption referred to above.

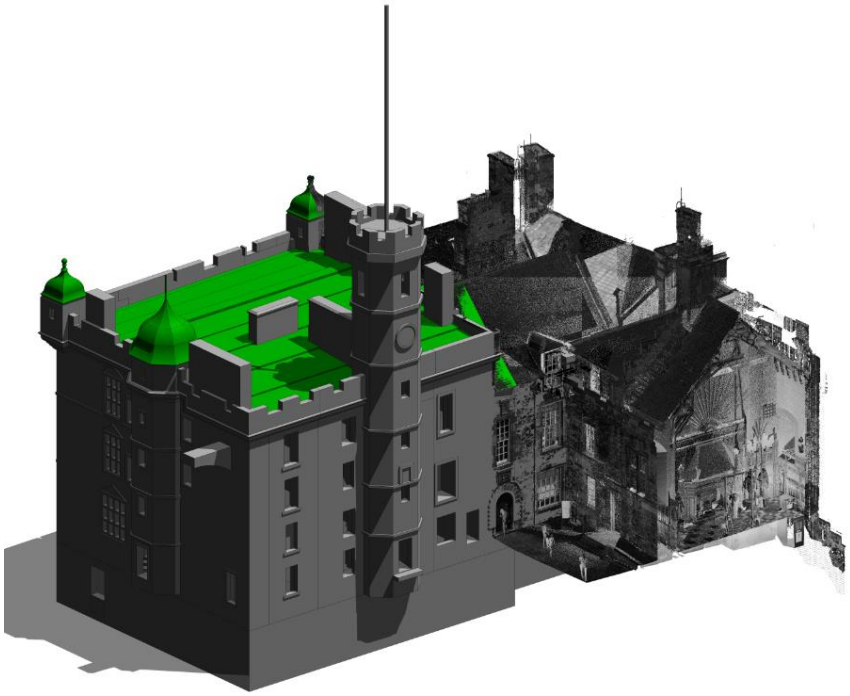


Figure 14c Laser Scanned Image of Edinburgh Castle Main Palace

5.2 BIM Workflow

5.2.1 Workflow description

In planning and implementing the HES BIM Project an effort was made to comply with the general principles of the BIM Level 2 standards and far as practicable, even though it was not always feasible to adhere to the standards in detail. The project workflow involved several stages as described below.

1. Stage 0: Planning

   This stage consisted of a number of foundational activities to establish project structures and to create an appropriate project environment. One of the key activities consisted of engaging with the HES Conservation Directorate senior management team, including the Director of Conservation and Heads of Estates and Projects. The objective of this process was to highlight the requirement for HES to comply with the Scottish BIM Strategy and to discuss ways in which this requirement could be met. The outcome was management approval in early 2016 to develop an outline business case and establish governance and team structures to deliver the HES BIM Project.

   Contact was also initiated with external stakeholders and partners, including Scottish

Futures Trust and the COTAC BIM4C group (now amalgamated with the BIM4Heritage group under the BIM4Communities umbrella). The planning stage also involved identifying key HES BIM staff, undertaking both internal and external training in BIM software and processes, and carrying out an assessment of the project's infrastructure requirements.

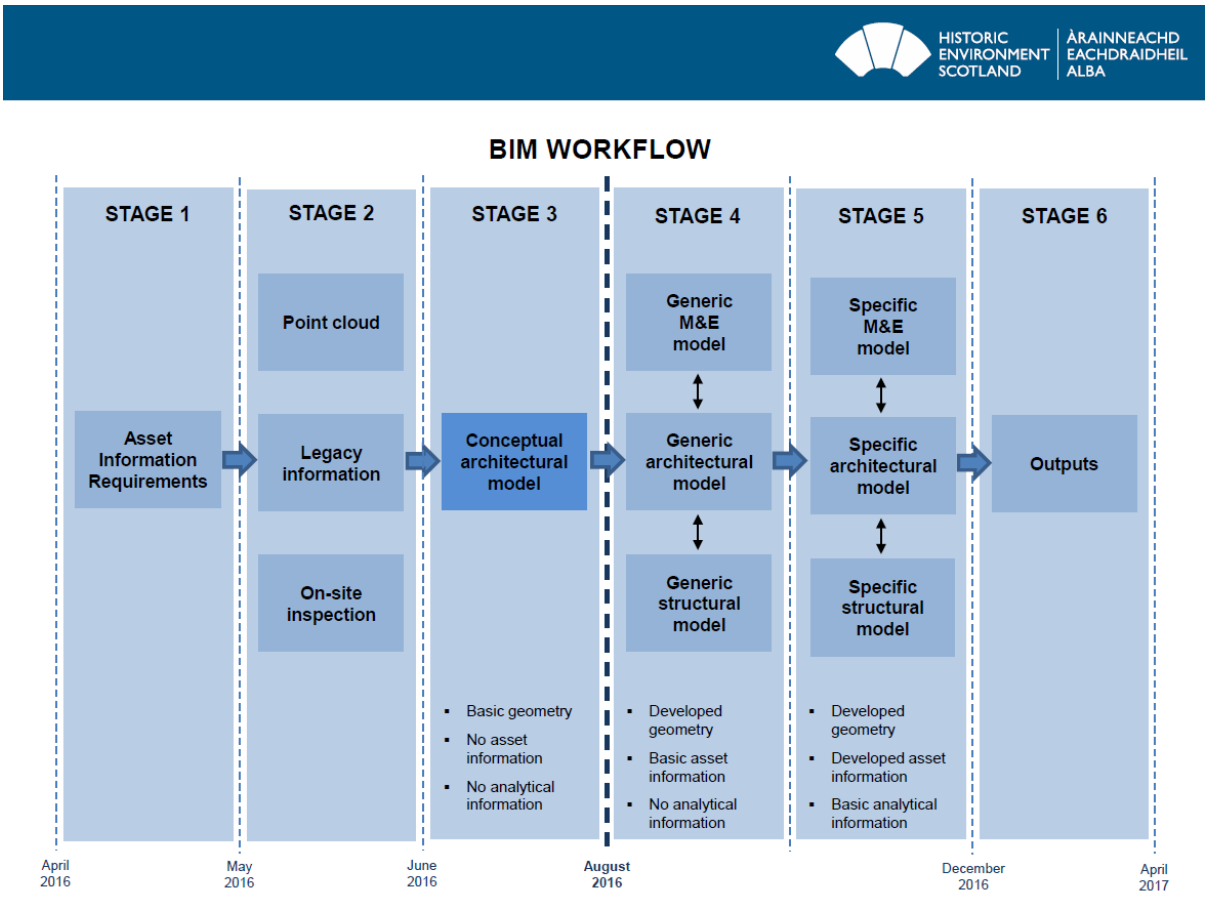


Figure 15 HES BIM Workflow

1. Stage 1: Identifying requirements

   This was a crucial project stage as it consisted of establishing the overall requirements for the Palace AIM and identifying the parameters for its production, use and management. Activities covered in this stage included holding awareness and brainstorming workshops for the project team to capture end-user requirements for the AIM. These workshops involved the participation of professional, technical and site staff from a number of teams within Conservation Directorate. Capturing end-user requirements was not an entirely straightforward process, as the level of BIM competence within the project team was not particularly high. Therefore a key component of these sessions consisted of educating end-users and managing their expectations as to what could be realistically achieved.

As the HES BIM Project was being delivered entirely using internal resources with no external supply chain involvement, there was no formal requirement for Employer's Information Requirements (EIR), Master Information Delivery Plans (MIDP) or pre/post contract BIM Execution Plans (BEP). Therefore the principal documentary output of this stage was a comprehensive Asset Information Requirements (AIR), which, in addition to specifying the information requirements for the Palace AIM, also contained some of the information that would normally be contained within MIDP and BEP documents.

2. Stage 2: Data capture

This stage comprised capturing baseline as-existing information for the Palace AIM. The key activity of this stage was the completion of a full laser scan survey of the Palace Block over a period of 4 weeks in June 2016. In order to minimise occlusion and ensure that adequate coverage was achieved, a total of approximately 500 scans were produced. Furthermore, the point cloud was subsequently decimated and segmented into a series of vertical slices so as to make the data more manageable and legible. The resulting point cloud is the most comprehensive source of spatial information on the Palace Block available to HES. In order to supplement the point cloud data, an assessment of legacy information, including existing drawings, specifications and other relevant documents was carried out. A particular focus of this exercise was to identify information relating to past M&E services installations. A further essential activity consisted of carrying out an on-site inspection of the building fabric and services. This is an ongoing activity to support and inform the development of the AIM.

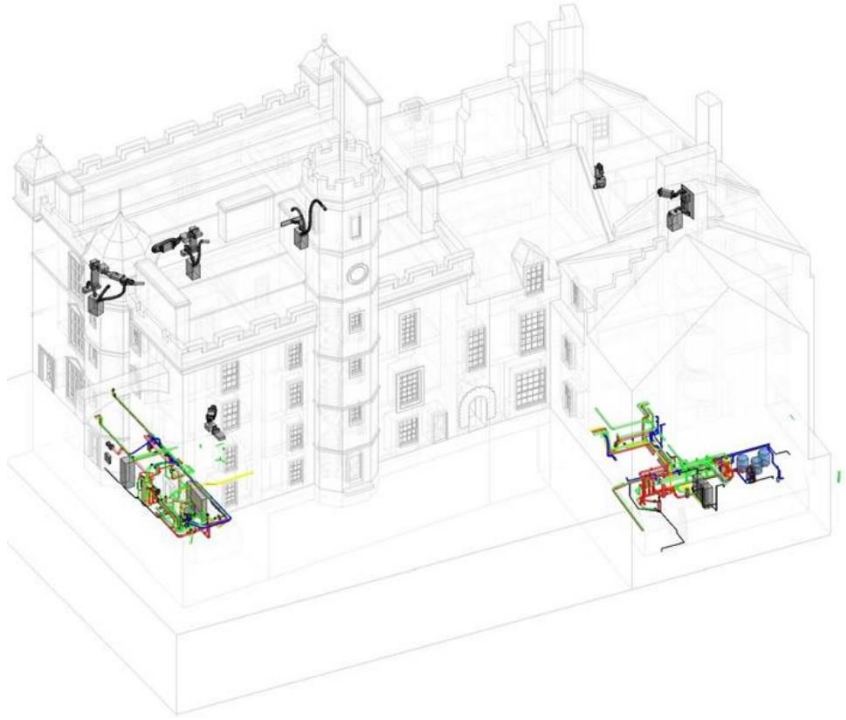


Figure 16 Laser Scanned Image showing some MEP services

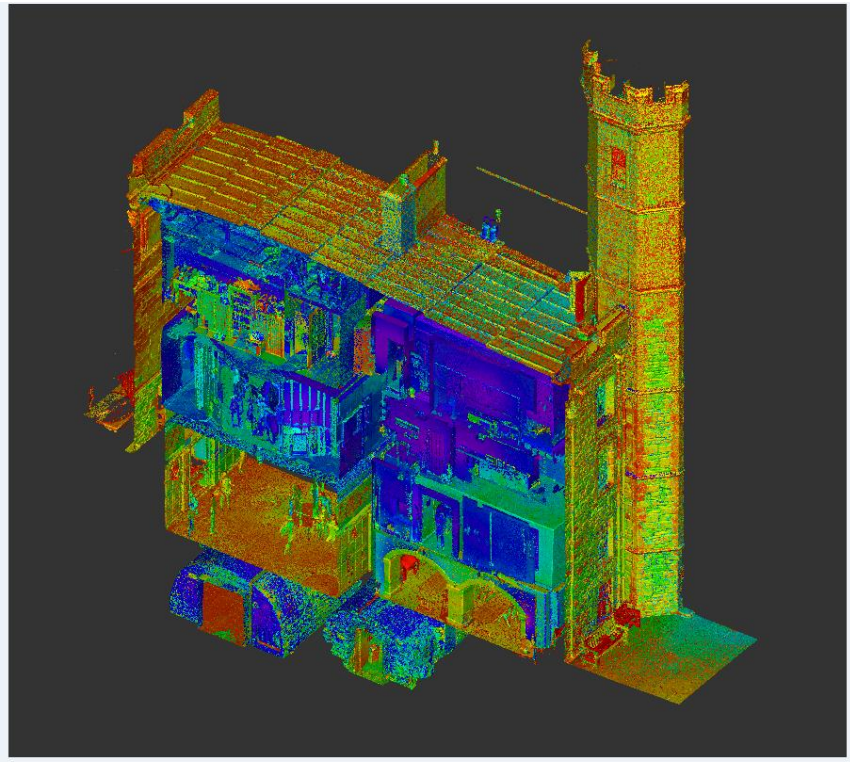


Figure 17 Laser Scanned Image of Edinburgh Castle Main Palace

3. Stage 3: AIM development

Following the collection of baseline geometric data, the AIM is currently being developed in an iterative manner to progressively higher levels of definition. At the time of writing, the first iteration of this process has been completed.

