From lonely BIM to Design for Manufacture and Assembly (DfMA): a learning curve for one SME

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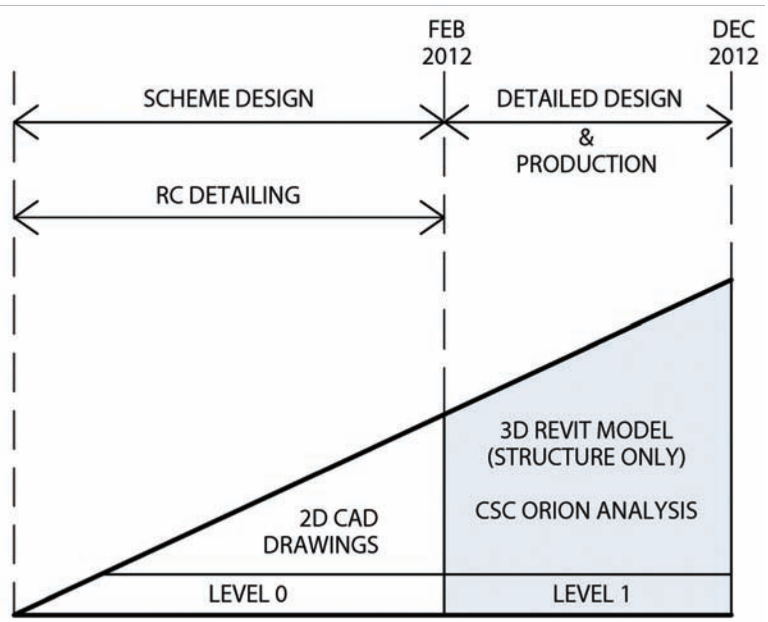


Figure 1 BIM Maturity Level 1 (adapted from reference 2)

Introduction

The current drive from the UK Government's BIM task group[1] sets out the following:

'The Government Construction Strategy was published by the Cabinet office on 31 May 2011. The report announced the Government's intention to require collaborative 3D BIM (with all project and asset information, documentation and data being electronic) on its projects by 2016.

Essentially the UK Government has embarked with industry on a 4-year programme for sector modernisation with the key objective of: reducing capital cost and the carbon burden from the construction and operation of the built environment by 20%. Central to these ambitions is the adoption of information rich Building Information Modelling (BIM) technologies, process and collaborative behaviours that will unlock new, more efficient ways of working at all stages of the project life-cycle.'

Mann Williams is a 30 strong practice of Consulting Civil and Structural Engineers based in Bath and Cardiff. It has a diverse workload ranging from new build university projects to the conservation of historic buildings. With fewer than 50 employees it sits in the 'small' category of the SME (Small and Medium Entreprises).

How relevant is the Government's BIM drive for the SME? Most SMEs will be unable to bid for large government projects for a number of reasons (turnover too low, PII level too small, lack of relevant experience etc.) and it is unclear if this will follow through to the smaller local authority projects where the SME can win work. This drive from government can seem irrelevant to our day-to-day business.

In late 2011, although in the depths of recession and competing against some suicidal fee bids we looked strategically at BIM. Perhaps our most relevant observation was (and not to sound too subversive) to remove 'the Government' from the quoted text above, and replace it with 'our practice'. With this in mind, our challenge was 'can BIM give us that percentage for our business and return profitability to pre-recession levels?'

The implementation and use of BIM has been a significant financial and technical challenge and the three projects in this paper follow our timeline, experience, pitfalls and lessons learnt, and set out where the benefits lie for an SME.

Bath Spa University's digital arts studio (start small and focused)

The first phase of our implementation was taken from a BIM maturity levels graph (Figure 1) which, in turn, was our summary explanation of the BIM maturity levels

