Technical Note No 93

Building Information Modelling – Principles for Building envelopes

Building Information Modelling (BIM) is being adopted by the construction industry led in part by some Main Contractors and driven by Government declarations on public procurement policy. 3-D modelling has been taken up by architects and engineers for visualisation of space planning and coordination of elements. BIM is a wide ranging concept that may be operated at many different levels of complexity and functionality. This paper aims to explain the principles of BIM and set benchmarks for the use of BIM when designing, constructing and operating building envelopes.

This Technical Note does not consider the merits, advantages or disadvantages of using any particular software packages. Rather it considers the strategies that should be adopted when implementing BIM on a project.

Introduction

BIM is not a new concept; it is an extension of a very old principle of collaboration between the various designers and constructors on a project. This has been embodied in BS 1192: 'Collaborative production of architectural, engineering and construction information – Code of practice', 2007. BS 1192 has evolved over several decades from a time when all drawings were prepared using pen and ink. BIM places a greater emphasis on the information that is captured and shared over and above the information contained in conventional drawings. BIM extends the basic concept of collaboration to include the building owners and maintainers who will use the design information throughout the life of the building; a later day version of 'as constructed drawings' and 'Operation and maintenance manuals'. Using BIM; operations and management information can be presented in a much more accessible and interactive format. A key part of the BIM lifecycle is that it also allows information to be gathered post-completion to be fed back into the design process for future projects.

A Building Information Model is a digital representation of the geometrical and functional characteristics of a building. A BIM is a shared knowledge resource for information about a building forming a reliable basis for decisions during its life-cycle from earliest conception to demolition

As an aspiration it is a basic premise of BIM that it enables collaboration by different stakeholders at different phases of the life cycle of a building. In its more developed forms BIM allows stakeholders to insert, extract, update or modify information in the BIM to support and reflect their roles as stakeholders. In reality even simpler forms of BIM can deliver benefits of economy and efficiency in the design, construction and management of buildings.

However, it must be remembered that the use of BIM has a cost of preparing and sharing data. The costs of implementing BIM on a project will depend on the additional information required over and above that normally provided to architects, engineers and contractors. The question is often not what it costs but who pays.

The greatest benefits are achieved by:

- Investing appropriate effort in developing a BIM model of appropriate complexity and detail that it delivers the benefits required, in the same way that a drawing should have contained only the necessary detail and information.
- Not regarding BIM as an end in itself; BIM should be regarded as a tool in the same way that a traditional drawing on paper was not a product in itself but was an efficient method of communication.
- Making clear to all contributors, at the outset, what they are required to do and when.

In the days of paper drawings estimators allowed for the cost of design by predicting the number and complexity of drawings required. This process is more difficult when using CAD and yet more so when using BIM but the same premise holds true. However, with drawings the cost of drawing largely facilitated manufacture and construction and mainly benefited the contractor who bore the costs, with BIM the costs accrued by the contractor may yield benefits to the Client throughout the life of the building but may not benefit the contractor through greater efficiency. With BIM it is necessary to ascertain the Client requirements for information on a particular project so that identification, separation and preparation of that information can be included in tender prices. The specialist contractors models will contain far too much detail and simplified 3-D models may have to be produced loaded with inherent data values such as thermal properties, unit cost, predicted life span, programme information etc. that may be requested by consultants, client or principal contractor.

Scope of BIM

BIM covers the whole range and complexity of information from simple drawings to fully interoperable data sets. This range of possibilities has been formalised as the Bew-Richards scale of BIM maturity to define four levels of BIM as shown in Figure 1.

To put the development of BIM into context the UK Government has announced that all centrally procured construction projects will be delivered using level 2 BIM by 2016. Between now and then various Government departments will be 'switched on' to BIM use, and in 2012 the Ministry of Justice tendered for the first exemplar schemes to require BIM use and other departments are currently preparing their 'roadmaps' to the implementation of BIM requirements.

Nearly all building projects that include systemised building envelopes are currently delivered using 2-D CAD, and sometimes 3D-CAD, so what does it take to progress to Level 2 BIM? And is it necessary to use 3D-CAD?