a. Iteration 1: LOD2

The first iteration comprises the development of a starter model of the building fabric based on point cloud and legacy data, containing geometric components only. At this stage, the AIM does not actually contain any significant asset or analytical information beyond the generic classification of components. The LOD2 model is intended to be used as a spatial framework to underpin the iterative development of the AIM to higher levels of definition.

b. Iteration 2: LOD3

This iteration consists of developing the AIM to incorporate a basic level of asset attribute information, using both embedded parametric data and hyperlinks to external legacy data sources. Wherever possible, the generic geometries of the LOD2 model are replaced with families, although the complex spaces and largely non-standardised components of the Palace pose some challenges to adopting this approach. A further component of this stage is the development of a series of interlinked discipline-specific models, comprising architectural, structural and

M&E services information.

c. Iteration 3: LOD4

This is the highest level of definition that is planned for the Palace Block AIM This iteration does not necessarily involve increasing the level of geometric complexity of the AIM, but rather focuses on developing the level of asset attribute and analytical information to meet the requirements specified in the AIR.

The use of model segmentation facilitates simultaneous working by multiple BIM users without the use of formal work sharing tools on a single model. This latter course of action was considered too risky at this early stage of BIM adoption, although its use is being considered for future projects.

4. Stage 4: Information delivery

As HES does not currently use a computer-aided facilities management (CAFM) system, the short-term intention is to deliver asset information in PDF format to end-users. It is acknowledged that this is not an ideal long-term solution, as it is impossible to establish bidirectional associativity between the AIM and its outputs. Consequently, it is planned to develop a comprehensive and robust information delivery process in line with the evolving PICAMS Project.

5. Stage 5: Post-project evaluation

A key component of the HES BIM Project is the production of an analytical post-project evaluation to inform a full business case for organisational engagement with BIM. It is anticipated that work on this will commence in mid-2017.

The information management role is being undertaken internally within the HES Projects team, and involves the following activities:

1. General management of the HES BIM project, including preparing project inception and business case documentation for management approval
2. Organising engagement and information sessions
3. Liaising with external partners and stakeholders
4. Coordinating with end-users to identify and document asset information requirements
5. Identifying applicable standards, protocols and benchmarks
6. Organising training sessions
7. Setting up and managing shared storage areas for project information
8. Formulating processes and working methods on the basis of trials and documented best practice
9. Managing project resources (staff and BIM tools)
10. BIM authoring and audit

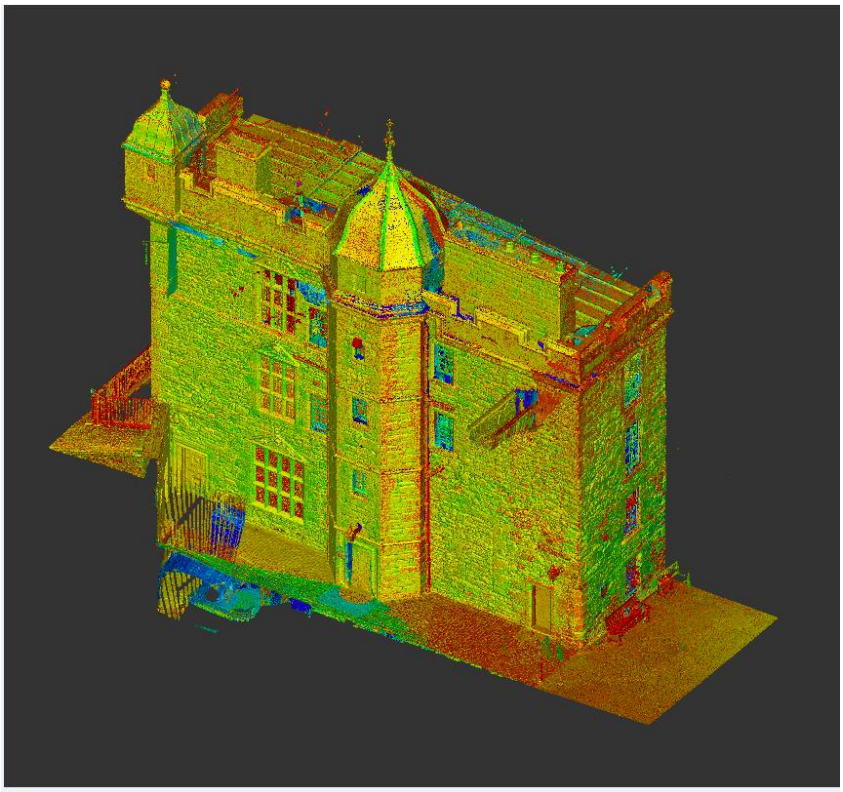


Figure 18 Laser Scanned Image of Edinburgh Castle Main Palace

Once the AIM has been completed, it is planned to transfer the information management role to the HES Conservation & Maintenance Team, which has direct responsibility for the care and maintenance of the actual building. A crucial part of this long-term role will be to take ownership of the AIM and ensure that it is kept updated and properly audited in line with real-world developments.

5.2.2 PAS1192 compliance

The key standard that applies to the HES BIM Project is PAS 1192:3. There is less immediate relevance for PAS1192:2 as the development of the Palace Block AIM is not specifically associated with a capital project. It is anticipated that minor or routine work to the Palace Block would result in the AIM being updated directly by HES staff, whereas major capital projects in the future would trigger substantial changes to the AIM through Project Information Models (PIMs) involving input from external supply chains. In this respect, HES is in a unique position with regard to the management of its PICs in that there are no plans in place for their disposal – the underlying assumption is that the PICs will be managed in perpetuity.

The project-specific AIR is the key document that underpins the Palace Block AIM. It should be noted, however, that the AIR has not been generated from formal Organisational Information Requirements (OIR), as HES does not have this document in place as yet. The reason for this reverse approach is that development of a formal OIR would require buy-in and approval at senior management level, which is unlikely to be forthcoming until the benefits of BIM are clearly demonstrated by means of a full business case.

The AIM is intended to be the primary source of approved and validated information relating to the Palace Block in the future. As such, it will consist of the following elements:

1. Asset Information Requirements
2. 3D models with asset attribute information

Although it is intended to establish interoperability with other HES enterprise systems (including factoring, condition monitoring and energy use monitoring), this remains aspirational until such time as the PICAMS Project at a more advanced stage of development. Moreover, it is anticipated that the AIM will consist of interlinked but discrete discipline-specific models, as there is no immediate requirement for a federated model. It should also be emphasised that the security of information relating to the Palace Block is of paramount importance, and as such, organisational policy dictates that particularly sensitive areas should be omitted from the AIM altogether.

It was not found feasible to implement a common data environment (CDE) that was in strict accordance with BIM Level 2 standards, principally because it would be impossible to secure organisational support for such an approach until such time as an overall HES BIM strategy had been approved at senior management level. In the interim, however, a low-level shared server area for project information is being used, which enables common data access with no changes to existing IT infrastructure and no additional investment. The shared server area is segregated as described in Figure 9 of PAS1192:3, with the information manager taking responsibility for its management.

5.2.3 Responsibility matrix

All the work associated with the HES BIM Project is being delivered entirely using HES's own internal resources. This approach was considered the preferred option for the delivery of the project due to the fact that HES's staffs are intimately familiar with the spatial and cultural complexities of the building. Moreover, undertaking the project using internal resources was deemed to provide a suitable opportunity to develop organisational BIM capacity and to examine the implications of using BIM on a key PIC at first-hand. This approach also provided a platform to develop internal BIM expert client competencies to effectively manage the procurement of BIM services through external supply chains in the future.

A number of teams within HES Conservation Directorate are involved in the project. The various responsibilities are as follows:

1. Information management: Projects Team
2. Laser scanning: Digital Documentation Team
3. Legacy information assessment: Conservation & Maintenance Team
4. BIM authoring: various staff from Projects, Digital Documentation and Conservation & Maintenance Teams, with input from internal structural and M&E engineering staff
5. End-users: Conservation & Maintenance Team

The flexible inter-disciplinary nature of the project team has enabled team members to gain a broad understanding of a variety of BIM roles and processes. This would not necessary have been possible in a more narrowly-defined project team structure.

5.2.4 O&M interface

As mentioned before, the Palace Block AIM will not immediately link to an organisational CAFM system, as HES's CAFM requirements are currently under discussion and will be contained within the evolving PICAMS Project. Therefore it was not deemed necessary to explicitly adopt COBiE as part of the eventual information delivery process. However in order to future proof the Palace Block AIM content, asset attributes are structured broadly in line with the COBiE conventions. Internal discussions are also ongoing with regard to the potential use of Industry Foundation Classes (IFCs) for information delivery and archival.

5.2.5 Technologies Used

Due to HES having a strong background in laser scanning and CAD, it already had up-to-date equipment that was suitable for the HES BIM Project. Consequently there was no requirement to procure new hardware, although it was found necessary to acquire suitable software. As HES is committed at organisational level to using Autodesk software, the most logical and cost-effective solution was to upgrade a number of existing licences to the required standard. In order to ensure interoperability, all software upgrades are carried out simultaneously through a network installation process that is managed by HES's IT department.

The following hardware and software was used on the project:

1. Workstations: HP Z220 with 3.4GHz Intel Xeon processor, 16GB RAM running Windows 7 64-bit.
2. Laser scanners: Leica P40 (time-of-flight) and HDS6100 (phase-based), Faro Focus 3D

(phase-based) used for small internal spaces.

3. Software:
    a. Point cloud processing: Leica Cyclone 9.1 (point cloud registration), Autodesk Recap 2014/16/17 (decimating and exporting point clouds in PTS format).
    b. BIM authoring: Autodesk Revit 2014/16.
    c. BIM coordination: Autodesk Navisworks Simulate 2016.
    d. Other software: AutoCAD 2014/16 (referring to legacy CAD drawings).
    e. Although Edgewise and PointSense scan-to-BIM plugins for Revit were trialled, they were not used in the actual project work. It is, however, planned to introduce some form of scan-to-BIM automation solution in future workflows.

5.3 Some Key Challenges

The HES BIM project has faced, and indeed continues to face, a number of challenges. These relate principally to organisational BIM uptake and engagement, although there are several technical and industry-related issues that are equally relevant.

5.3.1 Organisational challenges

One of the key organisational challenges involves securing senior management buy-in for BIM. Although there is an appreciation of the potential value of BIM within the senior levels of the Conservation Directorate, the general level of BIM awareness at the overall organisational senior management and board level is fairly low. This has a number of knock-on effects, including, crucially, limiting the interest in BIM uptake at other levels of the organisation. A consequence of this is the sporadic level of end-user engagement with the project, leading to difficulty in obtaining suitable asset attribute information with which to populate the AIM. In general terms, BIM is perhaps not seen as a priority by many staff, and indeed may be perceived by some as a rather unnecessary distraction from their day jobs.