Figure 2
Aerial view of completed structure

Figure 3
Structural Revit model

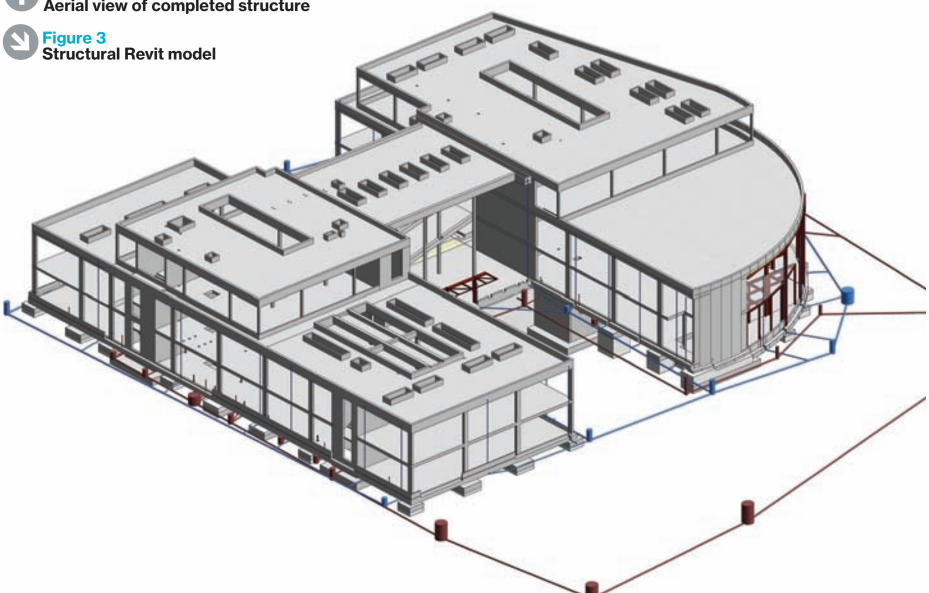
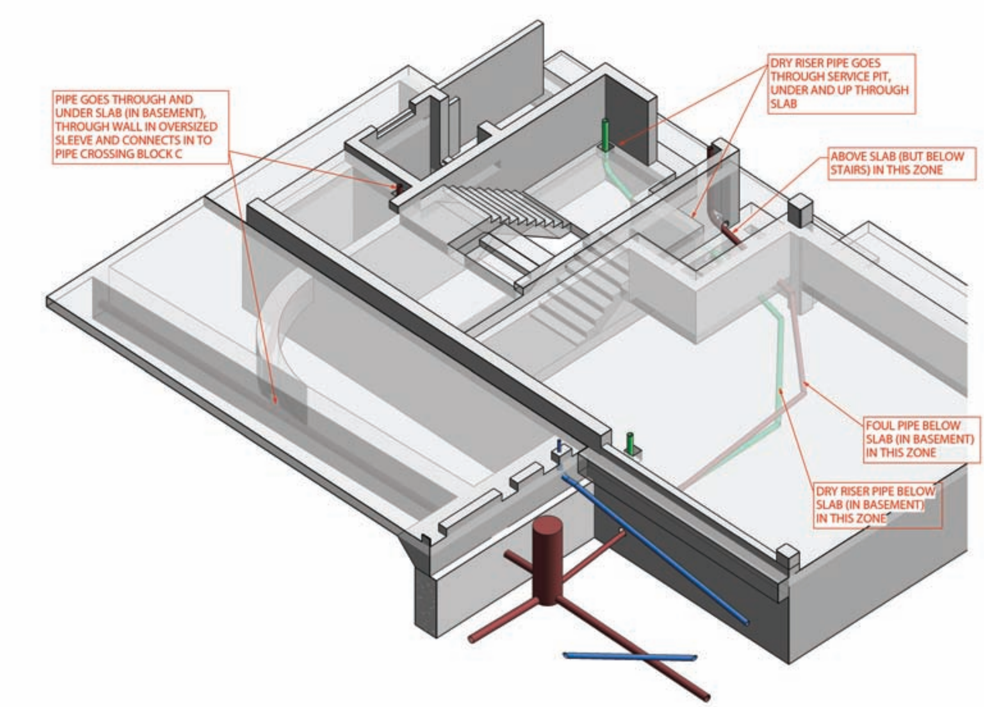


Figure 4
Annotated export from model (for RFI)



published in a 2011 government report[2]. The idea was to start small and use Autodesk's Revit Structure to complete a standalone (lonely) model for a project, from the detailed design phase to completion. This would be done with a small team (a director and engineer/technician) to keep the project focused and an eye on the delivery of our construction information.