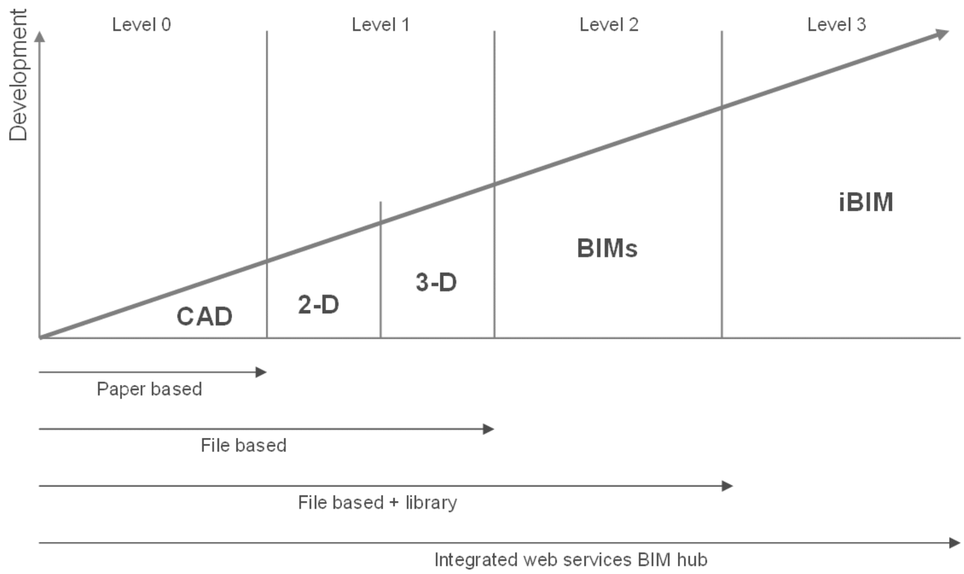

Figure 1 Bew-Richards scale of BIM maturity

Level 2 BIM requires Building Information Models (BIMs) for each construction package of the building. The BIMs commonly shown on slides at presentations are;

- Architecture (AIM)
- Structure (SIM)
- Façilities (FIM)
- Building services (BSIM)

These separate BIM models with separate owners require a means to exchange data between them for purposes of integrating design and clash detection. Although each has a separate owner creating them, they may be accessible by many parties involved in a project.

The standard form of delivery of information to the end user in the case of public projects is (at 2012) proposed to be the COBie format – a database of all information contained within the BIM data developed for a project. COBie data is most commonly issued as a spreadsheet as opposed to (or in some cases alongside) the original 3-D or 2-D building models produced by the various stakeholders involved in the design and construction process. COBie is described in more detail later.

The existence of separate BIMs with separate owners raises the question whether the building envelope should be modelled as part of the AIM or whether there should be an Envelope Information Model (EIM). This will depend on the form of construction and the degree of complexity of the façade but in many cases a separate EIM will be appropriate for systemised building envelopes.

A BIM comprises file based drawings and a supporting library of information. BIMs at Level 2 are written by a single owner (although they may be read by others), it is only at Level 3 that the information is required to be part of a single fully interoperable Building Information Model (iBIM). In an iBIM all information is resident on a common hub using a common data format and library.

Drawings comprise lines (and arcs) that are objects with properties of position, length, (radius), thickness, style, and colour. These may be combined to create objects such as rectangles, windows, doors and so forth. 3-D software packages comprise simple volumetric elements that may be combined to create objects such as windows or doors. Additional (non-graphical) information may be added to an object to create an enhanced object. Such information may include product information, performance parameters, supplier details and so on. This information is typically viewed by clicking on the object as it appears graphically on screen to reveal a properties dialogue box. The information may be stored within the BIM and/or be accessible through an external link.

Level and grade of detail in CAD

Traditional drawings of building envelopes were classified as;

- General arrangement drawings
- Detail drawings
- Workshop/component drawings
- Construction drawings

Whereas these used to be separate drawings it is possible using CAD to combine the general and detailed information in a single drawing by layering and the ability to expand or shrink drawings on screen. Whilst all of this information is required by the building envelope contractor much of it is of little or no value to the Main Contractor, Architect, Structural Engineer or Client. It is also the case that Specialist Contractors will rightly be reluctant to release detailed drawings that allow another contractor to benefit from their design experience and possibly replace them as specialist contractor on the project.

In a BIM environment there is a level of detail that increases as the project progresses. Level of Detail (LOD) is defined on a scale from LOD100 – conceptual design up to LOD500 – as-built information suitable for facilities management purposes. When providing information for use in a BIM it is important to know the level of detail of the model.

However, there will also be a requirement to provide elements drawn to a certain grade of detail.

Including too much information in drawings passed to other parties may make it difficult for them to filter and understand the relevant information and may overload storage and software capabilities. This is particularly the case with three dimensional models; a simple outline drawing can be handled much faster than a complex model when the image is required to rotate on the screen. Consider the chair shown in Figure 2.