A related issue is that the HES BIM Project is being delivered with minimal resources in terms of funding and staffing. This is due in part to its being a period of fundamental organisational change for HES, both with regard to the recent merger of its predecessor organisations and also to its new status as a NDPB. The freeze on hiring new staff that has been in place for some years also places considerable barriers to resourcing projects. Therefore a part of the HES BIM Process stakeholder engagement process comprised negotiating the release of staff in order to resource it.

In spite of the fact that a small number of the project team members had pre-existing BIM knowledge, most are new to the field. With a few exceptions, many of the project team members only receive intermittent exposure to BIM, and as a result, there is a downtime

and re-familiarisation involved in switching between activities. Therefore it can be challenge to coordinate the wide skills disparities in the team, particularly with regard to maintaining agreed processes and quality standards.

Furthermore, although HES has used CAD systems for many years, managing the cultural change associated with BIM adoption is proving to be challenging. In particular, there is a level of resistance to adopting standard information management processes, driven partly be a perception that information relating historic buildings, which are largely non-standard objects, cannot be effectively managed in this way. An extension of this notion is that BIM is only really applicable to the commercial new-build sector, or indeed that BIM is nothing more than a visual communication tool. A further source of confusion, particularly among staff without a significant IT background, concerns the difference between laser scanning and BIM.

5.3.2 Technical challenges

One of the fundamental technical difficulties faced by the HES BIM Project arises from the fact that the Palace Block consists largely of complex geometries and non-standardised components. This poses clear challenges in the use of proprietary BIM tools, often involving the trialling of alternative processes and workarounds to obtain the required results. Moreover, there are complexities associated with the interpretation, management and storage of large datasets and in maintaining robust links and interconnectivities between datasets.

A further challenge relates to the fact that it is not always possible to capture full asset attribute information on the historic components in the Palace Block. This is due to the fact that a historic building, by its very nature, contains a large number of unknowns. Part of the exercise to manage end-users' expectations relates to the fact that the Palace Block AIM will invariably be incomplete in certain areas. This is not an issue in the case of modern, standardised or proprietary components within the building, where fairly complete as-installed information is available.

5.3.3 Industry challenges

Due to the fact that much of the industry BIM focus continues to be on the generation and delivery of asset information arising out of capital projects involving complex supply chains, there is a distinct lack of suitable benchmarks to inform the HES BIM Project. This is in many ways a seminal attempt to test the adoption and use of BIM for the management a highly significant historic asset in the context of a project driven and delivered by a sponsoring organisation.

5.4 Some Key Lessons

The lessons learned from the HES BIM project relate directly to the challenges faced. These include:

1. It is essential to engage with senior managers who already have an interest in BIM with a view to raising the profile of the project within the organisation. Therefore a BIM champion at a sufficiently senior level to advocate the use of BIM and highlight its benefits is a key role. Allied to this, a significant portion of project activity should be focused on stakeholder engagement and education.

2. In order to capture meaningful asset information requirements that would add value to the AIM, it is crucial to closely involve end-users at all stages of the project. As mentioned earlier, this has been a considerable challenge. Part of the difficulty may be due to the distance between the project delivery and end-user teams that is customary before handover when using a sequential waterfall type project methodology. In order to remedy this issue, the adoption of an iterative scrum type methodology is being considered for future projects of this nature.

3. Training in BIM tools and processes is a chief priority, as this facilitates the efficient production of high quality outputs that in turn would serve to highlight the benefits of BIM to sceptics within the organisation. Instead of undertaking generic training in the use of BIM tools, it is advisable to assess specific skills gaps in relation to meeting the project objectives in order to procure targeted training.

4. The importance of effective information management and of adhering to standard processes and working methods cannot be underestimated, particularly when handling complex interlinked datasets. To this end, it is worth taking the time to prepare a comprehensive AIR document detailing the planned uses of the AIM and the applicable parameters. This provides a baseline document that can be referred to by the team members as required throughout the project.

5. With regard to the technical challenges surrounding the use of BIM on a historic building, it is as well to be clear about what the AIM is, and what it is not. The approach being used on HES BIM Project involves ‘mining’ the baseline geometric information (such as the point cloud data) to extract the minimum level of geometric definition that is capable of meeting the agreed information requirements. The AIM is not meant to be a perfect geometric representation of the actual building, but rather, it is a 3D database that contains the necessary information to support its operational management.

6. One of the ways in which the low profile of BIM in the heritage sector can be addressed is through engagement with external partners. This helps to provide a collective voice to organisations which may not otherwise be heard in a sector that is

to a large extent dominated by large commercial firms. A further benefit is that the issues surrounding the use of BIM on historic buildings can be discussed among peers with a view to agreeing standard processes and methodologies.

5.5 Some Key Benefits

The HES BIM project is still in the process of being delivered, and as such, the majority of the anticipated benefits are yet to be realised. To a large extent, the project success criteria involve satisfying the objectives set by the drivers as outlined earlier.

That being said, project progress thus far can be assessed against several key performance indicators. For instance, by raising the profile of BIM within HES, the project has facilitated the development of organisational BIM capacity and highlighted its potential benefits. It has also provided a platform for HES to engage with external stakeholders and to take a lead role in investigating the use of BIM for the management of historic buildings.

A Brief Summary of the four Pathfinder projects

A Brief Summary of the Four *Pathfinder* Projects

This previous section has provided detailed description of the four Pathfinder projects highlighting the key BIM-related aspects for each one of them. The selection of the four projects was driven by the fact that they represented different aspects of BIM adoption and also possessed quite distinct characteristics providing the breadth which was more representative of the industry at large. Although these projects may not have all aspects of L2 BIM in place like the BIM protocol or EIRs, all of them had some contractual requirements in place at least in terms of the client's expectation of outputs from the BIM models. However, despite the lack of EIRs (except in one case where a comprehensive set of AIRs have been developed by the client), three of the projects' supply-chains, entirely of their own accord, developed BEP documents to guide and streamline their BIM activities. To that end, although these *Pathfinders* are not fully Level 2 BIM compliant but they could arguably be claimed to be operating at somewhere between Level 1 and 2. It is also evident that they are well on their way to full level 2 BIM compliance in due course. All the project teams demonstrated a good level of awareness and understanding of the key BIM processes and technologies. The projects also clearly demonstrated tangible as well intangible benefits for their own organisations as well as the client's.

As an overall indication of the aspects of L2 BIM that were implemented in the *Pathfinder* projects, the following diagram, depicting the proportion of projects, suggests that although all key aspects of L2 BIM may not have been implemented fully in all these projects, all of them did implement a large proportion of what is required for a L2 BIM project.

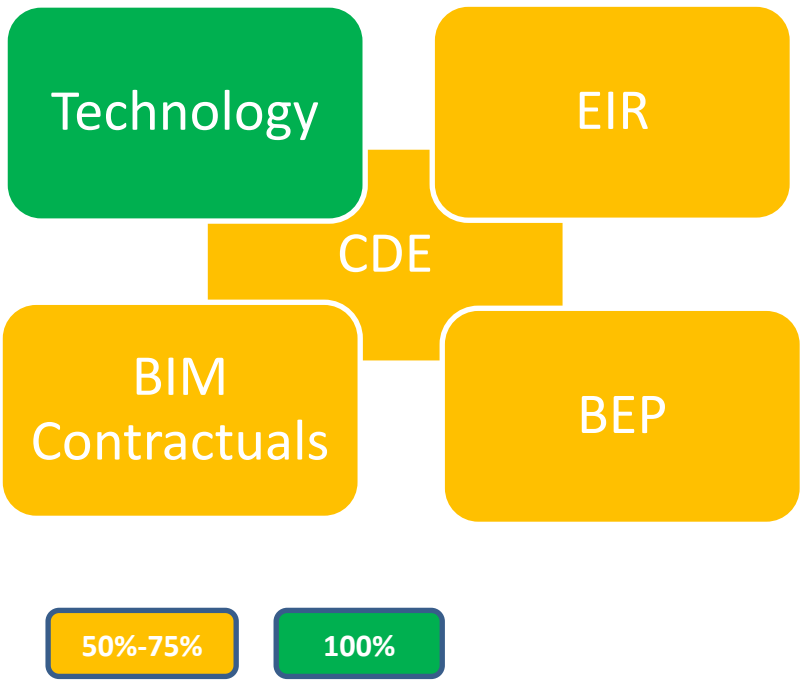


Figure 19 Implementation of Key aspects of L2 BIM in Pathfinder Projects

The diagram also indicates that none of the projects could be taken as exemplars of full implementation of L2 BIM as mandated by the UK Government and discussed in sections 7.2 and 7.3. It should, however, also be pointed out all these four projects started fairly early on in the journey towards full L2 BIM implementation and to that extent deserve credit for even partial implementations of L2 BIM. Interestingly, some versions of EIRs were present in most cases. One may wonder as to how could this be possible – the answer lies in the supply-chain's pro-active efforts to create EIRs 'on behalf of their client' sometimes with loose consultation/guidance from them and sometimes without and thereby base their BEPs on the EIRs thus developed. This actually points to an interesting angle to EIR development until such times that the client organisation has not attained maturity in L2 BIM. Several discussions with various sections of the supply chains of the *Pathfinder* projects appear to suggest that at the early stages in the cycle of L2 BIM maturity within the industry, several clients may be learning the ropes initially through being hand-held by some of the more developed members of their supply chains for things like EIR development and other activities in relation to L2 BIM implementation in their projects. This is clearly a positive sign and should be welcomed by the clients. Of course, there is always the possibility of outsourcing certain parts of the activities to other organisations and there is ample evidence of this happening too.

Analysis of Perceived Obstacles, Benefits and Training Needs

Analysis of Challenges, Obstacles and Benefits

6.1 Introduction and Background

This section presents an analysis of data collected from the project teams of the four *Pathfinders* on various aspects of their BIM activities. The data was collected from the project teams through interviews structured around a set of questionnaires. The data collection was intended initially to assess the BIM capability of the four project teams. However, their perceptions of key issues like challenges and potential benefits of BIM adoption based on their respective *Pathfinder* project as well as other projects they may have been involved in sheds some interesting and useful insights into these aspects which could serve as useful guidance for other interested parties.

The questionnaire comprised of around eighty questions that covered the following nine main topics:

1. General BIM practices
2. Present BIM activities of the organisation
3. Training strategies
4. BIM workflows
5. IT and data management strategies
6. Forward planning
7. Barriers to BIM
8. Training and Education needs
9. Benefits of BIM

The analysis presented here consists predominantly of three areas which were deemed to be interest for the wider industry. These are essentially centred on the last three topics in the list above, i.e. Barriers to BIM, Training and Education needs and Benefits of BIM. It must be pointed out that these results are drawn from the four *Pathfinders* and should be taken in that context alone. It is believed that these findings are useful as demonstration of challenges and benefits of adopting BIM in projects and are not representative, in any way, of the industry at large. As the four *Pathfinders* are quite distinct both in the nature of the projects as well as in bringing out different aspects of BIM, these do shed important light on different aspects of BIM adoption and can act as important pointers for anyone considering the adoption of BIM in their projects. It is believed that the breadth of scope for these *Pathfinders* is also quite useful in that it covers not just the *vertical assets* like buildings (as is generally believed BIM to be relevant for) but also *horizontal infrastructure assets* like bridges and highways as well as old, heritage assets like historic buildings.

6.2 Overall Key Challenges

Before a more detailed analysis of the three aspects mentioned above are presented, a general overall set of challenges and benefits are outlined here drawn out from the four projects and the overall interviews.

Challenge 1: Lack of Coherent Client BIM strategy

Challenge 2: Lack of Appropriate Contractual Protocols

Challenge 3: Scarcity of Properly Trained BIM Resources particularly in BIM Workflows

Challenge 4: Lack of Mature Data Sets in construction industry

One aspect that did not get a very high score as a major obstacle was the initial investments required for BIM adoption. This is an area which is quite hotly debated frequently in the industry and therefore was a bit of a surprise. A deeper analysis suggests that this is probably due to the fact that, certainly in case of the *Pathfinders*, the teams put a much higher weightage to other issues like lack of understanding and coherent BIM strategy of the client's part as well as contractual issues as much bigger obstacles to BIM adoption than investments required.

