buildingSMART®
International Alliance for Interoperability™

Constructing the business case

Building information modelling

raising standards worldwide™

BSI®

Contents

First published in the UK in 2010 by

British Standards Institution
389 Chiswick High Road
London W4 4AL

and

BuildingSMART UK
2 Church Road
Kenley
Surrey CR8 5DU

Designed and typeset by Jane Thompson
Printed in Great Britain by Berforts Group

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library
ISBN 978 0 580 70935 7

Introduction and summary

Building Information Modelling or BIM is a technology that brings with it a new way of working. Companies that adopt BIM can benefit from its streamlined approach, in which data is shared in a collaborative environment.

This guide is aimed at firms in all parts of the architectural, engineering and construction (AEC) industry, whatever their size, as well as clients who may be planning to require their supply chain to use BIM tools. It explains the background and enabling technologies, and sets out the business case.

The technologies that underpin BIM have their roots in shared, structured information which, once created, can be used up and down the value chain. If data is to be interoperable, standards – the open IFC standard is one of them – need to be observed. New technology can often seem a threat, but section 1 takes the mystique out of it and explains it in common sense terms. As the industry incrementally adopts the technologies and processes, it will move from a basic CAD approach to higher levels of seamless working and data management.

BIM has the power to encompass numerous functions, from checking planning regulations, through design, fabrication and construction to operations and FM right through to decommissioning and demolition, if need be – it can serve a project from cradle to grave. Its core strength is that all the parties contribute to the central model and draw from it. Completed projects confirm its rich potential. (Section 2.)

Why should we be thinking about BIM right now? With the potential for new efficiencies, uptake of BIM is gathering speed. Research in the US indicates a 75% increase in the last two years, and client demand is increasing around the world. (Section 3.)

Measured benefits include savings in:

- design co-ordination
- drawing production
- information management and exchange
- construction phase

Improvements in design quality, sustainability and client communication have also been reported.

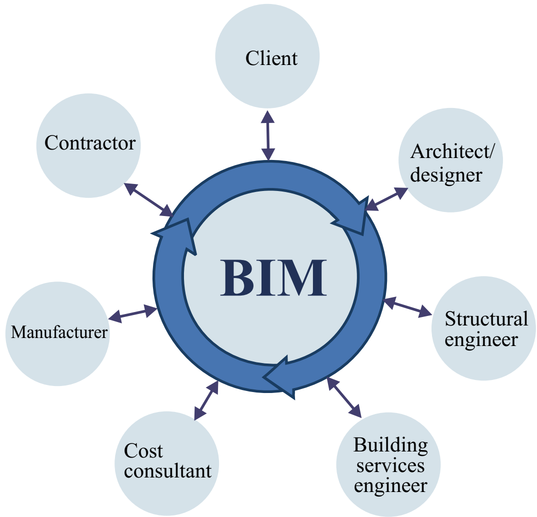
A small sample of UK projects using the technologies has shown that immediate benefits are there for the taking – and this is probably the tip of the iceberg. Benefits include clash detection, reducing the cost of changes, clearer scheduling and swifter fabrication using data from the project BIM. There are competitive advantages and green benefits. At the same time, training and process change are required and software interoperability could be improved. (Section 4.) Case study data is positive and is summarized in the box above.

Benefits to companies and the wider industry are incremental. As a BIM-aware and practised supply chain emerges, so a better co-ordinated industry can reap the benefits. Clients and industry leaders are encouraged to show the way, allowing all the parties to experience cost certainty, reduced risk and higher quality. (Section 5.)

1 On an upward curve with BIM

At the heart of the BIM approach is the ability to structure and share information. This section and the next are for readers who want an outline of what BIM is, how it works and the background against which it developed. The review of our progress towards higher levels of data and process management is intended both for those setting strategy and those implementing it. Section 2 looks at the functions covered by BIM and how they are being used in real-world projects. For senior leaders, section 3 ('Why BIM? Why now?) and section 4 ('Benefits and costs') set out the business case and reasons to adopt.

Figure 1.1 Major participants in a BIM using structured information on a new construction project



Source: BuildingSMART

A short definition

The building information model (BIM) is a set of information that is structured in such a way that the data can be shared. A BIM is a digital model of a building in which information about a project is stored. It can be 3D, 4D (integrating time) or even 5D (including cost) – right up to 'nD' (a term that covers any other information). As a receptacle for project information, BIM has massive versatility and potential (see figure 1.1, and figure 2.2 in the next section).

BIM offers the opportunity to achieve accuracy and certainty in the delivery of products and services. It improves efficiency and allows design processes to be repeated.

But how and why does BIM deliver this outcome? To understand what BIM does and the benefits it brings, we need to look at traditional approaches in construction and FM and their drawbacks.

Life before BIM

The construction and facilities industry has historically used a document-based way of working, through drawings and reports, and has communicated through 'unstructured' text such as letters and emails. Documents are embedded in the contractual arrangements – and in the very culture – of the industry. However, documents have a fundamental weakness. When a document is produced, by hand or computer, it is presented on paper or in a computer file as an unstructured stream of text or graphic entities. This can be understood and checked by human beings, but the lack of structure and meaning in the presentation means that it is inherently difficult to reuse or check. It cannot be used computer to computer – in other words, it is not computable.

In this traditional approach, computer-aided drafting may be used, but there is a complete absence of information-sharing and collaborative working. For this reason, we might call it 'level 0' style working, and this level is just the starting point for a more streamlined, efficient approach. As the enabling technologies are adopted and collaboration between supply-chain partners increases, we can expect the curve of efficient working practices to rise (see figure 1.4).

Improvements in efficiency can pay dividends against a background of complex project documentation. Life before BIM was characterized by the massive amount of documentation that had to be printed and stored. A construction company in Canada compiled data on a number of $10 million plus projects which showed that in each project around 50 different types of document were generated by 420 participant companies (comprising all suppliers and sub-sub-contractors), running to 56,000 pages of documents (study cited in Eastman et al, 2008).