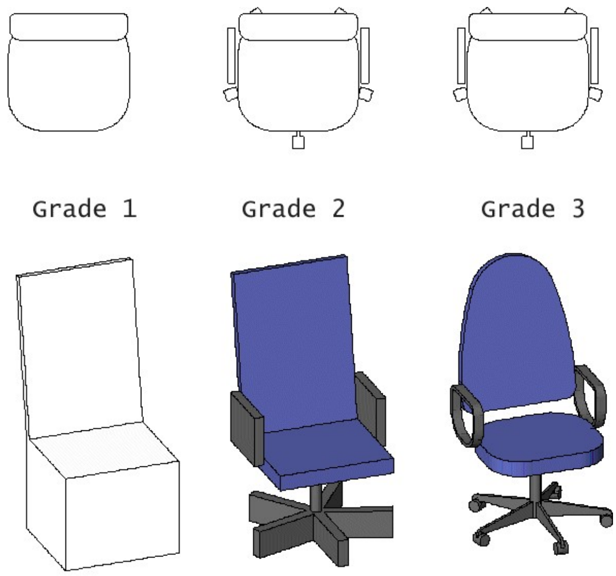

Figure 2 Appropriate grades of detail

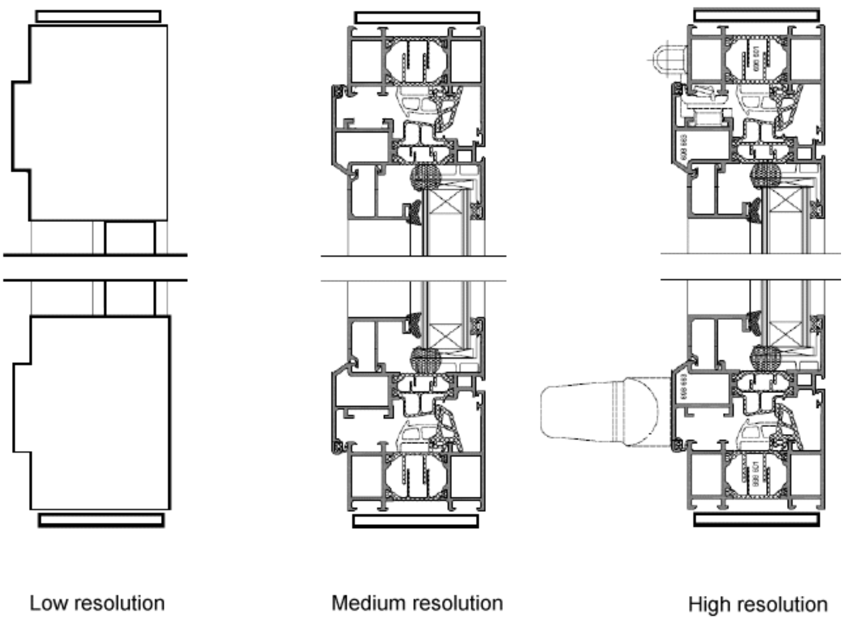

Figure 3 Grade of detail for a tilt-turn window

All three grades of detail are valid models of the chair. Grade 1 will act as a place holder and enable fit and clash detection; it may also be an object with extensive information about the product. Gradel 2 and Grade 3 levels have enhanced appearance and reality but at a greater cost of model creation, data storage and data analysis (particularly for 'walk through' and 'spin round' viewing).

Cross sections through a tilt-turn window drawn at different levels of resolution are shown in Figure 3. The low resolution drawing is a very rudimentary drawing that provides Grade 1 detail and acts as a place keeper in a general architectural model. The medium resolution drawing contains more detail than is normally required for a Grade 3 model and the large amount of data associated with this drawing will be burdensome when it is integrated into the whole building model. The high resolution drawing contains more information than is of use to either the building design team or the building manager and the associated data will be unacceptably large to the manager of the BIM.

Note that it is important to understand what to include and what not to include in a model. In the example given in Figure 3:

- It might have been more useful to include the operating handle in the medium resolution drawing (and even in the low resolution version).
- The internal gaskets and seals could have been omitted from the medium resolution drawing.
- A low resolution drawing showing at least the fixed and opening frames might have been more useful.
- Where greater detail is required to inform the site assembly process, and that information repeats for every window, it is more useful and efficient to have a single assembly drawing.