The Bath Spa University project is an 8000m^2 'state of the art' dedicated teaching and studio space for the digital arts that will be equal to anything found at leading commercial organisations and broadcast companies (Figure 2). The building is formed of *in situ* reinforced concrete flat slabs, columns and shear walls.

We had completed the design to Stage D with 2D AutoCAD drawings and specifications produced for tender. With the appointment of Skanska we agreed our deliverables as standard 2D drawings for construction from a Revit model.

The initial model was developed in a four week period, with weekly contractor team review meetings to check progress and review details. This modelling process was relatively straightforward with a frozen, clear scheme design and a simple concrete structure (Figure 3). An analysis model using CSC Orion was also developed within this four week period to complete the detailed design and define reinforcement requirements. Note: CSC Integrator and Orion now allow two-way model synchronisation, which would have saved a week of engineering time setting up the analysis model. Other software packages are also available which offer this advantage.

With the model populated with builders' work holes and drainage pop-ups, we completed the construction drawings from the model and traditional reinforcement detailing using AutoCAD. Setting-out .dwg files were also exported from the model for viewing and printing. With the structural works complete, there were a number of observations:

- Having developed a full 3D model, the number of site queries was minimal as the geometry has to be resolved to complete the model. Any queries on difficult areas could be answered with accurate annotated exports from the model (Figure 4)
- Request for information (RFI) queries relating to steelwork geometry and site setting-out at interfaces between steelwork and concrete were greatly reduced (Figure 5)
- By starting the model at detailed design stage (with a frozen layout) our focus and time went into the modelling, resolving problems and producing construction information

Figure 5
Steel to concrete

Figure 8
Initial concept

• The review process using the model simplified a number of co-ordination issues between architecture and M&E. One downside of this was the additional work generated in co-ordinating other disciplines that were outside our scope

University of Bath's Chancellors' Building (co-ordinating models)

In spring 2012 we successfully tendered for a new 7500m^2 teaching building at the University of Bath. The client's key requirement was for the building to open for teaching in September 2013. Stride Treglown Architects had been working in Revit for a number of years and it was clear that the only way the design team could achieve a compressed design programme was to develop the BIM model from concept stage (Figure 6). This gave us the opportunity to work with an architect co-ordinating information in the 3D environment.

With the BIM model complete for Bath Spa University, the same team took on this project with an additional senior engineer for design and analysis.

Using the architects' experience we agreed a method of working and swapped digital information to ensure co-ordination of models. During the initial design stages a combination of hand sketches, approximate methods of analysis and modelling were used to define the frame layout. Early in this process a number of key challenges needed to be resolved:

• 18m clear span transfer structures at second floor to achieve double height lecture theatres at ground floor
• Long span floors with no downstands to allow flexibility for M&E design

A braced steel frame with long span hollowcore planks, Slimflor steel beams and storey deep transfer trusses was used to address the challenges. Our initial model for the transfer trusses (Figures 7 and 8) could be set within the architect's layout at concept stage to demonstrate to the client how the frame would achieve the large open plan lecture theatres (Figure 9 shows the completed truss). This model was then developed with two-way model synchronisation between Revit Structure and CSC Fastrak to validate our design and provide an accurate steel weight for the cost plan. With the early analysis modelling we were able to complete a co-ordinated architectural and structural model for Stage D (Figure 10).

With the client's agreement, the steel

Figure 6
BIM Maturity Level 2
(adapted from reference 2)