BIM is inherently efficient because it brings project partners together to share information. This boosts industry efficiency – and AEC has some way to go here. Stanford University in the US looked at labour productivity in construction over a 40-year period (1964–2004) and found that productivity appeared to have dropped by 10% over the period. The reasons are complex but the fragmented nature of the industry, with its multiplicity of SMEs, and the slow uptake of innovative, collaborative tools among them, play a part (study by the Center for Integrated Facility Engineering, Stanford). The ability to work collaboratively and share information is key to more efficient practices.

Structuring information

Figure 1.2 Drawback of unstructured information which cannot be reused up and down the value chain

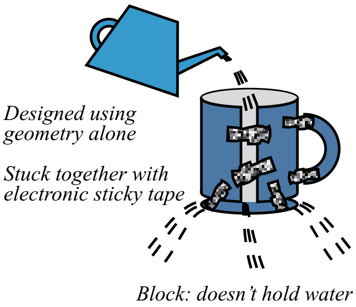
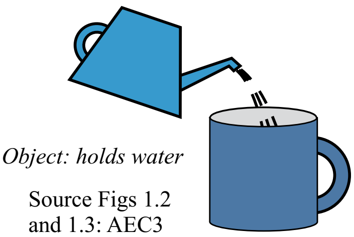


Figure 1.3 Design using computable structured information which can be reused



Source Figs 1.2 and 1.3: AEC3

If we structure information, we organize it so as to maximize its use. A computer can use this information and take action on it. 'Structured' information includes databases, spreadsheets and tables.

Let us take a simple example and design a cup or vessel as a 'block' or 'symbol' (different CAD systems have different names), using unstructured information in a collection of lines and shapes (see figure 1.2). Does that cup hold water, metaphorically speaking?

It does not! But if we design the cup using structured information and treating it as an 'object' – more on objects in section 2 – that cup holds water and the information used in its design can subsequently be reused by others (see figure 1.3).

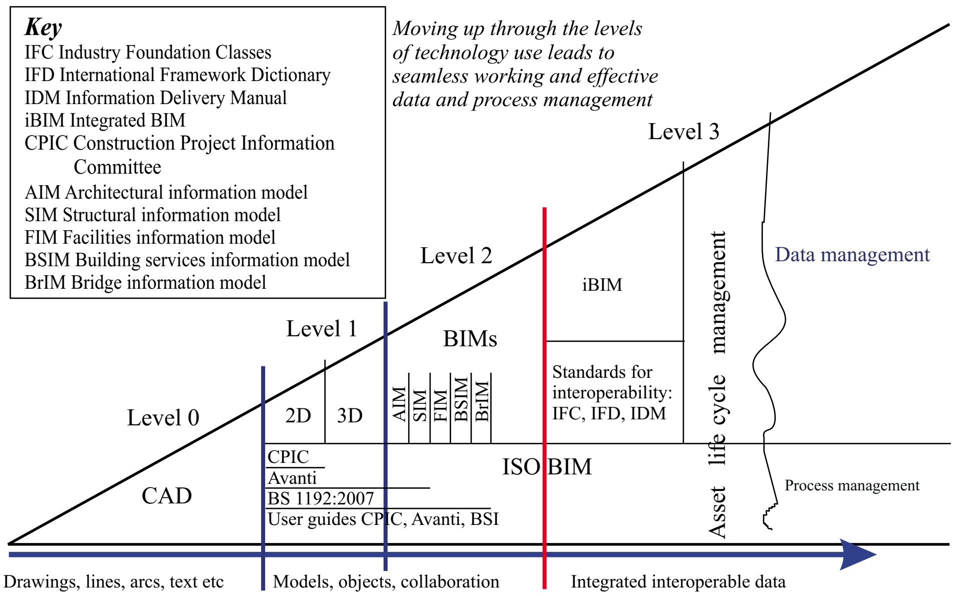
We can go one better here – by sharing that information with our partners on a project. We can bring together sets of information produced by different organizations into a common form. This means that information contributed by one participant is immediately available to the others. Common shared information allows an integrated, responsive value chain to be created.

BIM offers the chance to introduce the benefits of both shared and structured information. It enables more efficient processes and the introduction of better analysis and checking methods. Simply sharing documents may enable enhanced manual processes but sharing structured information enables the validity and quality of information used within the processes to be checked.

Once we start to structure and share information, we are moving to a whole new level. At this level, drafting is often in 3D (though 2D is still used) but there is a greater use of common standards and virtual building elements. We might call this 'level 1', the next stage on progress up the curve of efficiency gain (figure 1.4 again).

Structured information comes in various forms, from small temporary models created for a specific purpose to multiple-purpose shared models. Starting at one end of the spectrum, we might see a spreadsheet used to define spaces, together with their names and required areas, or a geometric model simply made up of basic shapes. A private or single participant BIM makes the model the primary tool for documentation, from which drawings and reports (such as plans and bills of materials) are derived. Moving along the spectrum, a discipline-specific private model offers an intermediate step where the models exist independently but can be brought together for a given purpose. This mirrors conventional practice where drawings are brought together for co-ordination at specific times in a project. By bringing together several such private models and running clash (interference) detection or even an interactive walkthrough, the parties will be able to uncover issues that need to be solved. Finally

Figure 1.4 Levels of information management, data sharing and collaborative working



Source: Bew and Richards, 2008

a shared model or collaborative BIM can be used by all the contributors to the project who add and amend their developments.

Enabling standards

Standards have been developed both by individual companies and by standards-setting organizations to allow complex information to be shared. Some standards may be set for a particular project to ensure consistency.

Standards are likely to cover the use of unique and trustworthy identifiers; the use of well-understood names; information exchange and methods of sharing information, using formats such as Industry Foundation Classes (IFC); and the use of product catalogues for types or families of products.

Standards should set down requirements for consistency, including the use of units and geographical origins. These basic requirements need to be supplemented by agreements on the identification and naming of project-specific datum points, spaces, zones, systems, cost types and quantity measurements. Classification systems such as Uniclass (Unified Classification for the Construction Industry) may be helpful here.

Projects often require their supply chains to use particular standards. Any supplier unable to do so will be at a disadvantage, either failing to win the tender in the first place or, by not implementing them properly, incurring penalties or liability. Contractual arrangements and clauses must make clear the expectations for information, and ISO 29481-1: 2010, *Building information models – Information Delivery Manual* Part 1: Methodology and format, to be published during the course of 2010, offers best practice guidance on how to exploit formal methods of information delivery.