3-D CAD

Three dimensional drawing is essential for building envelopes with very complex freeform geometry. It is necessary for designing, manufacturing and setting out these forms of building envelope. However, it is not necessary to use three dimensional drawing for simpler envelopes, particularly those comprising rectilinear grillages, glazing and infill panels forming plane walls or roofs. These simple forms of construction comprise the majority of building envelopes.

To use three dimensional CAD for simpler constructions is an unnecessary expense for the contractor (who will pass it on to the Client), and for reasons of technical capability will limit the number of potential building envelope contractors when tendering. Many smaller specialist contractors do not have the necessary software; more importantly there is a shortage of skilled 3-D CAD operators and difficulty in up-skilling older more experienced staff.

In the context of gaining savings and efficiencies from BIM it will often be better to use 2D-CAD and concentrate on improvements to the supporting library of information rather than to insist on the use of 3-D CAD.

Figure 4 shows a screen shot from typical design and estimating software used by many specialist contractors to design simple plane walls. Cross-sections are not required as the framing profiles are proprietary products of known cross-section and properties. In this case the production of a BIM model is a separate exercise and a simple 2-D model at Grade 1 or possibly Grade 2 level of detail is all that should be expected.

However, although 3-D CAD may not be necessary for the design, manufacture and construction of a building envelope the Main Contractor may wish to include the building envelope in a 3-D model for clash detection or to check the interface between the building envelope and the structure. This may be achieved by generating a very simple 3-D model of the envelope representing only the inner and

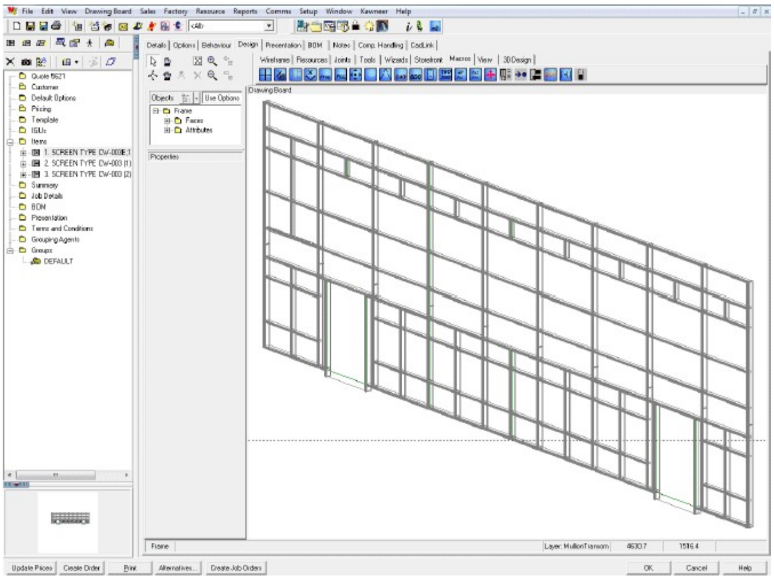

Figure 4 Typical design and estimating software

outer surfaces and possibly the brackets supporting the building envelope. This may be prepared by the Main Contractor from raw information provided by the Specialist contractor.

Higher order BIM

4-D BIM introduces time as the fourth dimension. This may be used by Main Contractors to show the construction sequence. It may be used to model clashes with cranes and temporary works. It is unlikely that the Building envelope contractor will build a 4-D model, rather it will be developed by the main Contractor from information provided by the specialist contractor. The geometrical detail in such models may be at a very low grade sufficient only to act as a place holder.

5-D BIM includes the cost information for the different elements while 6-D BIM includes the life cycle analysis of the different elements. Currently these are not commonly encountered on projects.

Early design stage models

Architectural design always starts before a specialist contractor is appointed and models required at this stage have to be developed by the architect. These models require only sufficient detail to provide a good visual interpretation of the finished building. In this context the building envelope may only need to be modelled as plane (or curved) surfaces and solid elements. It is more important that these are accurately coloured and textured than that they are precisely dimensioned.

Suppliers and contractors may assist architects by providing 3-D drawing objects that can be imported into the AIM. It should be understood that these need to be different from the modelling packages they use for engineering purposes. Many drawing packages now allow export in IFC format, a generic format accepted in all BIM software. Many pieces of BIM software also allow the import of various formats that can be exported from a large number of engineering and manufacturing design packages. In some cases there are additional benefits to producing proprietary models in specific modelling formats such as Autodesk Revit or Graphisoft's ArchiCAD as this allows greater use and interoperability but as mentioned earlier, any additional benefits should be weighed up against cost and stated requirements.

