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BIM – a driver for change

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Abstract

While the term *building information modelling* (BIM) is widely accepted as referring to a category of leading-edge software for building design, the term also evokes a process view in which the focus lies on the information over the full lifecycle of a building. This reflects the origins of these ideas in interoperability standards. The construction industry is currently migrating from using traditional CAD tools to BIM software which offers considerable advantages as a means to efficiently produce fully coordinated production information. It is the integrity of the underlying database which endowers BIM with wider strategic value. It is argued that BIM is a disruptive technology that presents opportunities to address many of the established challenges that the construction industry faces and a context to address the emerging challenges of sustainability, low carbon and resilience.

Keywords: BIM, process change, design, construction, resilient design.

1 Building information modelling

1.1 The origins of BIM

The term *building information modelling* (BIM) has been adopted by the major vendors of CAD software and it is now widely accepted as referring to a category of leading-edge software for building design and related applications. The computational foundation of BIM software is the object oriented paradigm for the design and implementation of software. While BIM software builds on the success of more traditional CAD applications, the intellectual concept underpinning BIM is that of a product model for buildings.

In this context a *product model* is a formal information model that defines agreed data structures which provide a comprehensive ability to capture engineering information about a particular class of artefact. The concept of an underlying engineering product model was originally developed to enable the creation of more robust data exchange standards, the approach being refined and matured in the context of STEP (ISO 10303). In the 1980s, these concepts were being adopted by researchers in the construction sector and applied to buildings. Much of the early work was associated with the creation of formal STEP standards for the construction industry but more pragmatic STEP-based approaches followed. These resulted in the establishment of important construction industry interoperability standards such as the CIS/2 for structural steelwork and the IFC for buildings more generally. Each of these open standards is underpinned by a published product model. Similarly BIM software applications are each underpinned by a proprietary information model, these are assumed to embody concepts drawn from the published product models.

Several definitions of the term BIM can be found in Chuck Eastman's BIM Handbook (Eastman et al., 2008) including a useful history of the term in the forward written by Jerry Laiserin. That book defines BIM as "a modelling technology and associated set of processes to produce, communicate, and analyze *building models*." With building models being characterised by *building components* (represented by digital objects that know what they are and can be associated with computable graphics, data attributes and parametric rules), *components* (that include data that describe how they behave), *consistent non-redundant data* (so changes are propagated to all views), and *coordinated data* (so the presentation of all views of the model is coordinated).

Among those authors who have attempted to define the meaning of building information modelling there is considerable divergence, some of this ambiguity is implicit within the term itself:

- Does the model refer to the underlying schema or to the model of a specific building?
- Is the term intended to be used as a noun or a verb?

Today BIM is usually written as building information modelling (rather than model) and the term is best regarded as having (at least) two distinct but complementary meanings:

- A particular category of applications software
- A process view which, in the limit, can be characterized as an information-centric view of the lifecycle of a building.

1.2 BIM – the software view

BIM software is still being (largely) marketed as a more efficient means for designers to produce fully coordinated production information. This characteristic is derived from the fact that, unlike traditional CAD which stores and manipulates 2D or 3D geometry, BIM software generates the currently required geometrical representation(s) on-the-fly from the occurrences of *building objects* (such as beams and slabs) in the BIM. Each of these *instances* has a location but no explicit geometry. Thus the underlying model is very much easier to manipulate than traditional CAD and the consistency of all the representations (2D, 3D and none-graphical reports) should be assured because they are all generated from what is a unified database. Critically, this consistency should also extend across different types of representation as found in different types of drawings and at different scales. BIM software employs a parametric object oriented architecture with change propagation, this ensures that a change made in any representation is propagated across the model and thus across all representations.

It is widely recognised that the potential of BIM software extends far beyond the immediate benefit of being more easily (and more reliably) able to produce coordinated production information; the underlying model provides the basis for a more integrated multi-faceted approach to design. Additionally this functionality has the potential to span the design, construction and operation of a building with the concept of a digital *virtual building* that parallels the real building.

1.3 BIM – the process view

Beyond the immediate attractions of the latest BIM software lies the process view of BIM. At a tactical level this is concerned with the short to medium term impact of BIM software on the processes of building procurement. At a strategic level current BIM software will only have a short lifetime compared with that of a typical building. What ultimately matters will be the flow, preservation and aggregation of all relevant information throughout the full lifecycle of a building.

The latter view is well articulated in the first US National Building Information Modelling Standard report, subtitled *Transforming the building supply chain through open and interoperable information exchanges*. This quotes the cost of current industry processes failure to adequately support such workflow as $15.8 billion per annum. This major report argues that although some BIM has existed in different guises for 20 years, it is a fundamentally different way of creating, using, and sharing building lifecycle data and the overall scope of BIM has yet to be defined. Three categorisations for doing this are identified: (1) an intelligent representation of data – authoring tools, (2) a collaboration process, and (3) a facilities lifecycle management tool. The scope of BIM will affects all stakeholders supporting the capital facilities industry who will need to share information via an information backbone (NIBS, 2007).