Documents also need to be structured so that the information can be tracked and reused. Standards allow revisions and records of issues to be maintained, versions to be compared and completeness to be assessed. BS 1192: 2007, *Collaborative production of architectural, engineering and construction information: Code of practice* offers guidance.

Building information modelling

The term 'building information modelling' began to be used at the end of the last century and in the early 2000s the term became the agreed headline name for structuring and sharing information via a model. Of course, successful use of a single model environment or project model (these and other terms are also widely used) was already familiar by then, with pioneering use on the Heathrow Express recovery project, Heathrow Europier and Smithfield Market redevelopment.

Individual applications have now opened up the opportunity to create information that is highly structured and can be used in an interoperable way. The open IFC standard (which software vendors can incorporate in their products) offers the opportunity to share this information independently from proprietary formats and tools.

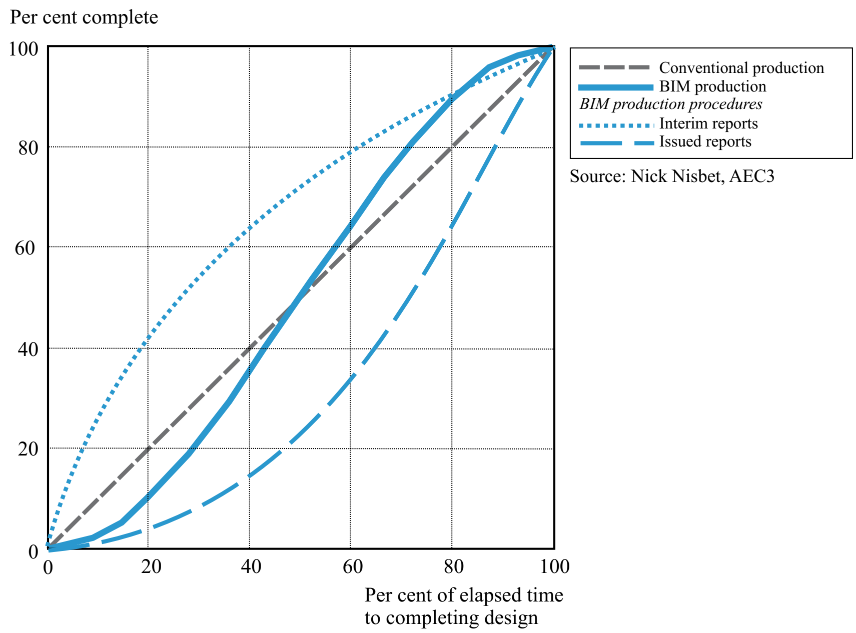
The construction and FM industry around the world has already begun to exploit shared and structured information. This development marks a steady gradual rise to 'level 2' on this upward curve of industry improvement (see figure 1.4 once more).

Improved information delivery

At the heart of BIM are three key benefits to information management:

- Information, once captured, can be reused and repurposed
- Information can be reviewed and revised, corrected and controlled
- Information can be checked and validated.

Figure 1.5 Timing of information delivery via BIM

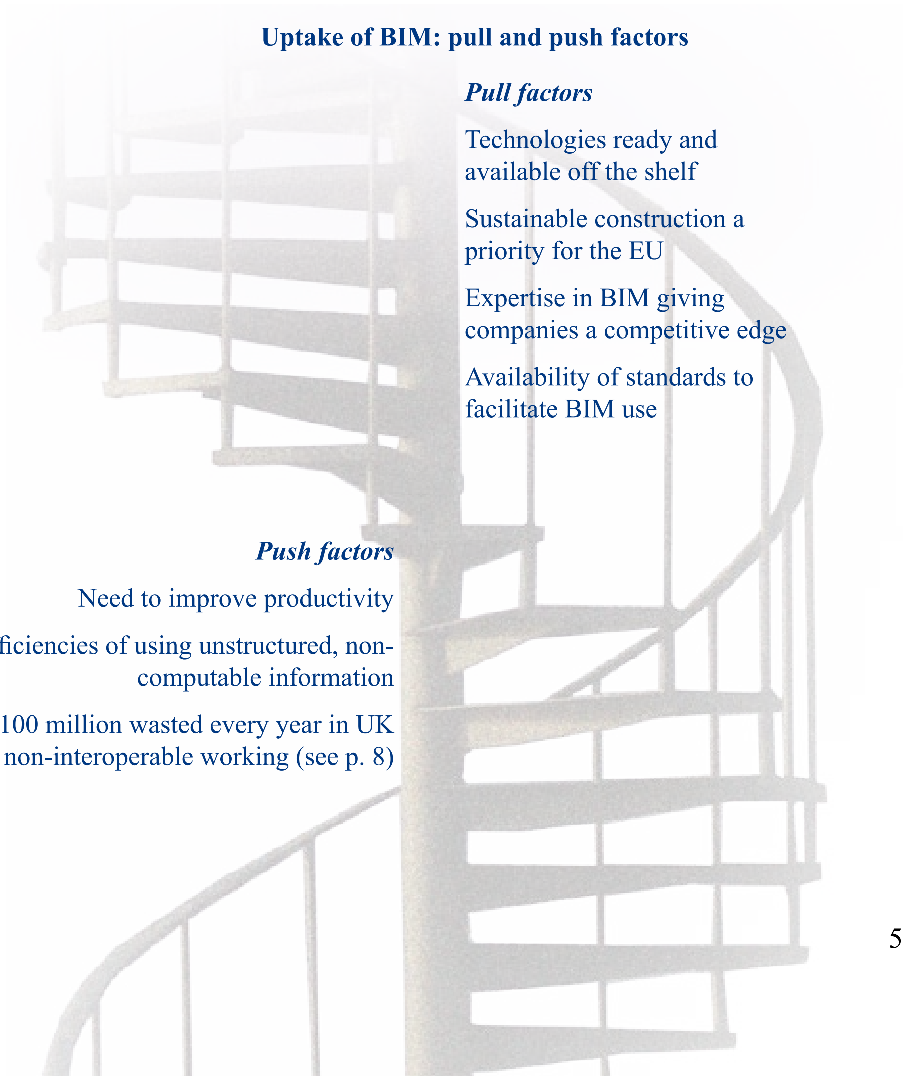


Source: Nick Nisbet, AEC3

People in the industry generally know what information is needed and when, but this knowledge is usually tacit and rarely stated in a form that is easy to understand and check. However, once industry starts to express its expectations in advance – 'to perform this process, I need that information' – the moments when the exchange of information is required can be mapped and highlighted. These exchange requirements, in the form of checklists, are nothing new in themselves but when the players are using BIM and working collaboratively, these requirements can be formalized. They can be broken down into functionally significant parts, making it possible to verify the results of information exchange and certify that the tools used for the exchange do in fact meet the stated requirements. The effect is to build repeatability and trust.