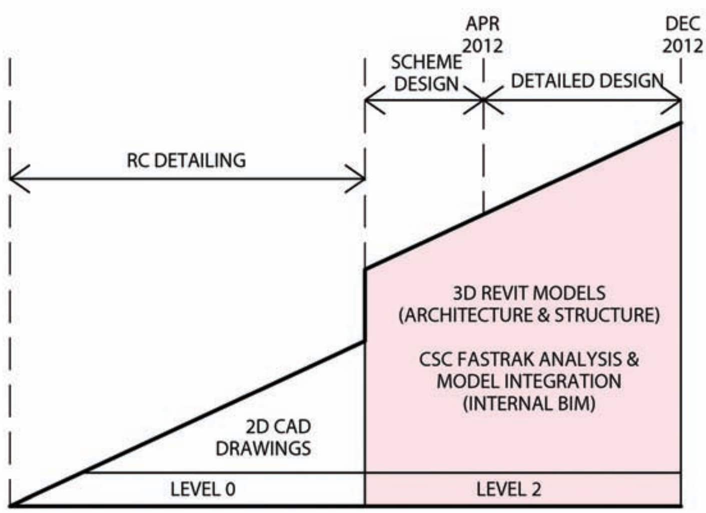
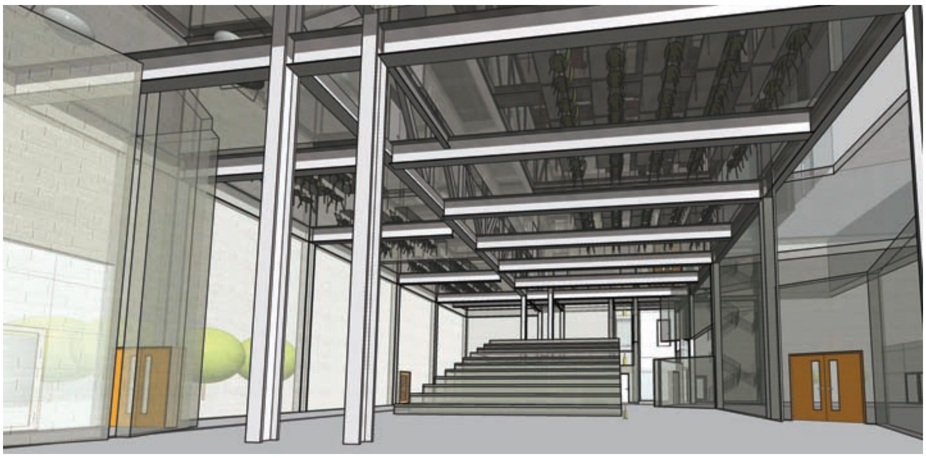


Figure 7
Concept model transfer trusses over large lecture theatre



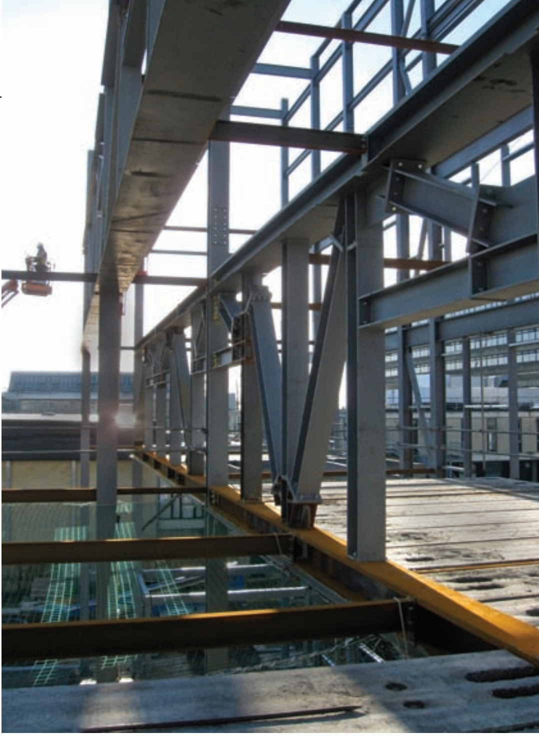


Figure 9
Erection of transfer trusses

frame was frozen at stage D and we were able to progress to the completion of Stage E and tender, while maintaining confidence that the frame would be co-ordinated with the architect's model.

With the building nearing completion for occupation at the end of September 2013 (Figure 11) there were a number of key lessons and observations:

- A distinct disadvantage of the BIM model is the need to complete the model (or part of it) before a drawing can be produced. At the scheme design stage, a significant amount of time is taken up with modelling, as opposed to producing drawings that can be reviewed by the client or team. On this project we had a client who would review the initial model images to understand the evolving design and the issues being resolved
- The project QS used both the architectural and structural Revit files to aid his take off and cost plan. This simplified his time and expense (and resolved the issue of producing drawings). In hindsight, with defined deliverables, perhaps our fees should increase and other team members' decrease as the BIM information we produce leads to efficiencies elsewhere?
- With properly managed model information and client sign off at design stages, the design programme can be reduced and design models can be quickly progressed to construction level information
- If two-way synchronisation is to be used between analysis and BIM models, the model must be initially set up in the correct format to save a large number of 'error' issues
- The steelwork contractor was appointed ahead of the cladding contractor and although an allowance was made for cladding rails, framing etc. a disproportionate amount of time was spent once the frame was in fabrication, trying to co-ordinate these elements. If both parties were on board at the same time (in line with the government's BIM strategy for 'lean manufacturing') this could be simplified and details incorporated at the correct stage