2 Deployment of BIM

2.1 BIM software

The market leaders are the two dominant vendors of traditional CAD to the industry: Autodesk with *Revit Architecture*, *Revit Structure* and *Revit MEP* and Bentley Systems with *Bentley Architecture*, *Bentley Structural* and *Bentley Building Systems*. Both companies are marketing suites of interoperable discipline-specific BIM applications with each suite being built on a common BIM platform. Neither of these leading vendors were marketing a true BIM application until about eight years ago (Autodesk bought Revit Technology corporation for $133m on 1 April 2002). The other BIM vendors have less comprehensive offerings. *ArchiCAD* which was initially released in 1984 was subsequently recognised as being the first BIM application. Still well regarded, the latest release introduced an innovative BIM server to facilitate synchronisation across a distributed project team, but ArchiCAD lacks strength outside its core area of architecture. *Tekla Structural* is explicitly limited to structural applications and is a development of a leading 3D steelwork detailing application.

Internationally, these are the four best selling BIM platforms and there are relatively few alternative vendors such as Nemetschek and Gehry Technologies. Unusually the latter has created *Digital Project*, a geometrically very flexible BIM like application, by using the powerful CATIA system as its graphics engine. In China, where the move towards BIM applications is less well developed, the overall picture is similar. Revit appears to be the most popular application (Autodesk has a tie-up with several universities) with Archicad and Bentley Systems also selling. Over 20 design institutes are understood to be using BIM but the most popular Architectural application is a Chinese application called T-Arch which is based on AutoCAD.

A key feature of current BIM software is the ability to define parametric constraints to enforce relationships between the relative geometry of objects. This may be used quite simply within a model to ensure for example that certain localised geometric relationships hold true when more global changes are made. It can also be used to define self-configuring assemblies of objects that will automatically re-configure depending upon the context in which they are placed. This approach, which is pushed to its current boundary by Bentley Systems *Generative Components*, is likely to become more prevalent.

2.2 BIM usage

Other than producing fully coordinated production information, and their inherent abilities as a design visualisation tool, the drivers for using BIM software hinge on the integrity of the underlying database. Critically this enables such software to act as a design repository able to interoperate with other specialist software to perform tasks beyond the ability of the BIM software – for example specialist analysis, detailed design, simulation (including the *4D* animation of the construction programme against time) and evaluation (including the related *5D* evaluation of expenditure against progress). Such software may be closely linked (via an API) or more loosely linked (via a data exchange file say) but the ability to "round trip" the information is common, allowing the BIM to act as the information integrator. Thus, within a particular discipline the BIM lies at the centre of the design process with the possibility of several designers working concurrently on different aspects of the model.

For a number of practical reasons it is still the case that complementary BIM models must be created for each discipline. This dilutes the full coordination of the design but, provided the BIM software comes from the same stable, there are powerful abilities to view the other disciplines models from within your own software. Even when this is not the case there are good tools for cross-checking between disciplines models but the advantage is reduced (this has implications for the future). Thus the usage of BIM during the design phase is already impinging on the processes.

Industry is currently transitioning from traditional CAD to BIM, some design companies are already 100% BIM and most larger companies are either rolling out BIM or are conducting serious evaluations. At least seven major BIM surveys have been conducted since 2005. In American a 2005/6 survey suggested 16% of architectural firms had some BIM software rising to 34% in a 2007 survey while a 2008 survey suggested almost 33% of structural engineering firms were using BIM to meet client needs (with another 43% expected to be doing so within 5 years). A 2007 survey of Nordic countries suggested that BIM was being used by architects in about 20% of projects and by engineers and contractors in about 10%.

A 2008 survey (SMART, 2008) of American architects, engineers, contractors and owners who are already using BIM suggested that:

- 62% of BIM users will use BIM on more than 30% of their projects in 2009.
- 72% of BIM users say that BIM has had an impact on their internal project processes.
- 45% (up 10% on last year) of current adopters will be using BIM on at least 60% of their projects
- As users gain experience with BIM, their view of its impact improves significantly.
- Contractors (61%) have the most positive view of BIM.
- 41% of owners reported that BIM has a positive impact on their projects (with 33% very willing to purchase BIM software for other team members).

2.3 BIM – a disruptive technology?

Traditional CAD was introduced into the construction industry over an extended period, with the uptake accelerating rapidly as costs fell significantly and manual draftsmen became hard to recruit. Some reorganisation within design offices was required, but CAD proved to be a largely incremental technology that delivered higher productivity and a useful degree of coordination.

With indications that the deployment of BIM is now accelerating, the probability is that BIM will prove to be a significantly more disruptive technology. This view is informed by the implicit rapid switch from 2D to 3D working and by the opportunities that the dual (software and process) view of BIM will create to further address some of the problems inherent in the construction sector. Others (Jordani, 2008; Arayici and Mihindu, 2008) have highlighted the need for dramatic changes in the current business practices.