Traditional productivity measurements, such as 'drawings produced per week', become less relevant with BIM. Information is captured and conveyed at a much finer level: informal information transfers and assessments can occur many more times between the more formal hand-off points.

A powerful benefit of BIM is its ability to make information available earlier during the project. Hold-ups on the critical path due to lack of information are as destructive as lack of physical resources, and conventional production only delivers information towards the end of each phase. But by using BIM, information is available sooner and interim checkable reports can be produced more frequently. The number of requests for information (RFIs) is probably the most useful measure of the value of BIM. With high-quality collaborative BIM, the number of RFIs may be expected to fall significantly. Since each RFI requires work to resolve, fewer RFIs means more productive work time available and better design, construction and operation. Some industry professionals, however, have found that RFIs are shifted to the front end of a project and do not diminish as much as they had hoped. Figure 1.5 shows how the use of BIM leads to checkable reports becoming available much faster.



Uptake of BIM: pull and push factors

Pull factors

Technologies ready and available off the shelf

Sustainable construction a priority for the EU

Expertise in BIM giving companies a competitive edge

Availability of standards to facilitate BIM use

Push factors

Need to improve productivity

Inefficiencies of using unstructured, non-computable information

£100 million wasted every year in UK through non-interoperable working (see p. 8)

2 More about BIM – form and function

Structuring information into 'objects' for AEC industry

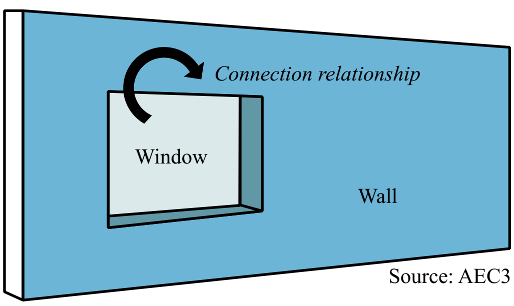
The building information model is usually created by software that uses object technology. An object, in computing, is something that has a name and properties, as well as relationships.

AEC objects are large, complex and dynamic, reflecting the host of interdependent and multidisciplinary activities that go into a construction project. The different software vendors have their own proprietary systems which use different rules for the definition of object families, so their systems are not interoperable. However, to overcome this problem and to ease the flow of information between the parties involved in a project, a standard known as IFC (ISO PAS 16739: 2005, *Industry Foundation Classes*) has defined AEC objects – physical items, the spaces between them and the processes involved. In this way, rich and useful information can be shared between project partners, without loss of accuracy or design intent.

This is much more than simple geometric information. The beauty of objects and the relationships they represent lies in their scope and versatility. Relationships can cover abstract ideas as well as material buildings, and objects can be linked to all sorts of activities: planning, co-ordinate mapping, costing, work plans and scheduling and much more. Figure 2.1 shows how specifications and relationships are recognized and preserved with IFC objects; these connection relationships carry important information.

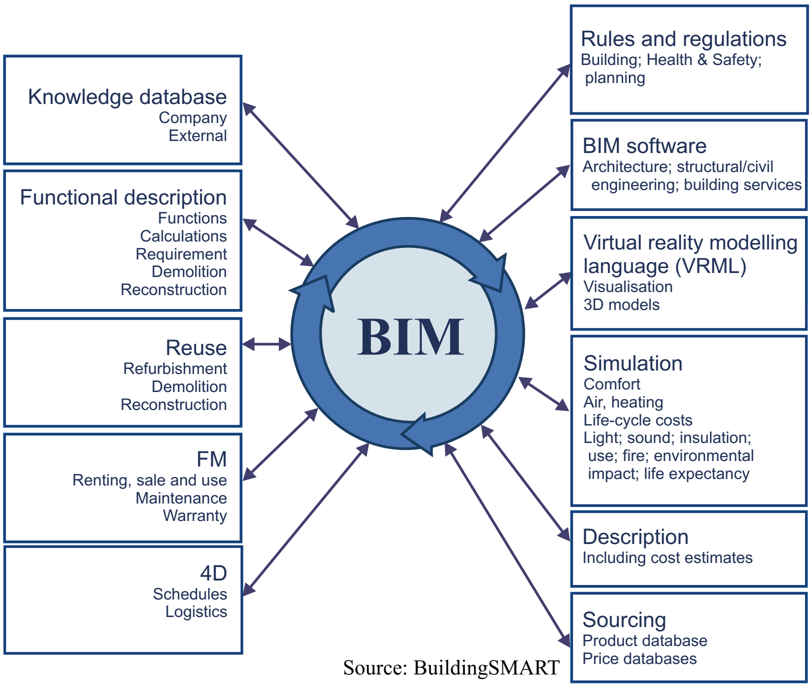
The IFC object is an information-rich tool that will help design and construction work more efficiently.

Figure 2.1 Relationship between wall and window captured by IFC



Source: AEC3

Figure 2.2 A fully functional BIM



Source: BuildingSMART

While not every BIM is IFC based, those that use IFC-compliant software offer the greatest potential.

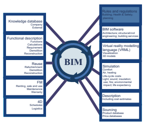
Knowledge intensive services

The ability to share such rich information chimes with a fundamental shift in the industry and is pushing it forward. Once, the AEC supply chain designed and delivered the project, rectified any defects – and moved on to the next project. As-built information reflected a moment in time.