6.3 Overall Key Benefits

Some of the key benefits of utilising BIM on the four *Pathfinder* projects are summarised on the next page.

Benefit 1: More effective coordination and clash detection saving substantial amounts

Benefit 2: Hugely Reduced Re-design Effort

Benefit 3: Decreased Supplier Costs

Benefit 4: Better Service to Clients

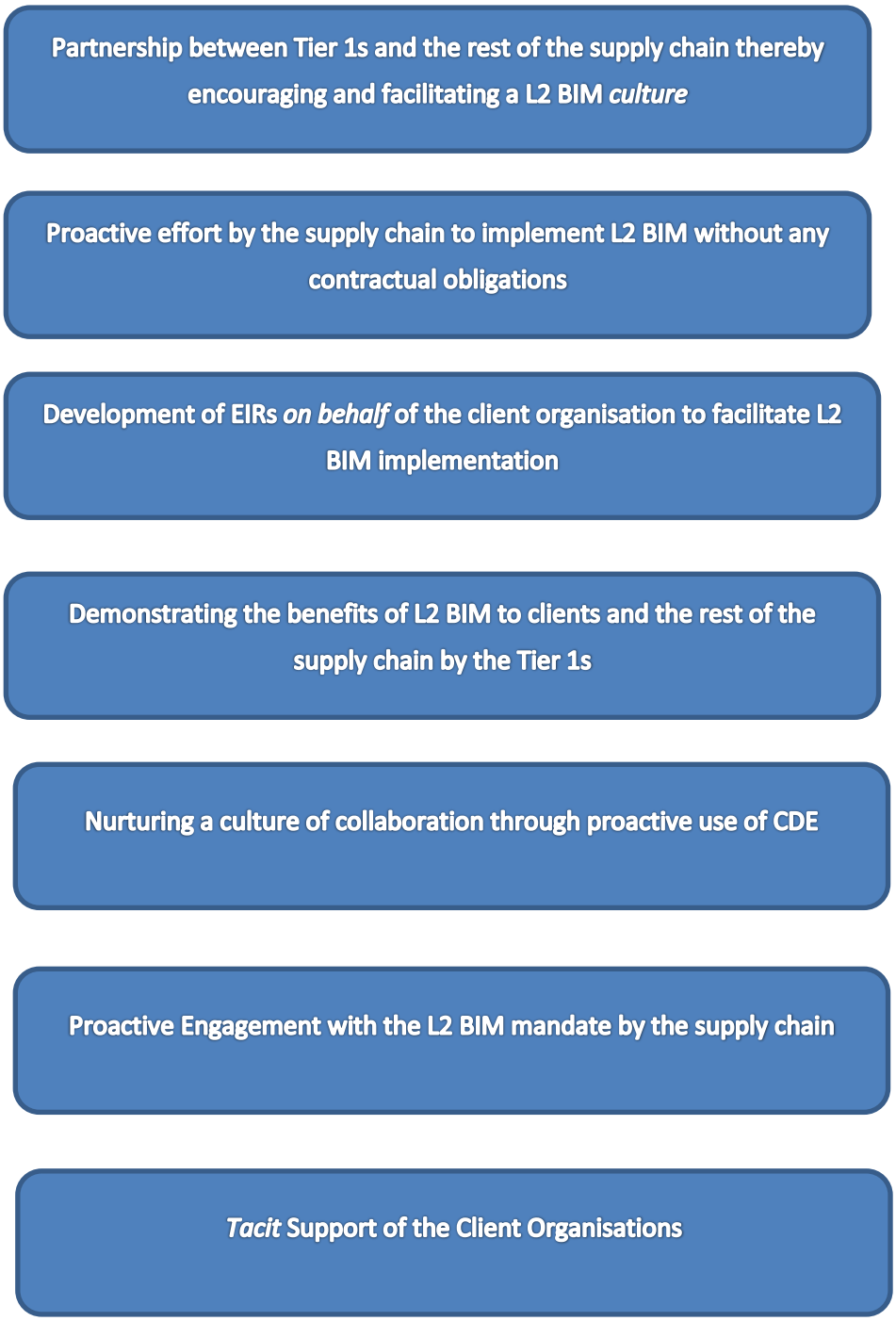
Benefit 5: Cost savings in O & M for Clients

Benefit 6: Better Engagement from Site Personnel

Benefit 7: More effective Options Appraisal potentially saving substantial sums

6.4 Examples of Good Practice

Despite a lack of a full implementation of L2 BIM, all the four *pathfinders* provided some examples of really good practice in relation to BIM implementation. Here are the key ones as given below.



6.5 Detailed Analysis of Survey Results

As part of this project, a detailed survey was carried out across the four *Pathfinder* projects with a view to establishing the BIM capability of the project teams as well as eliciting the main challenges and benefits of BIM adoption in their opinions for wider dissemination.

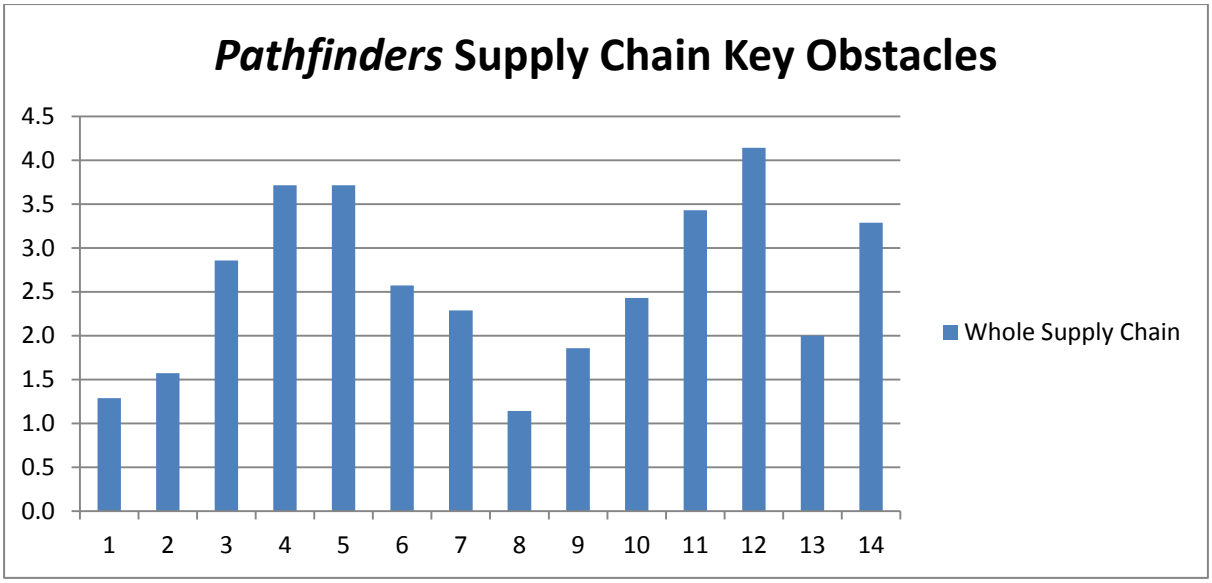
The analysis has been carried out for the four pathfinders as a whole using average scores. These scores are calculated from the responses of the project teams and have been separated for the supply chain organisations from the client organisations. However, out of the four *Pathfinders*, data could only be collected from two of the client teams. Interesting results are obtained by juxtaposing some of the supply-chain data against the client data giving some insights into the often divergent thinking between supply chains and the clients. As an obvious example, lack of understanding of BIM on client's part scores fairly highly among the supply chain organisations whereas lack of qualified resource-related issues like creation or validation of datasets score very highly for the client organisations. Two sections, Present Activities and BIM workflows, were designed to elicit more detailed responses and therefore these were not score-based responses and hence had to be evaluated in terms of percentage responses in each category. Detailed analyses follow.

6.5.1 Key Obstacles to BIM Adoption

The following chart on the next page shows the perceptions of the supply chain of the four pathfinders in relation to the key obstacles to BIM adoption. The teams were asked to score (on a scale of 0 to 9) the potential thirteen obstacles as follows:

1	Investment in BIM software
2	Investment in staff training
3	Scarcity of BIM competent staff
4	Software interoperability issues
5	Lack of definition around clients BIM needs
6	Cost of process change, developing new standards and libraries
7	Project culture is not ready for BIM e.g. adversarial / no collaborative approach
8	Projects are not set up to nurture a collaborative environment
9	Information exchanges and creation of non-graphical data sets are difficult
10	Validation of BIM data set are time consuming
11	BIM processes and data-sets are not mature in the our sector
12	Clients do not understand the BIM process
13	Clients do not require BIM on their projects
14	Type of contracts we use: D&B, traditional design bid build etc.

Averages were then calculated for the scores from all the organisations and these were plotted as shown in the chart.

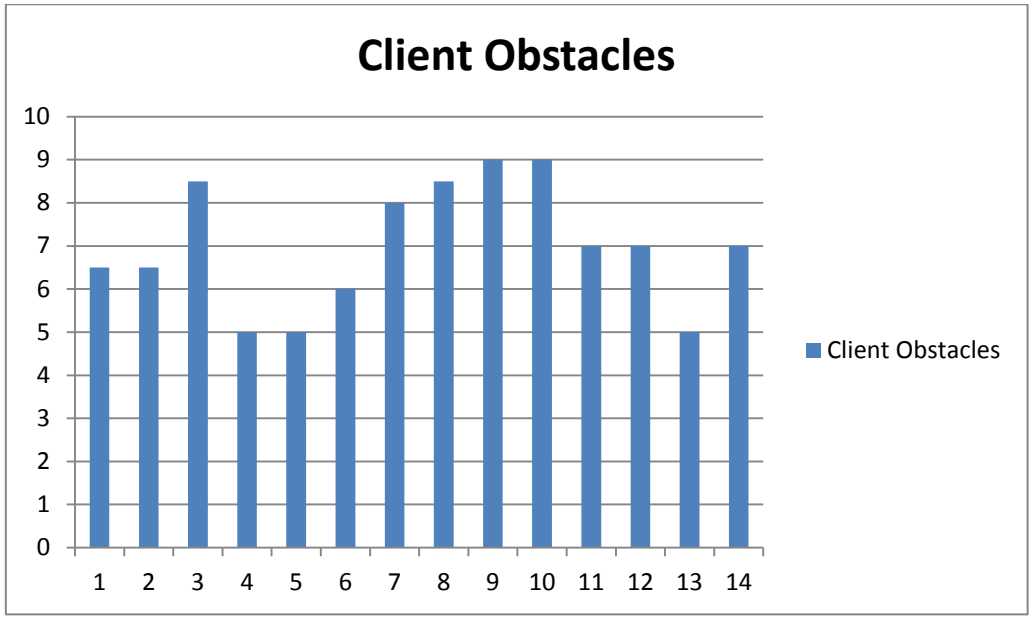


Highest Averages

4	Software interoperability issues
5	Lack of definition around clients BIM needs
12	Clients do not understand the BIM process

14	Type of contracts we use: D&B, traditional design bid build etc.
11	BIM processes and data-sets are not mature in the sector
3	Scarcity of BIM competent staff

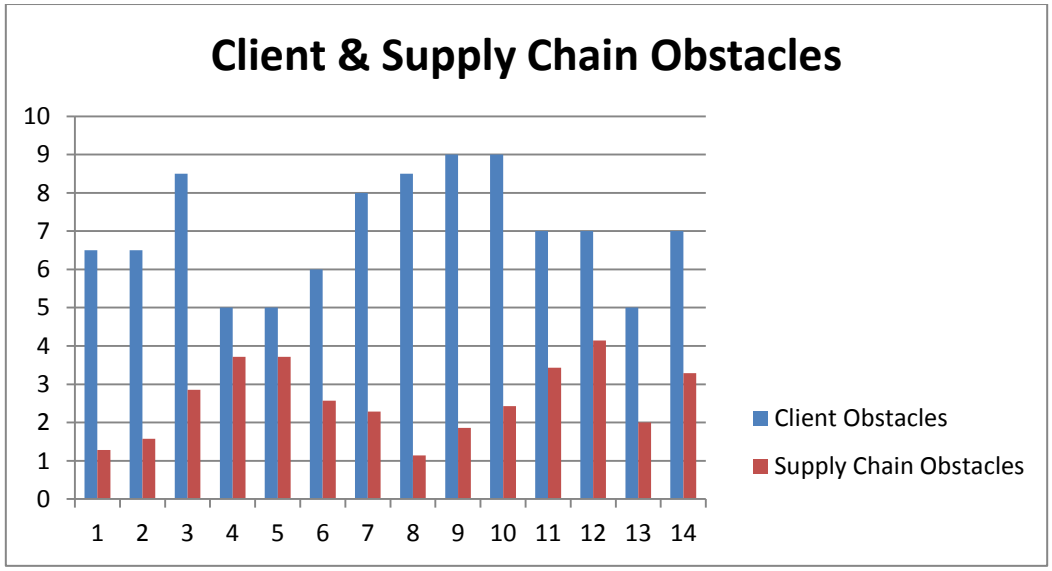
As is clear the supply chain organisations considered the client-related issues as some of the main obstacles to adoption of BIM in the projects. Some other high score issues were the software interoperability issues, contracts and to a lesser extent albeit still fairly high was the scarcity of scarcity of BIM competent resources.