3 Opportunities for change

Much has been written about the economic importance and the inherent problems of the construction industry. In the UK this includes a significant number of official reports, most recently (Business and Enterprise Committee, 2008). The underlying problems (including a contractual and confrontational culture and a fragmented structure) have been widely articulated; initiatives have been launched and progress made (partnering and public private partnerships for example). However, further improvements are needed. The industry has embraced ICT but without the degree of transformation seen in many manufacturing and some services sectors. Does BIM present an important opportunity to address some of the challenges?

3.1 Egan report project process challenges

Although the "Rethinking Construction" report (Egan, 1998) largely predates BIM, it speaks of the project implementation team needing to work together from design to construction and commissioning using computer modelling to predict the performance for the customer and minimise the problems of construction on site. The challenges that follow are drawn from the Improving the Project Process chapter of that report.

Repeated processes: Significant inefficiencies in the construction processes, potential for much more systematised and integrated project processes with significantly reduced waste plus quality and efficiency improvements → BIM provides a firm foundation for implementing a systematic and integrated approach to project processes, particularly for a sequence of similar projects. It also helps to reduce waste and improve quality and efficiency.

Integrated projects processes: The full construction team bringing their skills to bear delivering value to the client; efficiency constrained by largely separate processes for planning, design and construction; learning, innovation and development of skilled and experienced teams inhibited by a lack of continuity between jobs → BIM will increasingly support integrated project processes involving all the participants (including the client) and allow the bringing together of the planning, design and construction phases (4D). It is likely to evolve into a platform for learning from previous projects (for example) and should already be a substantial aid to innovation. These characteristics may encourage project teams to stay together to address specific types of projects.

Focus on the end product: Continuous development of the product and supply chain; innovation and elimination of waste blocked by the lack of continuity of project teams → The potential of BIM in these areas has already been outlined.

Product development: Continuously developing a generic construction product – requires detailed knowledge of client's aspirations plus effective innovation and learning from objective measurement of completed projects. This implies a project team that focus on a particular type of project → BIM is already been used in the housing sector which could provide an early example of this approach. BIM has been identified as an integrator of performance measures from completed buildings and could provide a natural route into the subsequent re-analysis of the design of such a building.

Product implementation: Translate a generic product into a specific project – the full team should design the engineering systems, select key components and pre-plan manufacturing, construction and commissioning; use of standard components, precise engineering fit and extensive pre-assembly → BIM can make a major contribution strongly supporting the transformation of generic into particular solutions, facilitating the active participation of the full project team (even when geographically dispersed) and the selection of appropriate components via the internet. Similarly BIM provides a platform for the planning of manufacturing (the generation of reports and integration with external applications for example), construction (4D) and commissioning (potential for driving this from the information within the BIM and storing the results). BIM can actively encourage the use of standard components (component libraries) while its implicit unified geometric model provides the foundation for overall accuracy and accurate prefabrication and pre-assembly of components.

Partnering the supply chain: Not easy but critical to driving innovation and sustained improvements → BIM technology and particularly the associated philosophy can permeate along supply chains making them more efficient and more stable.

Production of components: Detailed design of components and sub-assemblies, management and improvement of production processes, right-first-time, just-in-time delivery, ongoing improvements → The potential of BIM in these areas has already been outlined, with right-first-time and just-in-time delivery being substantial beneficiaries.

Egan also highlighted the challenges of health and safety, an area where considerable progress has been made. BIM has the potential to facilitate substantial further improvements in all phases of a building's lifecycle through initial design, planning and simulations, awareness of what is there etc.

3.2 *The emerging challenges*

We face very substantial challenges in the areas of sustainability, moving to a low carbon economy and designing more resilient infrastructure. The multi-faceted and frequently conflicting requirements, with significant uncertainties and generally spanning the whole lifecycle, will require a very substantial paradigm shift to engage them fully. Ultimately the big challenge is likely to be identifying what is the most appropriate solution, given the environmental, political and fiscal risks and uncertainties plus the diversity of evaluations and simulations that will be required.

The dual software and long-term process view of BIM provides an appropriate context for starting to address these challenges. The BIM software vendors have been quick to recognise the commercial opportunity and some useful evaluation modules are now available. A more comprehensive capability will necessitate many such tools, a high level of BIM integration and a design approach that is able to locate optimal solutions in a very complex design space. This will require considerable investment and innovation and is likely to see knowledge based techniques fully integrated into the BIM concept.

4 Conclusions

Succar defines a series of (increasingly integrated) stages in the deployment of BIM and notes that the associated changes at an organisational and industrial level will be transformational rather than incremental (Succar, 2009). The current evidence is that industry is rapidly adopting BIM software. Many firms are probably driven by the relatively immediate productivity advantages but BIM will soon be widely embedded as an agent for further change. There is already significant awareness of the strategic aspects of BIM and the desirability of open process and informatics standards to realize the full benefits (Howard and Bjork, 2008). The future construction industry will be shaped by several forces including the commercial interests of BIM vendors, pressure from clients to address the challenges identified in section 3.1 and the growing necessity to address the newer challenges such as resilient design identified in section 3.2. Just how this will resolve itself is unclear but, as Succar implies, some form of IT based integrated project delivery will be part of the solution.

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