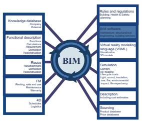
Now the knowledge available has ongoing value for the whole life cycle of the built asset. Energy analysis and life-cycle costing carried out at an early stage will have a lasting impact on the building. At handover, the as-built information, contained within the BIM, becomes a living tool for operation and maintenance. So the role of the supply chain is not only to create a physical building but to provide a 'knowledge service'.

The full BIM and its functions

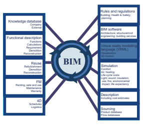
Figure 2.2 shows a fully functional BIM. Most BIM-based projects do not yet use a BIM for every single function but select functions of most immediate use. Indeed, for clients and new adopters, it is sensible to opt for a partial BIM. But each of the functions can bring much to the shared knowledge pool and has much to gain from it. This section highlights some of these functions, with real-world examples.



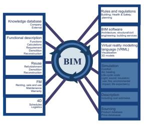
BIM can be used at the very start of a project, in the planning approval process and in checking that the project conforms to regulations. The Science Lab Plaza in Amsterdam used a BIM to liaise with city planners, while the planning authorities in Norway and Singapore handle applications digitally.



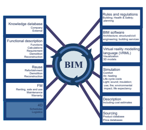
BIM is widely used at the various design stages of a project. When the individual disciplines – architecture, structural engineering and building services engineering – contribute their own models to the BIM, a growing picture is built up. Clash detection software can be run to identify any conflicts. A hotel and retail project in Atlanta, US, used a BIM for clash detection during design. The BIM revealed over 590 clashes and led to cost savings estimated at $800k.



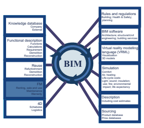
BIM also allows 3D visualization of the design, so that the project comes alive before it is built. This helps the project team to explain the design solution to the client, especially useful with one-off construction clients. At the new Bridge Academy school in Hackney, BIM was used to explain the complex design to the client and gain client confidence.



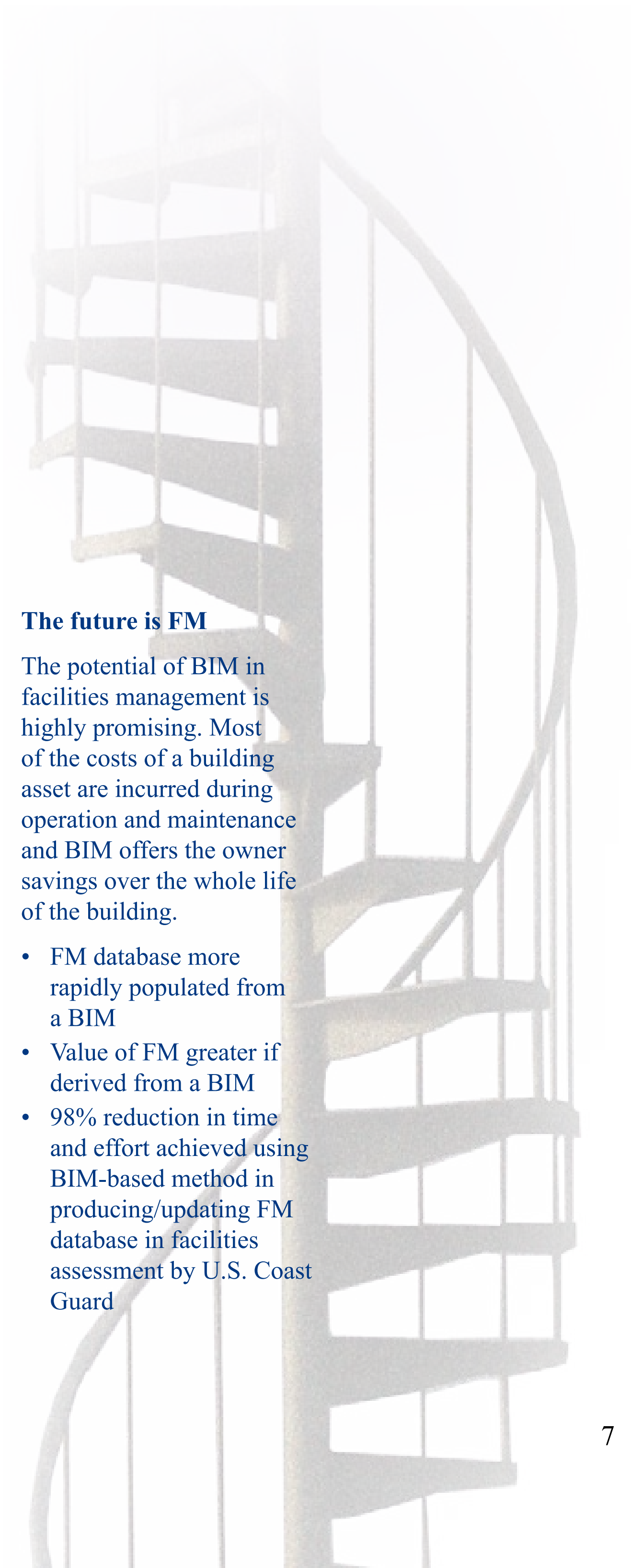
BIM allows a wide range of functions and checks to be performed. Design can be improved by exploring heating, lighting and comfort, or looking at life-cycle costings (analysis tools are available); costs can be extracted; fire ratings and safety information can be checked; and specification can be extracted from the model.



A time dimension can be added to the BIM to assist with scheduling and construction management. The Bird's Nest Stadium, built for the Beijing Olympics, used an IFC-based construction information model with a linked 4D construction management system. This allowed progress to be visualized and provided a real-time understanding of what was going on.



Finally, the BIM can be handed over to the building operator at completion. This is an area offering high value, as the Sanger Institute, Cambridge – a major player in human genome research – recognised: at the completion of its new campus buildings, the BIM was handed over to operations and maintenance.



The future is FM

The potential of BIM in facilities management is highly promising. Most of the costs of a building asset are incurred during operation and maintenance and BIM offers the owner savings over the whole life of the building.

- FM database more rapidly populated from a BIM
- Value of FM greater if derived from a BIM
- 98% reduction in time and effort achieved using BIM-based method in producing/updating FM database in facilities assessment by U.S. Coast Guard

3 Why BIM? Why now?

Industry observers and practitioners – Sir Michael Latham and Sir John Egan among them – have long believed that there is a great deal of waste in design and construction. Greater efficiency could achieve significant savings – up to 30% has been argued.