University of Bath's R6 residential block (DfMA)

With the scheme design underway for the Chancellors' Building, we were successful in winning a new student residential project for the University of Bath. The brief was to deliver 700 single, en-suite bedrooms clustered around kitchens and a large refectory. All of this needs to be ready for occupation in September 2014. A key point in our winning bid was our ability to deliver BIM projects and to show the programme benefits this achieved. This also met the client's drive as part of their long term view

Figure 11
Building nearing completion

Figure 10
Co-ordinated scheme design models

for asset management and the benefits BIM can deliver.

This project, by its nature, had a large degree of repetition and was ideal for training two further technicians in the use of Revit. This was not without its difficulties and the cost in lost productivity equated to about one month of fee earning time for the individual. This put significant pressure on our programme that could only be met by a significant number of extra hours being put into the project. This aside, both technicians have now been using Revit for about nine months and are successfully using it on other projects.

The leap in our BIM experience came following tender with the appointment of Laing O'Rourke. Until this point, our focus on BIM was in the production of 3D models and using them to generate our traditional drawings. It had felt more like an evolution of how we work (much like the early days of CAD) rather than the BIM revolution that had been promised.

Laing O'Rourke brought a 110 page BIM manual with an extensive set of digital protocols and a drive to deliver the whole project in BIM. This, coupled with their push to use as much Design for Manufacture and Assembly (DfMA) as possible, has given us an insight into how BIM Level 3 might work in practice (Figure 12) as well as a deeper appreciation of the 'Information' part of BIM being the key to the revolution.

The challenge we were set was the re-design of the *in situ* reinforced concrete structure forming the transfer deck and large open plan space to the refectory (Figure 13). Laing O'Rourke wanted to utilise precast concrete columns, twin walls and lattice plank slabs to reduce construction time on site. These elements are all manufactured by them at their Explore Industrial Park facility in Nottinghamshire.

In addition to the re-design, we went through a number of BIM reviews with Laing O'Rourke to understand how our 3D model information needed to be populated with the necessary data sets and attributes for manufacturing.

Within our BIM model we were able to accurately define individual precast components and attach information, such as: geometry, location, reinforcement and concrete grade. This information was used to produce our own drawings and schedules, and was embedded in an export model. By using the industry foundation classes (IFC) model (an industry-wide neutral data format) we were able to seamlessly transfer this data from our model to Explore Industrial Park's manufacturing software package.