Highest Averages

9	Information exchanges and creation of non-graphical data sets are difficult
10	Validation of BIM data set are time consuming
3	Scarcity of BIM competent staff

This chart shows the averages for the client organisations. The contrast is quite evident although the scarcity of BIM competent staff fares very high and is common to the supply chains as well. Lack of appropriate contract (14) appears as one of the higher scores as well.



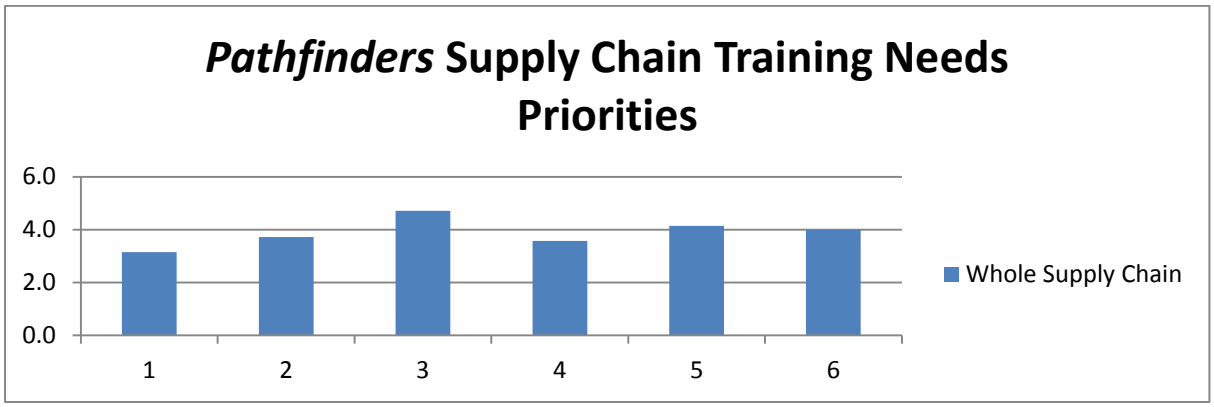
The chart above combines the two sets of responses in one place and juxtaposes the two together. Some of divergent set of thinking between the two groups is evident from this and confirms the view that the supply chain essentially scores the client related issues much higher than others whereas the client's major problem appears to centre around the lack of skills and BIM competent resources.

6.5.2 Training Needs Priorities

The teams were asked to prioritise the training needs for BIM in their judgement. The six different potential training needs given to the team to prioritise were as follows:

1	Education of staff in the use of proprietary BIM tools
2	Education of Level 2 BIM processes eg PAS 1192-2/3
3	Education of staff in the creation or use of non-graphical data e.g. COBie
4	Education of staff in the development and use of Level 2 BIM documents
5	Education of staff to facilitate discussions with clients and supply chain
6	Education of staff in relation to Information Management

The respondents were asked to rate these on a scale of 0 to 9 and the averages were calculated for the whole supply chain as well as the client teams separately. The following charts show the average response values.



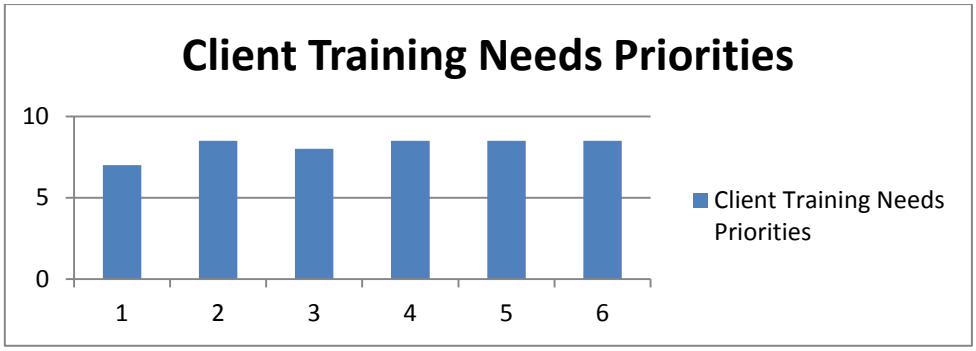
The training needs that were perceived to be of highest priority were as follows:

	Highest Averages
3	Education of staff in the creation or use of non-graphical data e.g. COBie
6	Education of staff in relation to Information Management
5	Education of staff to facilitate discussions with clients and supply chain

It is clear from these scores that there is a perceived lack of skills in information management skills. As mentioned before, Level 2 BIM is an overall information management for the entire lifecycle of an

asset and not just the use of BIM software in design and modelling and construction, this is an important finding in that it indicates strongly even among the larger, tier 1 organisations, the lack of such skills. Interestingly, the software and technology skills did not appear highly in the responses indicating relatively sufficient levels of skills already existing at least in these organisations. As pointed out earlier, this survey should not be taken to be representative of the whole industry. However, it does give a fair indication of what might be the prevailing situation as the supply chain of the *Pathfinder* projects does include some very large to relatively small organisations within the industry.

The following graph relates to the client team responses for training needs priorities.



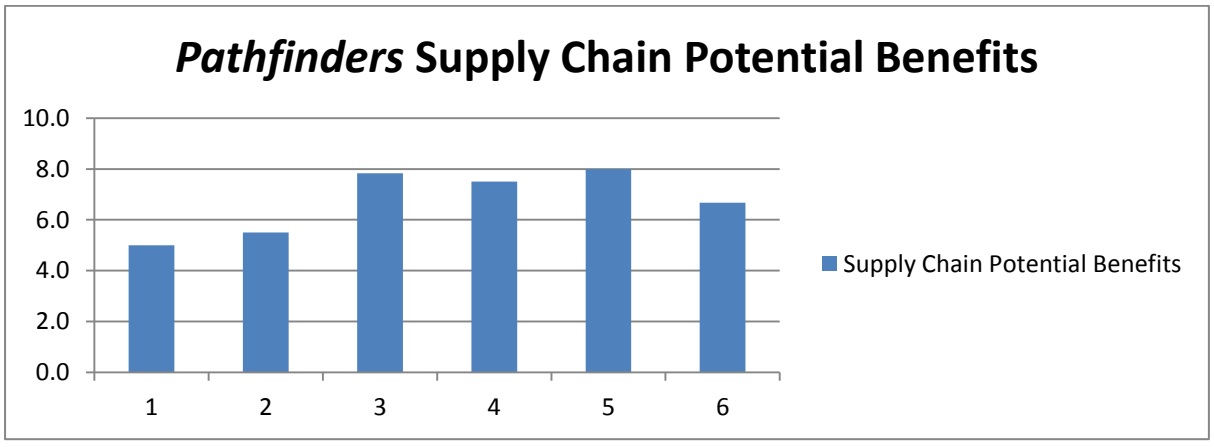
It is interesting to note that the clients' perceptions are quite markedly different from those of the supply chain at least for these *Pathfinder* projects. The clients perceived a very high need for training across pretty much all the six categories indicating they might well be behind the curve compared to the supply chain organisations at this point. As is evident from the chart above, it is difficult to pick a single category as the relatively higher priority. So, it is fair to say that at this point in the cycle, the training and education needs of the client organisations appear to be much higher. It should be pointed out that all the clients in these *Pathfinders* are public sector organisations and it may well be a different scenario among the private sector organisations. It should also be pointed out that at least one of the *Pathfinder* clients (NHS Scotland) has moved on considerably since their *pathfinder* project was awarded and may be well ahead of many other comparable organisations in the public sector at this point.

6.5.3 Some key Benefits of BIM Adoption

The teams were asked to prioritise the training needs for BIM in their judgement. The six different potential benefits given to the team to rank were as follows:

1	Increase our profit margins
2	Reduce our workload (time to complete our own work)
3	Allow us to deliver a better service to our clients
4	Allow our clients to manage their assets more effectively
5	Receive better co-ordinated designs from the design teams
6	Reduce our construction times

The respondents were again asked to rate these on a scale of 0 to 9 and the averages were calculated for the whole supply chain as well as the client teams separately. The following charts show the average response values.

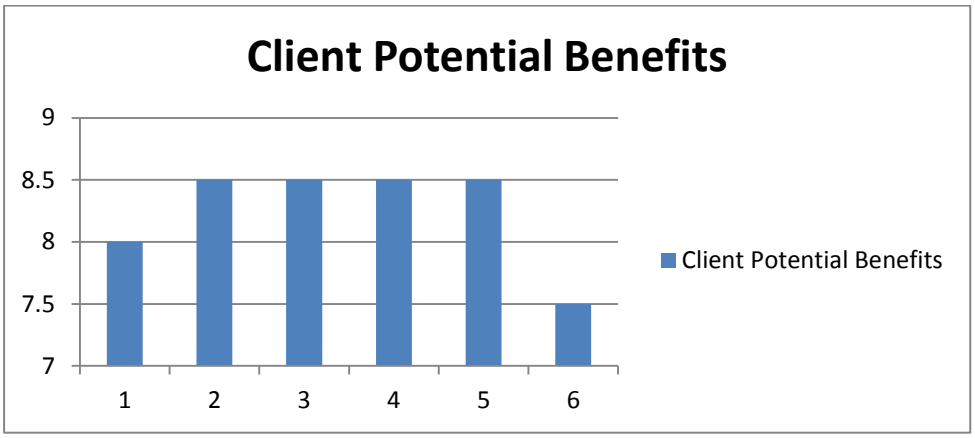


Highest Averages

5	Receive better co-ordinated designs from the design teams
3	Allow us to deliver a better service to our clients
4	Allow our clients to manage their assets more effectively

It is clear from the chart above that the most important potential benefits in the supply chain organisations' judgements were essentially centred on better service to their clients. Although

improving their profit margins was not rated to be the most important benefit by the supply chain, it did command a moderately high score too. Arguably, better service to clients should translate into increased flow of work and consequently higher revenues for the supply chain. An intangible benefit which should not be overlooked is the improved client-service provider relationship as a result of the modified asset procurement processes.



Highest Averages

2	Reduce our workload (time to complete our own work)
3	Allow us to deliver a better service to our clients
4	Allow our clients to manage their assets more effectively
5	Receive better co-ordinated designs from the design teams

It is clear from the chart that the clients rated the issues related to the management of their assets in a more efficient manner (reduced workload) higher than other issues like reduction in construction times. It could be argued that the client team is more focussed on anything that could make their processes more efficient in terms of high-level overall design, construction and operational management than the detailed low level aspects of design construction. They appear to concur with the view that BIM could possibly help them achieve that more effectively than the traditional approach.