Wasted effort is caused in large part by duplicated work in a complex supply chain, where data used further down the supply chain has to be re-entered or recreated by other suppliers, largely because the software used by each party is not inter-operable. The National Institute of Standards and Technology (NIST) looked at this problem in the US a few years ago and estimated the total cost of inadequate interoperability at $15.8 billion a year, the equivalent of 2.84% of the annual value of construction (2002 figures).

The true cost of the lack of interoperability in the UK has not – and probably could not – be accurately measured but estimates suggest that the scale of waste due to a lack of shared structured information for owner operators in the UK amounts to £100 million a year. Two-thirds is incurred directly by owners and one-third through the facilities management industry. There is, in any event, wide agreement that process and technology change could be harnessed to deliver improvements in cost and quality. Collaborative working, using a central BIM, offers a practical way forward.

But not everyone believes that the time is now. Practitioners are often sceptical of ‘first mover advantage’ and fear that using new technology too soon is a recipe for trouble. Let some other firm, they argue, act as guinea pig!

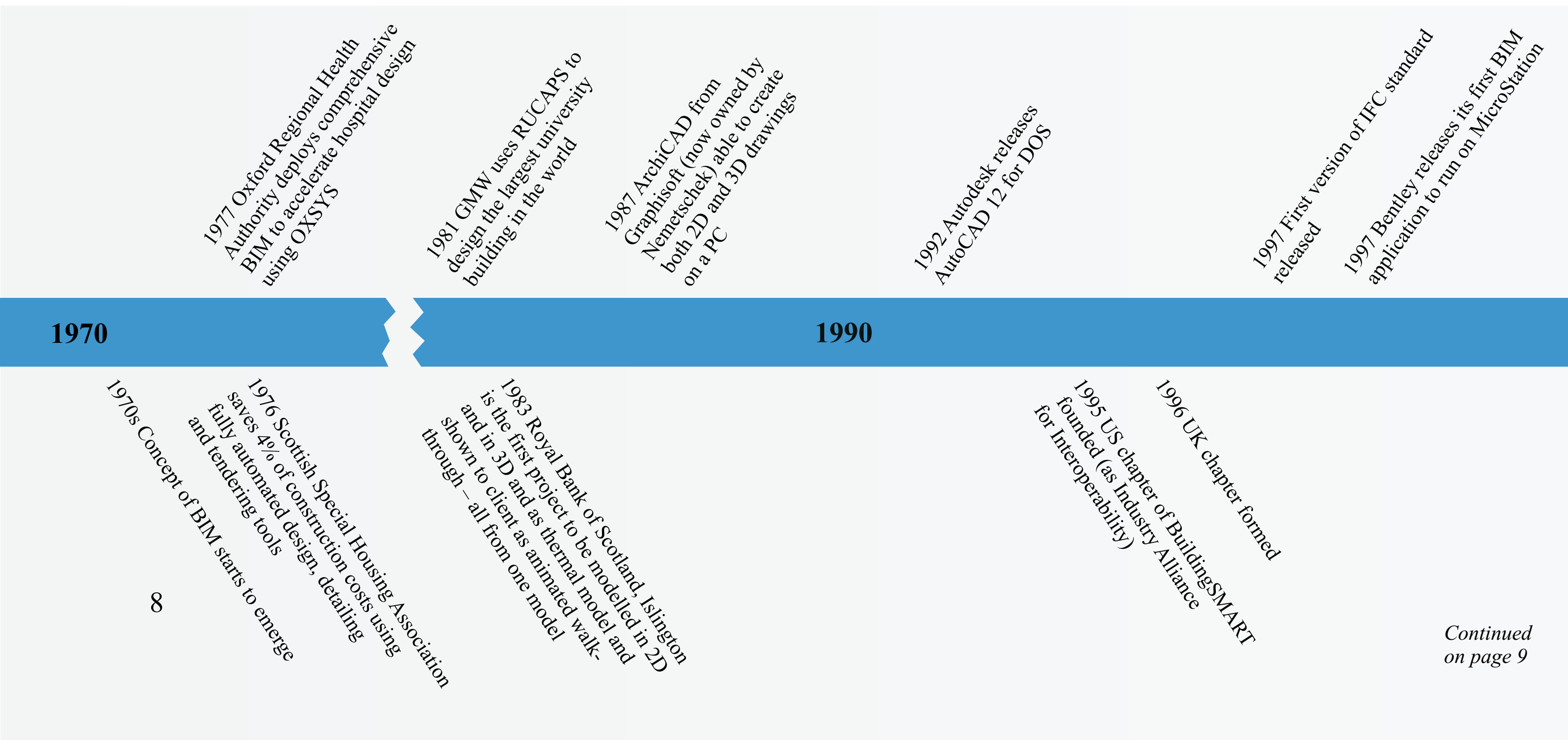
An irreversible trend

In fact, the technology of information exchange has advanced significantly over the last decade. The open IFC standard for interoperable exchange, which many of the software houses use, has increased its coverage over a series of releases, while keeping to the same basic platform. A new IFC release – IFC2x4 – will be available at the end of 2010, offering major enhancements. Software companies have also made continuing advances since their early products in the late 1980s and in the 90s (see timeline in Figure 3.1). Nonetheless, some gaps have yet to be covered; this is discussed in the next section.

Uptake of BIM is gathering speed. McGraw-Hill Construction measured the use of BIM in 2007 and 2009 in the US (again, there are no figures as yet for the UK but industry conditions are comparable). Over the two-year period a 75% increase in use was noted. In the Mc-Graw-Hill research – *The Business Value of BIM* – the pace and extent of BIM are explored using a variety of measures. Over the two years 2007–09, the number of expert or advanced BIM users had increased three times (the 2009 figure stood at 42% of all users). More contractors, the research found, were using BIM and non-users were being converted to the cause .