Figure 12
UK Government BIM maturity scale

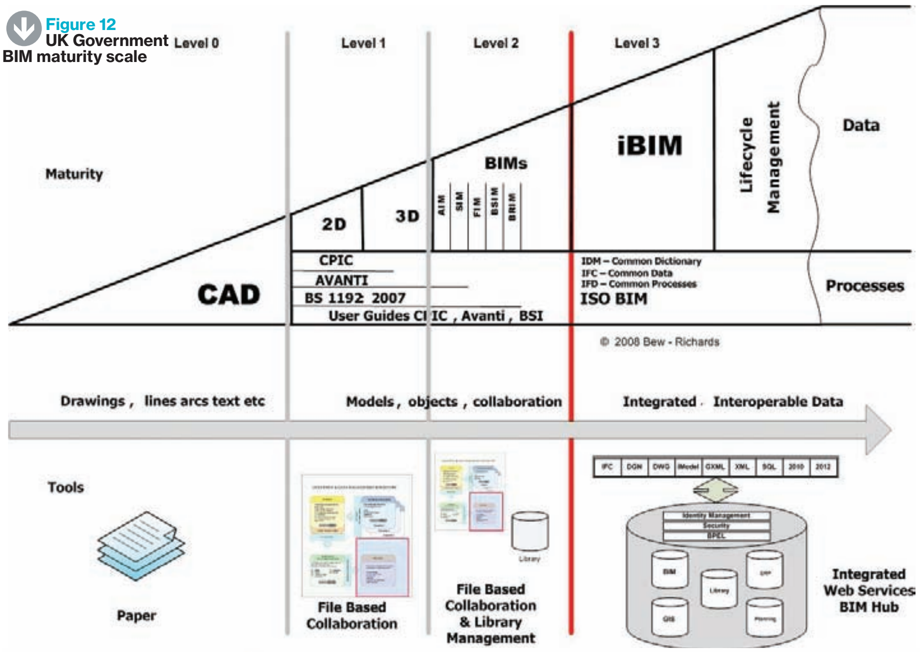


Figure 13
Westblock (refectory and transfer block in foreground)

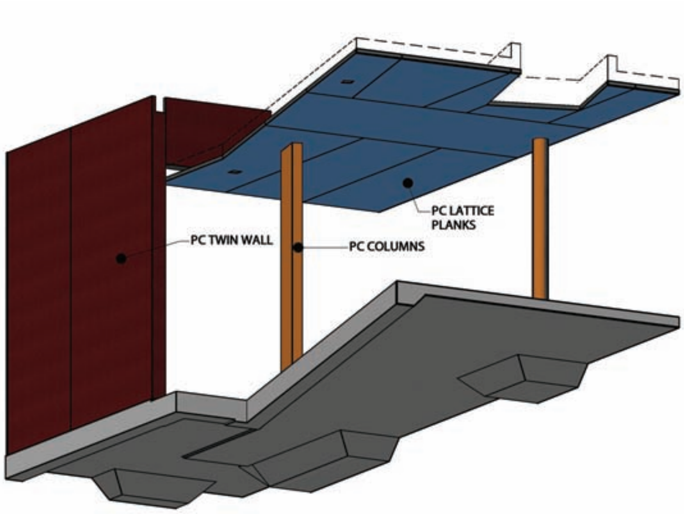


Figure 14
Design of precast elements

Figure 15
R6 lattice planks during manufacture

Figure 16
Completed refectory and transfer deck

This meant they only had to add information specific to the manufacturing process, rather than reproducing a model from scratch. We found this had benefits for us, as well as Laing O'Rourke. This enhanced information transfer saved on the duplication of modelling (an issue we currently have with the steel industry) and removed the risk of error from human interpretation of 2D drawings. As there was little reliance on 2D information, we didn't have to produce a raft of drawings and could focus on producing supplementary information within the model. As the information is not lost or reproduced during the process, the drawing and approval stage of manufacture was compressed, and our time checking the fabrication information was greatly reduced.

Seeing a small part of a project from design, through manufacture and to site (Figures 14-16) highlighted the significant efficiencies that can be made by adopting a BIM process at every stage. However, the process did place additional responsibility on us that needed to be checked with our insurers; and the boundaries of ownership and accountability of information needed to be clearly defined at all stages.

In addition to DfMA, this was the first project where we have worked with the full design team (architect, M&E engineer, kitchen designer etc.) in the 3D environment. A key benefit to us has been the ability to clearly define builder's work early in the process and incorporate this in the construction model. This has been facilitated by all disciplines exporting a Navisworks model (Figure 17) that the Laing O'Rourke digital co-ordinator combines for review at a fortnightly BIM workshop.

Joining a contractor who has both a detailed methodology and understanding of the benefits of BIM has been a valuable experience. It has raised a number of issues with the higher maturity levels of BIM:

- When confronted with working at a higher BIM level don't be afraid to ask questions of other team members. Some have been through the learning process and will help to focus on what is needed and how to deliver
- Ensure a rigid discipline of accuracy in the model. The use of DfMA puts additional responsibility on the accuracy of our information. With any offsite manufacture, if the model isn't accurate it will be difficult to assemble on site
- Check and review any new information processes and accountability with PI insurers to ensure cover
- Where a project has a high degree of repetition, use it to train other members of the company in BIM. Care is needed on the impact of training on productivity and a back-up plan of how to manage this is essential
- Fee levels need to be re-assessed. Our fee was too low for delivering a fully co-ordinated model. If BIM is to become an industry standard, fee levels will need to be carefully assessed against the BIM information required by clients and contractors