6.5.4 Present BIM Activities

This section of the survey assesses the respondents understanding and knowledge of the policies and management processes put in place to facilitate the implementation of BIM

The section comprises of seven questions:

1. Does your organisation have a BIM or Information Management policy signed by a board level director?
2. Does your organisation have a published BIM strategy, BIM goals or a implementation road-map?
3. Do you have someone within your organisation who is responsible for delivering your organisations BIM strategy?
4. Does your organisation currently make provision for or intend to invest in BIM?
5. Does your organisation measure levels of BIM adoption and or benefits realised?
6. Does your organisation have a BIM steering group or working group?
7. Is BIM recognised within your organisational structure?

The choice of responses to these questions is Yes, no, Don't know for questions 1 to 3, 5 and 6. The choices for 4 and 7 are more descriptive and the respondents were given the freedom to choose more than one choice.

The choices for question four were:

A) Yes, we currently make an organisational budget provision for BIM

B) We build BIM costs into our project tender allowances

C) No but we intend to invest over the next 1-2 years

D) No but we intend to invest over the next 3-5 years

E) Don't know

The choices for question seven were:

A) Yes we have explicit BIM roles within our organisation to help mobilise and implement

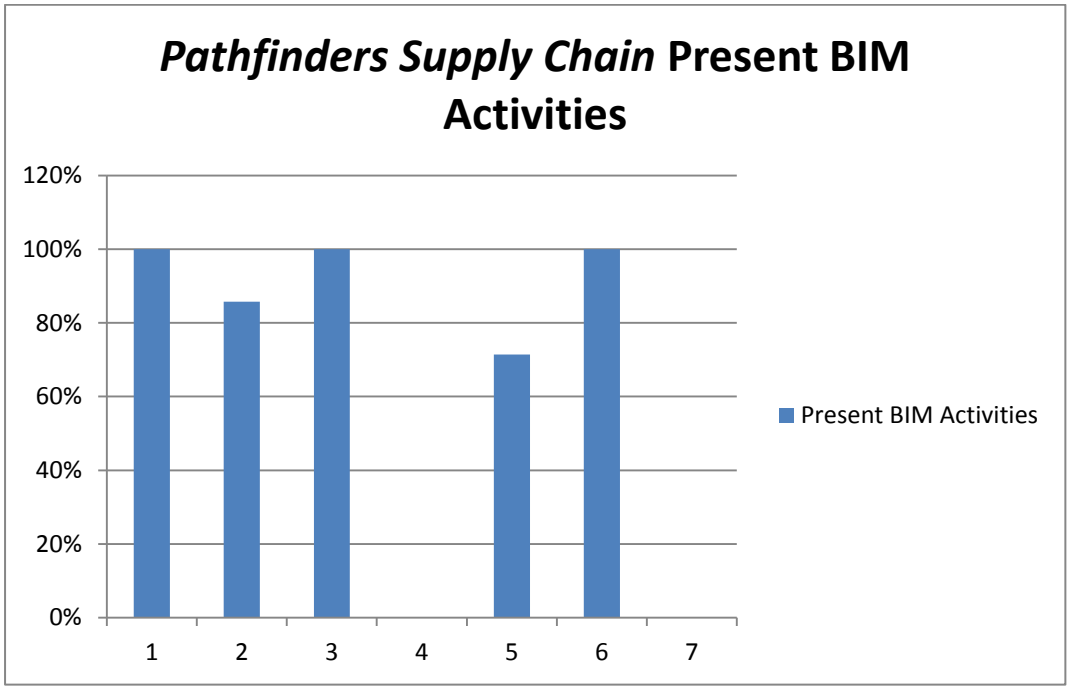
B) Yes we have defined BIM champions within each of our offices or business units

C) We have an individual who is our organisational BIM champion

D) No we have not yet inducted BIM into our organisational hierarchy

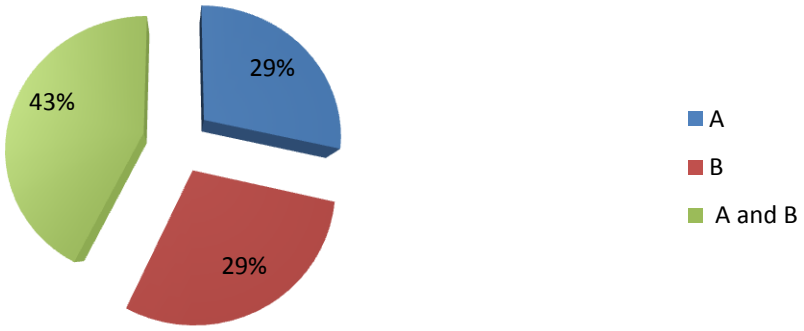
E) Don't know

The answers to this section of the survey are generally positive indicating that there is a good level of understanding and appreciation of the management processes being put in place.



The chart above shows the 'yes' responses to all questions in this category except 4 and 7 across the supply chain of the *Pathfinder* projects.

Question 4



The pie chart above shows the responses to question 4. Organisations responded either with option A or B but in majority of cases (43%) they seemed to suggest that they use a combination of currently making an organisational budget provision for BIM or building BIM costs into their project tender allowances. This suggests an interesting mix of approaches at this point.

Question 7

The pie chart above shows the responses to question 7. Organisations responded either with option A or B or a combination of A and B or in some cases a combination of A, B and C. This suggests an interesting mix of approaches at this point. However, more importantly they all point to the fact that there is generally a recognition of BIM-related roles within the *Pathfinder* supply chain organisations.

6.5.5 BIM workflows

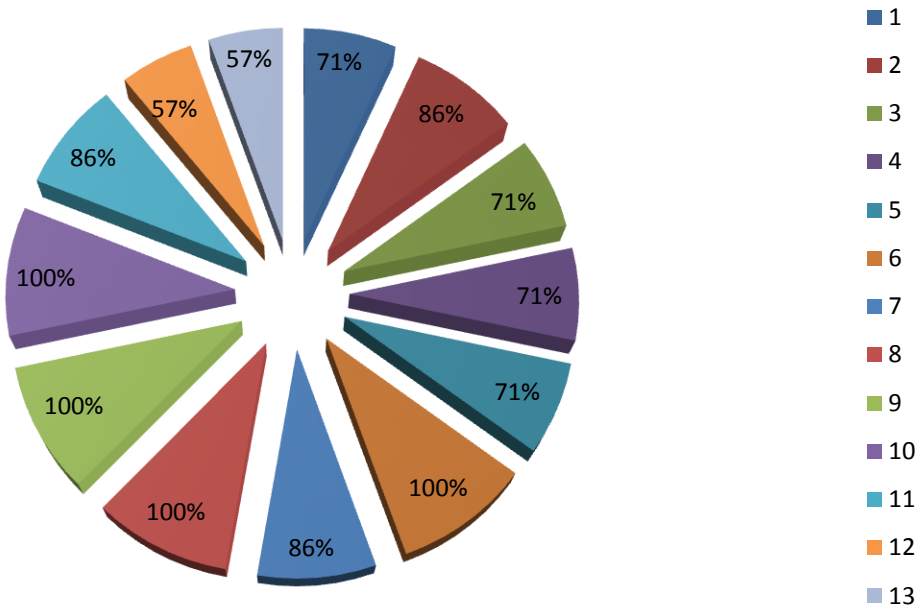
This section of the survey assesses the respondents understanding and knowledge of the present BIM technologies and processes adopted within the workflows of the organisation.

The section comprises of thirteen questions as follows:

1. Does your organisation work to a BIM standard as part of its Quality Assurance process?
2. Does your organisation use processes for managing a common data environment e.g. BS1192:2007 and PAS1192:2:2103?
3. Does your organisation use Employer's Information Requirements?
4. Does your organisation use BIM protocol documents**?**
5. Does your organisation use BIM scope of services documents**?**
6. Does your organisation use BIM Project execution plans?
7. Does your organisation treat BIM as an iterative process with a defined "level of information" at each of the project delivery stages?
8. Does your organisation develop and implement BIM Execution Plans for relevant projects?
9. Does your organisation have workflows to ensure reliable information exchanges during the project life-cycle?
10. Does your organisation have workflows for testing and validating your digital data?
11. Does your organisation have workflows for model-federation?
12. Does your organisation monitor and/or audit the supply chains ability to implement BIM within the project?
13. Has your organisation developed workflows for automated creation of non-graphical data from a 3D model?

As will be shown in the charts later, the responses to these questions were generally very positive for the supply chain. However, the client organisations did appear to lag quite considerably behind.

Pathfinders Supply Chain BIM Workflows



The chart above is the overall averages for the thirteen questions across the supply chain of the *Pathfinder* projects. This is a generally encouraging picture suggesting that the supply chain organisations already have a fair amount of understanding and control over most of the key BIM workflows. It should be pointed out that there were a few 'Don't know' responses from one particular organisation suggesting the overall picture is not quite as rosy as may be implied by the other responses of these organisations.

However, it should be pointed out that the responses from client organisations painted a very contrasting and somewhat interesting picture on this aspect of our survey. The responses were consistently in the negative for all but one question (number 4) on the use of protocol documents! The upshot of this is that the client organisations (particularly in the public sector) appear to be somewhat behind on the learning curve compared to the predominantly private sector supply chain organisations. This seems to correlate to the responses to the other sections detailed earlier which points to some of the reasons behind this misalignment between the private and public sector organisations.

6.6 Discussion

Evidently, there are a lot of positives coming out of these *Pathfinders* through this survey and a close examination of the projects discussed earlier in section two.

It is interesting to compare and contrast the results of these two sections taken together. Although there is a relatively high percentages of perceived usage of BIM in the organisations' present activities, there appears to be somewhat a disconnect between those responses and their responses to the use of BIM workflows. It is clear from the BIM workflows section that a number of the organisations did not use even the basic BIM workflows prescribed in PAS1192: Part 2. This makes one wonder as to what might be behind this disconnect – one obvious point that comes to mind is perhaps some organisations simply imply the use of BIM technologies as the mainstay of BIM implementation. This is not entirely surprising as the general perception about BIM still revolves predominantly around the use BIM technologies in modelling in design and to some extent in construction stages.

As mentioned before, although none of the four *Pathfinder* projects could claim to be fully Level 2 BIM compliant, each one of them has clearly embarked upon that journey showing a sense of commitment and engagement with the process of ultimately achieving full compliance in due course. One of the reasons these projects may not be fully Level 2 BIM compliant could be that there was no contractual obligation for them to do so. This makes it all the more impressive and creditable on their part to take that leap entirely on their own. Closer scrutiny and discussions with the project teams made it abundantly clear that none of them was regretting embarking on this journey as they could see clear evidence of benefits and value creation from BIM adoption in more ways than one. Every project team confirmed their commitment to taking this further and implementing all the key elements of Level 2 BIM in their future projects.

Finally, there are several intangible and long-term benefits from BIM adoption for the concerned organisations as well as the industry as a whole that may be possible to assess over the course of the next few years. In the meantime, what these *Pathfinders* do show is that apart from some tangible, solid value creation, there is also at least some rudimentary evidence of smaller supply chain members being forced not to underbid by exploiting the lack of information and consequently recovering their initial losses to make money downstream in the projects. The experience with these *pathfinders* most certainly suggests that these kinds of impacts of *high-quality information based project delivery,* which is what Level 2 BIM purports to achieve, will become increasingly more evident down the line in due course.

Upskilling and BIM Strategy Development Recommendations

Proposed BIM Upskilling Routes

7.1 Introduction

This section proposes a number of various routes to achieving Level 2 BIM maturity based on the findings of the surveys of the *Pathfinders* detailed in earlier sections. It should be reiterated that the surveys appear to suggest that the public sector client organisations may be lagging behind somewhat their supply chains involved in these *Pathfinder* projects. Besides, arguably the client organisations are the ones who need to be driving the implementation of Level 2 BIM in their projects. Therefore, this section could well be taken as a primer for the client organisations to kick start their BIM strategy. This section argues that the full blown implementation of Level 2 BIM could only be achieved in a stepped, gradual manner and a number of step by step, phased workflows will be proposed.