Other figures from surveys in the US bear this out. Asked when they thought they would have to use BIM to meet their clients’ needs, over 90% of structural engineers said within 24 months – and 64% said they would have to use BIM right now (survey published in *Engineering News Record*, April 2008). A survey of US architects found that

Figure 3.1 International BIM timeline



Continued on page 9

in January 2007 20% of firms were using BIM on billable work; the figure a year later was 31% (American Institute of Architects survey). And over two-thirds of larger firms were using BIM on billable work.

Across the US and parts of Europe, we are reaching the critical point at which BIM becomes an irreversible requirement – a tipping point. While no figures are available for the UK, similarities with the US and anecdotal information suggest that uptake is also increasing here and that the tipping point may not be far over the horizon.

Once BIM has been adopted, users find, to their satisfaction, that there is no going back. Those who were early adopters have started to embed BIM use in their practices; those who are about to embark on it believe it will bring value. Most are agreed that BIM has unlocked potential, offering better design, reduced risk and fewer claims, and that this potential will be realized over the next five years.

Client demand on the increase

Government bodies across the world have begun to require their supply chains to use BIM. From 2001, the Finnish state property services agency, Senate Properties – which manages a large portfolio, including university, cultural and prison buildings – developed a series of pilot projects using BIM. The success of the pilots led Senate to require its suppliers, from 2007, to use BIM for a number of functions such as early-stage visualizations, architectural design and energy simulation. Public sector agencies in other Nordic countries are doing much the same: in Denmark BIM use has been a requirement for larger state projects since 2007; in Norway, the Statsbygg agency will require IFC/BIM use from 2010 and has already built up extensive experience and demanded IFC from all entrants in a major design competition.

In the US demand for BIM use in the public sector is starting to move fast. Two large owners of public assets, the U.S. Coast Guard and the General Services Administration, have led the field in requiring BIM use for certain functions. The U.S. Army Corps of Engineers and the Smithsonian Institute also have BIM requirements. Now individual States are following suit, with Wisconsin and Texas demanding BIM expertise and use from their suppliers.

In the private sector, enlightened clients have specified that BIM will be used on the project. What is forward-looking today will be commonplace tomorrow. BIM use is no longer at the cutting edge. This is the time for firms to build competence and for clients to seek out suppliers who have that competence.

The answer to the question 'why now?' is twofold. BIM use is already widespread, so industry practitioners should take care not to be left behind. If they develop BIM capability, they will be on the front foot as more clients make BIM use mandatory.

Key drivers for uptake of BIM

- A leaner more productive model
- Lower cost, less risk, higher quality
- Easy design optioneering for more sustainable building

Continued from page 8

2002 Autodesk acquires Revit Technology Corporation and changes its basic platform

2002 Singapore launches CORENET e-submission – a collaborative digital tool for planning applications

2003 IFC2x2 released

2003 General Services Administration (GSA) sets up its National 3D-4D-BIM programme

2005 IFC becomes ISO PAS 16739 (publicly available specification)

2006 Bentley's MicroStation V8i BIM application released

2007 In Finland and Denmark BIM use required for public-sector projects; in the US, the GSA also mandates BIM use

2008 Revit 2009 released

2008 Bridge Academy, Hackney: new £50 million 7-storey school building opens – the project made targeted use of BIM

2008 Heathrow Terminal 5 opens, having achieved unprecedented savings through structured information sharing

2008 Akershus Hospital opens in Norway BIM was a vital tool throughout the project

2009 48% of the US industry using BIM (McGraw-Hill survey)

2000

Source: Dinesen and Thompson, 2010

4 Benefits and costs

What are the benefits of adopting BIM? What extra work – and cost – is entailed? Anyone thinking about BIM will want to weigh the costs and benefits. This is not straightforward, as one construction project is different from the next, making it hard to compare and measure. Much of the saving lies in the avoidance of rework, and who can put an accurate price on savings achieved through something that never happened?

Nonetheless, some work has been done to measure savings in the UK by a government-sponsored project called Avanti. The Avanti team worked with client owners and suppliers on implementing BIM techniques, and costs and benefits were recorded. (The Avanti Object Modelling Guide, an outcome of the project, offers best practice for exploiting BIM.) The Avanti project found significant savings were achieved by using BIM techniques. Figure 4.1 summarizes cost benefits measured on case study projects; in some of them Avanti tested the processes used.

Cost-benefit analysis of BIM may be unnecessary, and even specious, as BIM use starts to approach a tipping point in the UK – some argue it already has. Once a technology becomes dominant, that is the way to go. Think about the use of a quill pen versus a typewriter, or a typewriter versus a PC. How far would a cost-benefit analysis of the different modes really have helped in the transition?

But prospective users need to know where the labour, and even the pain, will lie and where they can expect to find quick wins and longer-term improvement. This section will give new users realistic expectations.

Benefiting both project and players

As the project partners share information via the BIM, the project is able to progress more smoothly. Project benefits include:

- entering data only once and reusing it throughout the life cycle of the project
- blending geospatial and building information for planning
- reducing requests for information and change orders
- reducing rework
- improving awareness of progress and current status

Figure 4.1 Costs and benefits of collaborative working

St Helens and Knowsley

The St Helens and Knowsley PFI is a £350 million project to redevelop a dual hospital site in Merseyside. The St Helens Hospital facility opened in 2008; the Whiston Hospital Main Building is opening in spring 2010, six months ahead of schedule. Collaborative working and information-sharing were adopted, using a common data environment. **Costs**: CAD rework cost £20–30k (but could have been avoided by earlier adoption of collaborative approach). **Benefits**: Waste driven down, with 60–70% saving in time to find documents; 75–80% saving in design co-ordination; positive impact on the critical path.

Endeavour House, Stansted

Endeavour House, an office building for KLM, was the third of a series of six buildings commissioned by BAA Lynton. Project-wide CAD standards and procedures were established to enable collaborative working and data sharing, and a fully co-ordinated 3D model was used for spatial co-ordination, clash detection and the identification of areas of ambiguity. A library of standard components was created for use on the next building in the series. **Benefits**: Cost savings of 9.8% of project costs and 18% saving in the cost of drawing production (independently audited).