Lessons learnt

Over the last 20 months, these three projects have formed the cornerstone for our implementation of BIM. This process is about three quarters complete and sits alongside traditional 2D CAD drawing and hand drawing for the production of information. It has been a rapid process, putting us in a select minority that, according to the recent NBS survey[3], notes only 8% of companies are aware of the BIM levels and think they have reached Level 3. Some of the key issues and lessons learnt (so far) which hopefully will aid other SMEs in their adoption of BIM are:

Implementation

- Identify a director/partner and a technician to start the BIM process. Make this part of their CPD and set aside time to read up, go to seminars etc.
- Invest in training of the technician to use Revit (or similar). Make use of free 30 day licences for training
- Understand the BIM overlay to the RIBA Outline Plan of Work[4] and use it as a basis for the BIM activities at each work stage
- Use a project with the scheme design complete, to produce a standalone (lonely) BIM model for the structure. Don't commit

to delivering the model on the first project
• If possible, start with a reinforced concrete structure as this is the simplest form to construct in a model
• Engage with architects who regularly use BIM and pick their brains for ideas, issues etc. Where the opportunity presents itself work collaboratively in BIM
• Roll out BIM in short measured doses. Too fast and the production of information grinds to a halt. Again make use of free 30 day trials on software for training
• Check any issues with PI insurers to ensure coverage

Costs

• A REVIT licence costs in the region of £7,000. A computer with sufficient RAM and graphics card is also needed to run the model and these cost about £1,000.
• Learning on a project costs about one month's salary in lost productivity. At the end of this, a technician can grasp the basics and produce a model. There is a continuing learning curve but the benefits gained appear to quickly outweigh the time spent learning

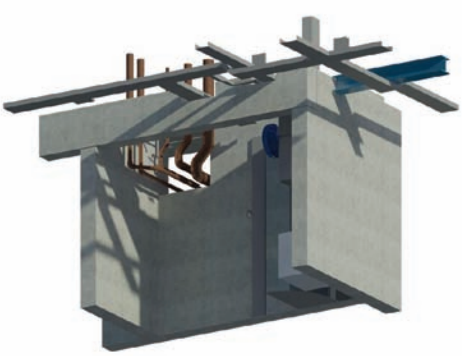


Figure 17
Services/Structure combined model and completed precast structure

Benefits

• Software compatibility and synchronised analysis saves the duplication (and potential for mistakes) of setting up and running two separate models
• Helps technicians and graduate engineers visualise and understand how buildings are put together. They are bringing modelled solutions for review rather than expecting to be given the answer
• Being able to demonstrate how the structure is arranged in 3D solves the majority of design and construction queries and reduces time spent
• The M&E services and their co-ordination with the structure can be set early and builders' work can be incorporated early
• There are noticeably fewer site and fabrication RFIs when compared to traditionally drawn projects
• It provides a boost to staff to see the next step for the construction industry
• With correctly managed data, the transfer of information to other designers and contractors is simple and allows for easy co-ordination
• 1:1 accuracy and co-ordination of models from different disciplines at the design stage reduces problems on site (see also Issues)

Issues

• The initial costs are high and you need to be clear about what the model is going to be used for. In the first few projects it is easy to be side tracked perfecting a model as oppose to producing information that can be built
• There is a substantial amount of jargon to sift through and understand
• On a small project the cost of setting up a BIM model outweighs the benefits (we are still trying to find the breakeven point). The exception to this is where the architect is working in 3D
• 1:1 accuracy is required to allow for design co-ordination and to save problems on site. This requires time and discipline from all members of the team using the model. A traditional shortcut of providing an accurate measurement on a mark-up would be quicker and more cost effective
• A strong set of in-house guidelines need to be developed and adhered to. This stops individuals working in different ways when setting up and saving data
• The model needs to be complete before full sections and complete plans can be taken out of the model. This needs to be communicated with other team members who are expecting traditional 2D information
• Accountability. Care is needed when agreeing to data production. It is easy to step into producing more information than originally allowed

Conclusions

We have found BIM has paid for the initial investment, improved profitability across the three projects and boosted staff confidence about the future of the construction industry. The key issue for SMEs (and perhaps the industry in general) is to ensure the costs are proportionate to the level of BIM data required by clients and contractors.

References

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