The proposals made in this section are loosely based around the Learning Outcomes Framework (LOF) proposed by the BIM Task Group. The following diagram presents the LOF in a nutshell.

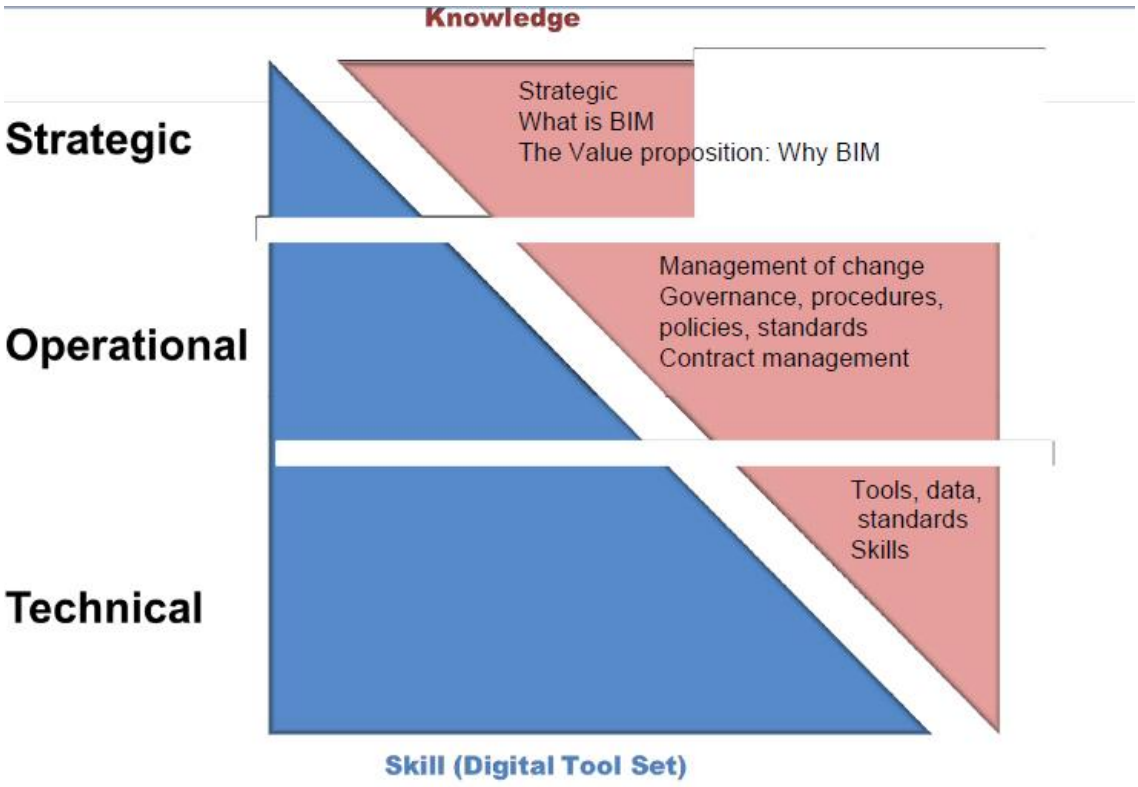


Figure 20 BIM Upskilling Activity Categories (taken from BIM Task Group Website)

Contrary to general belief, the LOF suggests training along three dimensions and not just focussed on technical aspects of Level 2 BIM implementation. As the diagram above shows, training and education (and consequently upskilling) for Level 2 BIM should be designed along three dimensions of Strategic, Operational or Management and Technical issues. The diagram also distinguishes between skills-based training versus knowledge-based training and education. The Strategic issues largely deal with knowledge-based issues like business case for BIM and higher level organisational issues and their implications. At the operational level, the issues to be addressed are management

of change governance, BIM processes and standards for information exchange as well as contractual and legal issues. Finally, the Technical issues relate to the software and hardware based aspects of BIM implementation.

7.2 A Framework for BIM-based Asset Procurement Strategy Development

This section lays down some guidance in terms of developing a Level 2 BIM strategy for asset procurement. It is proposed that essentially there are five elements for developing such a strategy. These are:

1. BIM-based Process Map Development
2. Information requirements Specifications
3. BIM Project Executions Plan Development
4. BIM Contractual and protocols including Appointments of BIM-related roles and as specified in a Scope of Services document
5. BIM Infrastructure Plan including model/information sharing mechanism utilising standard classification systems and schemas.

First and foremost, a process map needs to be developed which aligns with a typical information delivery lifecycle (PAS1192: Part2: 2013). As mentioned earlier in section on research methodology, this is accomplished through a series of iterative focussed workshops and feedback loops which takes the existing asset procurement process and maps its keys stages with the corresponding stages of a BIM-based version of the process. Once this is in place, associated guidance documents and templates need to be developed aligned with the BIM-based process map for specifying the information requirements and ensuring and assuring their delivery by the project team.

7.2.1 Process Mapping

To summarise the whole process of implementing a BIM-enabled asset life cycle, this section presents a high-level workflow that brings together all the ideas discussed earlier in this paper. Figure 3 shows a high-level view of the workflow that should be typically followed for any BIM-enabled project. The process starts with the definition of a need for either a new asset or refurbishment or enhancement of an existing asset. In the case of a new asset, the process starts off with a clean sheet with a set of requirements that the asset owner (the employer) might have. This is what would be compiled together in an IR (information requirements) document. Based on the IRs, a project procurement process may be initiated, which will be driven by the IR document in terms of which procurement route to adopt as well as informing the tender documents. The tenders could well be single or multistage ones, but such details are omitted here because the focus is to outline the overall workflow. The tenders received will be based on the IRs and any protocols that the project may follow. At this stage, the information may well be at a higher level but may include BEP (BIM Execution Plan) documents including the tenderers' proposed approach as

well as their capability and competence in relation to BIM. This will then be followed by the awards of the contract after various negotiations and clarifications. At this stage, a more comprehensive BEP document will be prepared, agreed and signed off by all stakeholders of the project. In addition to the BEP document, an IDP (Information Delivery Plan) will be prepared. At this stage, the PIM (Project Information Model) starts taking shape, consisting of essentially graphical (building information models), non-graphical and other documents that will include populated templates from the BEP and other documents as stipulated in the IR document. At the end of the construction phase, the completed PIM essentially becomes the AIM (Asset Information Model), which is handed over to the asset management and facilities management group. In the case of a refurbishment or enhancement project for an existing asset, the AIM already in place for the asset in question becomes the starting point when specifying the need for the project, and which is then followed by the same steps mentioned above for a new build project.

At the start of the process for developing a BIM Implementation strategy, this BIM workflow, must be mapped onto the existing project/asset procurement process in the organisation. This is typically done through a number of feedback workshops where the practitioners of the existing processes will brainstorm each of its stage and work out the appropriate BIM workflow stages that they naturally map onto.

7.2.2 Information Requirements Specification

As mentioned earlier, once the process map has been developed, the first document that needs to be developed is the information requirements templates that will mainly answer the following question,

1. What information does the client organisation need to operate and maintain the asset after handover?
2. What standard formats and schemas must the supplied information comply with?
3. What levels of detail should the supplied information adhere to?

This question implies that the asset and facilities management teams need to contribute in a significant way to this stage when the information requirements are being specified. These requirements will be driven, to a large extent, by the input requirements for the CAFM (Computer-aided Facilities Management) and EAMS (Electronic Asset Management System) currently in use by the client (asset owner/employer) organisation. To facilitate and streamline the process of specifying the requirements, a standard template can be developed which can be adapted for specific projects based on the specific requirements of the asset in question. In the UK, this template (or document once it is fully developed for a particular project) is called the EIR (Employer's Information Requirements). It must be stressed that the importance of EIR document cannot be over-emphasised as everything else hangs off this document. Finally, a word of caution on EIRs***, it is generally not wise to use a standard template from other sources to develop EIRs as each organisation and project have quite unique set of information requirements.***

7.2.3 BIM Protocols/Contracts

The primary objective of the protocol is to enable the production of the models at defined stages of a project. The protocol should incorporate provisions which support the production of deliverables for 'data drops' at defined project stages. The protocol also should provide 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. Finally, it should deal with the intellectual property rights (IPR) in relation to the production, ownership and usage of the models by different stakeholders in a project. Different countries have their own approach to dealing with these issues. In the UK, as far as level 2 BIM is concerned, the default position is that ownership of the models lies with whoever produces it and the other stakeholders essentially get a license to use the models in relation to any project-related activities. This can, however, be amended to suit the requirements of a project if required.

7.2.4 BIM Project Execution Plans

Similar to a typical Project execution Plan (PEP) in a traditional project delivery process, every BIM-enabled project should have a BEP document agreed and signed off by all stakeholders, right at the start of the project. Contractually, this document becomes an addendum to the contract documents in the UK. Therefore, every stakeholder of a project is contractually bound to comply with this document. There are several reasons why a document such as a BEP is essential to ensure that all stakeholders in a project deliver what is expected of them. Introducing BIM in a project usually means bringing in new processes, particularly in terms of information management. In order to successfully manage information in a project, everyone involved in the project needs to sign up to processes and standards in advance of execution of the project. This can only be achieved by careful advanced planning and documenting all processes mapped on to the responsible parties alongside the different stages of the project. Therefore, whenever there is a lack of clarity, dispute or confusion about any aspect of delivery of information throughout the life cycle of the project, the BEP is the document that the project team should rely on for resolution. It is, therefore, not hard to imagine the crucial and important role that this document can play in successful project delivery. Although the BIM PEP is supposed to be provided by the supply chain in response to the EIRs addressing the question, "How they will deliver the information specified in the EIRs?", it is recommended that in the interest of consistency of formats, the client/employer organisation should have its own BEP template which the supply chain should fill in as required.

As pointed out in the schematic on page 75, although the BEP is prepared by the supply-chain, ***it is probably a good idea for a client organisation to have a standard BEP template which they should get their supply chain to use in response to their EIRs. This is likely to result in less onerous negotiation process and will provide a consistent set of responses from members of the supply chain which will be tailored to their own requirements.***

7.2.5 BIM Infrastructure Plan

As mentioned in the earlier sections, once all the initial set up of the project is finished by having the IRs, contracts relating to BIM protocols for ownerships of models and BIM PEP in place, a mobilisation plan needs to be developed which ensures that the technology and other infrastructure to implement the project is in place. The one single most important aspect of this plan is to ensure that the required hardware and software infrastructure for a structured and managed exchange of information between all stakeholders is available and operational. In this context, it is relevant to point out the role of a Common Data Environment, CDE (shown below taken from PAS1192: Part 2) which acts as a central repository for all information exchanged and facilitates a managed process for achieving a seamless and yet disciplined exchange of information. A CDE should not be confused with a Project Extranet (PE) as it is more than just a passive repository. Perhaps one way of describing a CDE is that it is a managed PE and includes a number of gateways to assess the veracity and quality of data to be shared with others and eventually passed on to be archived. Another important part of the technical infrastructure should include the use of standards for capturing, storing and exchanging information through the use standard schemas like, but not necessarily, COBie (Construction Operations and Building information exchange) which is a part of IFC (Industry Foundation Classes) schemas and a standard classification system like Uniclass.