Manufacturers can produce generic BIM elements, or families of elements, to be down loaded and incorporated in project BIM. These may be made available on their own websites or hosted on sites such as NBS BIM Library or BIMStore. These generic BIM elements would be expected to offer generic performance information such as U-values, acoustic performance, load/span data and links to literature and third-party certification.

The early design stage model may be taken forward and developed into the Main Contractor's BIM but it is often more efficient to carry through the bare x, y, z coordinates of critical dimensions and form a new BIM that meets the need of manufacturing and construction and continues through the service life of the building.

Supporting information

Supporting information has always been provided by Specialist contractors for use by Main contractors, Architects and Clients and over recent years this has become more extensive and detailed. It will include:

- Component information
- Performance characteristics
- Test certificates
- Method statements
- Installation instructions
- O&M manuals

BIM Level 2 requires this information to be in an electronic format which may simply be .pdf format documents. However, the information has to be coordinated with the drawings and supported by drawings. CAD drawings may be prepared as enhanced objects with information embedded in them. For instance a glass specification may be revealed by clicking on a glazed opening on the drawing. Maintenance information may be revealed in the same way, may be in a stand-alone maintenance manual or may be accessed on a manufacturer's or specialist contractor's website. One thing to be borne in mind is the permanence of information external to the BIM.

For simple plane rectilinear facades greater efficiency may be derived from using enhanced objects in a 2-D CAD drawing rather than preparing complex 3-D drawings that only portray the geometry, and by efficiently correlating supporting information with drawings.

COBie

BIM level 2 requires information to be passed to the Building owner/manager at completion of the project. The minimum format for this information is a spreadsheet containing information to facilitate the maintenance, repair and upgrading of the building.

The standard format required is the Construction Operations Building Information Exchange (COBie) template. Further information and example spreadsheets are available through the BIM Task Group.

The information required is at an element or component level and comprises:

- Component description
- Location
- Supplier
- Performance characteristic
- Maintenance requirements

COBie templates have been developed around the needs of building services and other high maintenance elements of the building which are easily located by floor, room and so on. When developing a COBie document for a curtain wall it will often be easier to designate it as an external element of the building and reference the components within the wall from a reference drawing viewed from the outside rather than by their location within a room or compartment as viewed from inside. In the case of separate windows mounted in a wall of say blockwork construction it may be easier to simply reference them by room or compartment.

Whichever approach is taken to referencing it is important that it is coherent and comprehensive. The provision of reference drawings or marking of components is essential. Marking may be by labelling or printing and it may be directly readable or barcoded. It is also possible to used RFID (Radio Frequency Identification) tags the cost of which continues to fall. These can contain large amounts of information and may be either read or read/write tags. Read/write tags are appropriate for items such as actuators which have a service requirement but simple passive read only tags are sufficient for most façade components. RFID tags have the advantage that they may be embedded and do not affect the appearance of the envelope.

The information required in the COBie should be agreed at the beginning of a project and it should be remembered that it is the information required to operate the building. This may include the need to replace damaged or failed components. The information may be given as product information or as a technical performance specification. The latter is more robust as Manufacturers may cease to trade. Similarly, if information on maintenance is given simply as a reference to a manufacturer's website that may not be supported long term, it is more robust to have documentation within, or alongside the COBie in the building manager's ownership.

The technical information provided for the different elements of the wall is shown in Table 1. The lists given are not exhaustive and the exact information required will depend on the scope of performance of the wall or window.

Proceeding to a project

On any project the lead consultant or main contractor should have prepared a BIM Execution Plan that details the information listed below. While many state that the key to BIM is the 'I' for information, without clear communication and protocols in place the process can easily become convoluted and inefficient.

When implementing BIM on a project it is necessary to establish:

- What is expected from the BIM
    - Who is the user of information in the BIM
    - What purpose is it to serve
- Who will prepare and manage the BIM
    - What software is to be used
    - What functionality will it provide
- Who will provide information
    - What information
    - In what format
- Who owns and is responsible for information

It is clear that whereas a project specification would have required the specialist contractor to provide construction drawings, method statements and O&M manuals, CWCT (2006), it is now necessary to specify any provision of information as a separate EIM or the content and format of data to be handed to the manager of the BIM. This may be the basis of pre-qualifying tenderers on a contract. This should be given in the Employers Information Requirements.

The BIM Strategy Report published in March 2011 concludes that in adopting BIM at Level 2 'no significant amendments are required to contracts currently used by the construction industry'. This assumes that a BIM Execution Plan has been prepared. Of course all contributors to the BIM have the same duty of care in preparing information as they do when they prepare drawings, maintenance manuals and so forth.