Figure 15 – Extending the common data environment (CDE)

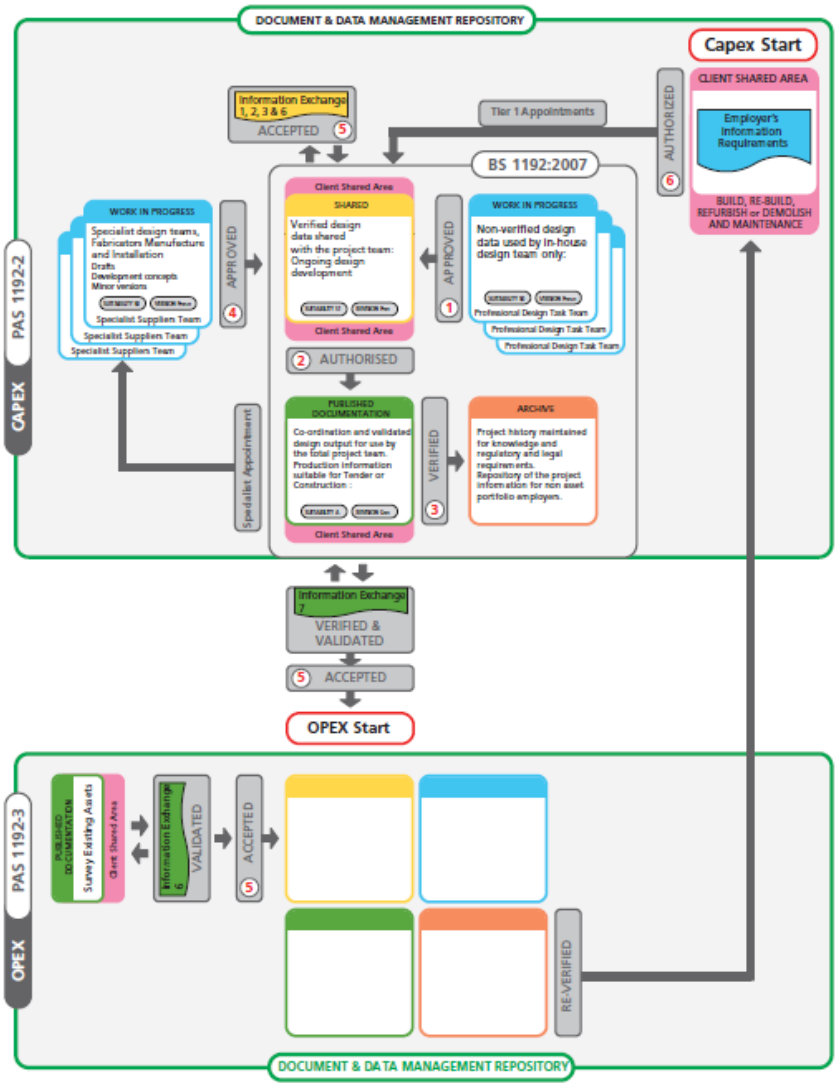


Figure 21 A Schematic of Common Data Environment (taken from PAS1192: Part 2)

In summary, once the information requirements have been specified, the asset owner's team is satisfied about the delivery of these requirements as detailed in the BEP, and the contracts are in place binding all stakeholders to these and the infrastructure is in place, essentially all the key ingredients are in place for a BIM-driven procurement of assets.

7.3 A step by step guide to implementing a Level 2 BIM strategy

This section proposes a step by step guide to establishing a BIM strategy, particularly for a client organisation. It is proposed that at the outset an Information Manager (IM) should be appointed by the organisation. It is generally argued that the Information manager's role is project-specific.

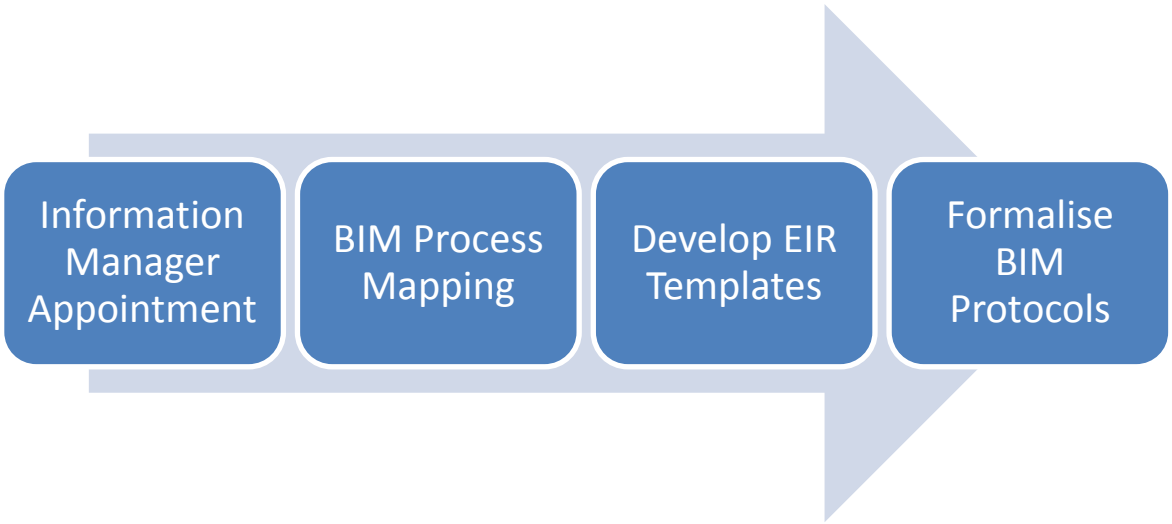


Figure 22 Overall Steps for BIM Strategy Implementation

However, in a minor departure to the accepted view, it is suggested that particularly for a large client organisation with a considerable portfolio of assets, this should be a permanent position and resourced internally rather than outsourced to another organisation. This is because of the immense importance of the role in relation to a L2 BIM. The specific responsibilities of this role are outlined in CIC's BIM Protocol document and should be seen to be an over-arching role that is responsible for the effective implementation of the different aspects of the L2 information delivery lifecycle. The following collage of different aspects of L2 BIM implementation, in essence, covers the entire gambit of the IM role. The BIM Protocol, as it currently stands, puts the onus for appointing the IM on the client in any case. So, the suggestion here is that this is a permanent role overseeing BIM activities for the organisation with other roles attached at the project level. For example, putting together the EIRs (Employer's Information requirements) is a major exercise which should be driven and managed by the IM in addition to the management of CDE (Common data Environment) among other things detailed later.

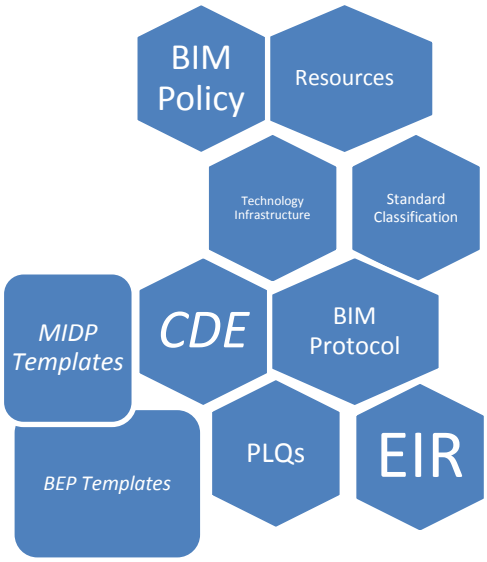


Figure 23 A Jigsaw representing different elements of a L2 BIM Strategy

The jigsaw above shows the different elements of a L2 BIM strategy that need to be in place before embarking on a L2 BIM-based asset procurement. It is proposed that an organisation needs to have a BIM policy signed off at the board level. Subsequently, the resourcing needs to be addressed. It is apparent from the *Pathfinder* surveys that one of the weakest areas where substantial upskilling may be required is in the areas of BIM processes, standards and workflows. As a client organisation, the two most important and essential things that should be in place are the *EIR templates* and the *BIM Protocols*. PLQs (Plain language questions) as a tool for data validation at data drop points need to be developed alongside the EIRs as the two are linked. Then, obviously it needs to be ensured that the technology infrastructure needs are in place. In the collage above, there are two boxes with a different shape and text in *italics.* These are elements of the overall process which typically should be put in place by the supply chain. However, again in a departure to the common view, it is being proposed that for the sake of consistency and simpler management process, the client organisation may want to have its own templates for the BIM Execution Plan as well as the MIDP (Master Information Delivery Plan) which its supply chain will need to adhere to. These are arguably not essential elements for a client organisation. For all intents and purposes, the absolute essential pre-requisites for a Level 2 BIM project are:

1. EIRs (and associated PLQs)
2. BIM Protocol
3. BEP (and MIDP)
4. Technical Infrastructure (including CDE)

Arguably, if these are in place, one could proceed to the project implementation phase. It is hard to justify classifying a project as a Level 2 BIM without at least these elements in place.

As pointed out in earlier sections, the *Pathfinders* did not have all these elements in place although they did have some of these implemented indicating a definite progression towards full blown Level 2 BIM. Therefore, the step-by-step guide could be summarised as below:

1. Appoint an Information Manager
2. Appoint the Soft Landings Champion
3. Set up the Common Data Environment (CDE)
4. Specify the OIR/AIR and EIRs based on the guidance provided in the NHS Scotland EIR Template document including the PLQs as well as LoDs and LoIs
5. Develop the Pre-Contract BEP Template for the suppliers
6. Draw up the Protocols and incorporate in the contracts
7. Negotiate the changes/modifications to the pre-contract BEP
8. Sign-off the Post-contract BEP
9. Develop the MIDP (with LoD and LoIs)
10. Assess each data drop point information deliveries against PLQs
11. At handover (drop 6/7), ensure that all the information delivered comply with the EIR templates and GSL

The setting up of CDE warrants some explanation here. The common understanding that prevails in relation to CDE is that it is set up at the project implementation stage. Whilst this is not incorrect, a slight variation being advocated here is that it would probably add value to an organisation if the CDE is set up at the organisation level right at the outset when EIRs are being collated together. The main objective here is to streamline the process of EIR development as well as to set up a collaborative information exchange environment in place well before the project actually gets to the implantation stage. The progression to the implementation phase then becomes a relatively seamless and painless process. However, it must be borne in mind that there may well be a need to set up a satellite or altogether separate CDE dedicated to the project implementation phase depending on the size and complexity of the project.

It is also important to point out that one should be wary of using a standard EIR or BEP template which is readily available on the internet from various sources. Each organisation has a unique set of information requirements and therefore a template specific to the organisation should be developed which should then be adapted for each project. This is also true for BEP and BIM protocols templates.

The Key Recommended Steps for Level 2 BIM Implementation

7.4 Client/Supply Chain Responsibilities

The preceding graphic has given an outline of different steps and activities to be undertaken potentially in a phased kind of manner to achieve L2 BIM compliance. The table below provides an indication of the division of responsibilities for fulfilling the key requirements for achieving L2 BIM compliance. This has been explained before in section three as well but the table gives the same information at a glance.

Table 1. Division of Responsibilities between Client and Supply Chain

Requirement	Mechanism	Responsibility
Capability to deliver	PAS91	Client/Supply Chain
Detailed Information Requirements and PLQs	EIR	Client
Right to use Information	BIM Protocol	Client
Agreed Models Outputs along with LoDs	Model Production & Delivery Table (BIM Protocol Appendix 1)/PAS1192:Part 2	Client
BEP and MIDP	Supply Chain	Supply Chain
Defined Data Drops and Exchanges	BIM Protocol (Appendix 2)	Client
Information Manager Role	Scope of Services and BIM Protocol	Client

Table 1 above suggests a particular way of dividing the responsibilities between the client and supply chain organisations. It must be pointed out that although this may be the ideal scenario, there are several other variations of this cropping up out in the industry with encouraging results. As mentioned in summary of section 2, there are good examples of a *partnership* approach between client and supply chain (mostly Tier 1s) to fill in any gaps on the part of client organisation's capabilities and these were evident with desired effect in some of the *Pathfinder* projects. It is fair to say that at this stage when most of the industry (including client organisations) is still in the upskilling stage, these kinds of approaches are only good and encouraging developments and should be complemented.

7.5 Concluding Remarks

This report has presented the findings of L2 BIM implementation in four *Pathfinder* projects across Scotland. The overall results are encouraging and although in a theoretical and ideal sense, none of these projects may have been fully compliant with L2 BIM, in a pragmatic sense they embody many of the key aspects of L2 BIM. It is fair to conclude that this is an encouraging start particularly in light of the fact that none of these projects had a detailed contractual obligation to implement L2 BIM. This demonstrates the immensely positive aspirations of the industry to embrace new ways of delivering projects for their own as well as their client's interests.

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