Glass	Window	Curtain wall frame	Spandrel
Type (layer 1)	Frame U-value	Frame U-value	U-value
Thickness	Security	Framing system	Insulation material
Type (layer 2)	Acoustics	Framing profiles	Surface materials
Thickness	Framing system	Finish	Finish/Colour
Safety/containment	Framing profiles	Colour	
U-value	Finish		
g-value	Colour		
Light transmission			
Colour			

Table 1 Information included in COBie

It is also important to understand the roles of the different parties; in particular the BIM Manager is only responsible for setting the formats and standards and coordinating the flow of information. The BIM Manager is not responsible for the accuracy of information supplied and the role is distinct from that of design coordinator.

What do we want from BIM?

On any project it is necessary to understand the benefits that can be delivered by BIM and the most effective and efficient way to deliver those benefits.

Table 1 shows the purpose for which building information modelling may be used at different stages of a project and the formats and grades of detail that may be required.

Further guidance

BS 1192 gives guidance on the referencing of information contained within BIM using the uniclass referencing system. BS ISO 12006-3 also covers the topic. Uniclass is a classification system managed by CPIC (Construction Project Information Committee) www.cpic.org.uk.

Avanti was a Government funded project to study the uptake of ICT in construction. The reports produced are a valuable source of information and may be found at http://www.cpic.org.uk/en/publications/avanti/index.cfm

The BIM task group has a website that contains useful information at http://www.bimtaskgroup.org/

More information on COBie and example spreadsheets are available at http://www.bimtaskgroup.org/cobie-uk-2012/

The 'BIM Strategy Report' is available at http://www.bis.gov.uk/policies/business-sectors/construction/research-and-innovation/working-group-on-bimm

The NBS BIM Library is available at www.nationalbimlibrary.com/

The BIMStore is available at www.thebimstore.com/

Abbreviations

AIM	Architectural information model
BIM	Building information model / Building information modelling
BSIM	Building services information model
CAD	Computer aided drawing
EIM	Envelope information model
FIM	Facilities information model
iBIM	Interoperable Building Information Model
SIM	Structural information model

References

BS 1192 — Collaborative production of architectural, engineering and construction information. Code of practice, British Standards Institution, 2007.

CWCT (2009) — TN 53 - Method statements for the construction of building envelopes, CWCT, 2009.

CWCT (2006) — Standards for Systemised Building Envelopes, CWCT, 2006.

ISO 12006 — Building construction — Organization of information about construction works — Part 3: Framework for object-oriented information, British Standards Institution, 2007.

CWCT
The Studio, Entry Hill, Bath, BA2 5LY

T: +44 (0) 1225 330945
cwct@cwct.co.uk
www.cwct.co.uk

Stage	Purpose	Information	Format	Responsible	Information required from specialist contractor	User
Planning/Scheme design	Architectural images	Solid elements or plates accurately colour rendered	3-D	Architect	Co-ordinates of outer surface of envelope (if appointed)	Architect
Detail design	Clash detection	Solid elements	3-D	Main Contractor System company	Co-ordinates of elements (if appointed)	Main Contractor
Construction	Construction programming	Solid elements	3-D	Main Contractor System company	Co-ordinates of elements (if appointed)	Main Contractor
Envelope design	Manufacture and fabrication	Various	2-D / 3-D	Specialist Contractor		N/A
Envelope design	Checking structural interfaces	Various	2-D / 3-D	Main Contractor/ Specialist Contractor	Co-ordinates of fixings (if appointed)	Main Contractor
Envelope design	Checking service interfaces	Various	2-D / 3-D	Main Contractor/ Specialist Contractor	Detail sections	Main Contractor
Envelope design	Checking interfaces with adjacent cladding packages	Various	2-D / 3-D	Main Contractor/ Specialist Contractor	Detail sections	Main Contractor
Construction	Construction	Method statements	.pdf documents	Main Contractor/ Specialist Contractor	Method statements (CWCT 2009)	Main Contractor
Construction	Construction	Installation drawings	.pdf documents	Specialist Contractor	Installation drawings (CWCT 2009)	Main Contractor
In use	Maintenance	O & M manual	.pdf documents /COBie	Specialist Contractor	O & M manual	Client
In use	Repairs	Component information	.pdf documents /COBie	Specialist Contractor	Suppliers and specification of components	Client

Table 2 Use of Building Information Modelling