Palace Exchange, Enfield

Palace Exchange was a £30 million retail development that links the town's main stores and provides parking. Design concepts had already been developed by the time the decision to adopt collaborative working was made, so a consultancy was brought in to advise on spatial co-ordination and do the 3D project modelling from 2D designs. A methodology known as Standard Methods and Procedures (SMP) was adopted. **Costs**: Restructuring the drawings cost (but could have been avoided by earlier adoption of collaborative approach): 24 man-weeks or £60k. **Benefits**: Improved information management, estimated at nearly 800 man-hours or £50k; use of project extranet for information exchange saving up to 50% of effort and improved spatial co-ordination and cost certainty.

Festival Place, Basingstoke

Opened in 2002, Festival Place is a large regional shopping centre in Hampshire, redeveloped at a cost of £110 million. New buildings had to be fitted around existing shops in a complex jigsaw, so a 3D model was used to simplify the process, enable spatial co-ordination and clash detection, and help sequence the construction programme. **Costs**: The initial model took two modellers three months to complete. **Benefits**: Savings of around 9% (est) realized in the construction phase.

Heathrow Express recovery project

In 1995 BAA started a recovery project for the Heathrow Express (HEX) rail project after the collapse of one of the HEX tunnels the previous year. A single model environment (SME) was set up, enabling (among other things) 3D modelling and spatial co-ordination, visualization and electronic drawing management. **Benefits**: Risk reduction through use of SME; no formal figures available.

Terminal 5, Heathrow

BAA again used a single model environment for Heathrow's Terminal 5 which opened in 2008. This was a massive undertaking, comprising 16 projects and 147 subprojects, with complex discipline interfaces. A single CAD system – the SME – was developed to store and share data. The models for the rail station, multi-storey carpark and main terminal building were brought together in an integrated 3D model, and 4D construction planning was used for part of the project. **Benefits**: Again, no formal figures available but observers believe that savings through SME use were very considerable.

General Motors plant extension in the US

GM needed an extension to its plant in Flint, Michigan to be completed as a super-fast-track project. Swift steel fabrication to tight deadlines played a crucial part in successful delivery. All project participants had to use BIM tools. The steel fabricator, already experienced in BIM, worked directly from the BIM model, eliminating the traditional 2D CAD paper-based workflow. An iterative process was used between the steel fabricator and the architect/engineer as individual 3D models from other parties were incorporated in the BIM. **Benefits**: steel structure erection completed 35 days early; project delivered five weeks early; good ROI (figures not disclosed).

- avoiding clashes
- reducing cycle times between reviews
- creating a time-based simulation of construction activities
- reducing costs
- ensuring lower whole-life costs for the asset through sustainable design – tested out at the design stage.

There is a collective value to the project in using BIM that adds up to an improved end-result for the client. As information is captured within a BIM, it can provide input to analysis that promotes certainty. There is better understanding and control of costs and schedules, as well as the ability to ensure that the right information is available at the right time to reduce requests for information, manage change and limit (or even eliminate) unforeseen costs and delays.

At present, the greatest value from BIM is seen in design development, construction and preparation of construction documents and fabrication. Figure 4.2 highlights the areas where the use of BIM has proved attractive to early adopters.

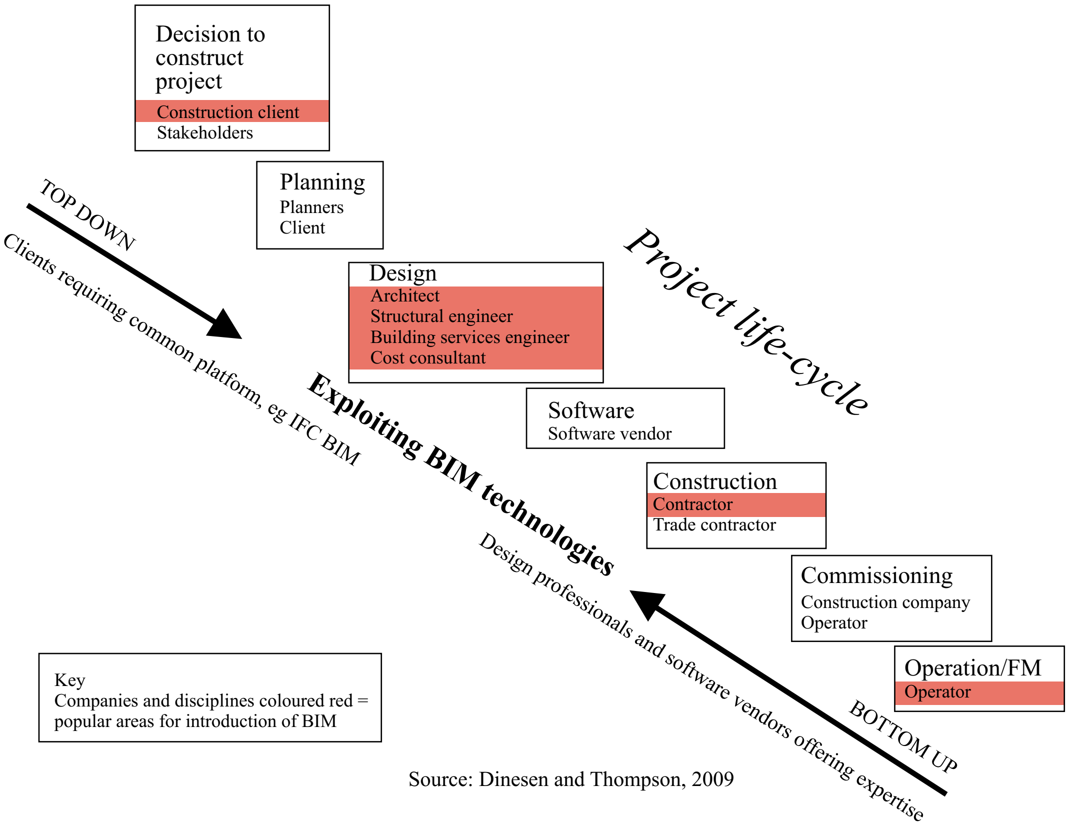
Clash detection

A powerful and popular use of BIM is for clash detection: to identify if any elements of the design are vying to occupy the same space in the building. Spatial co-ordination via the BIM can also dramatically reduce costs by ensuring that problems are resolved early on and not once construction has started. This is a quick win for the designer, contractor and project owner.

Reducing the cost of change

BIM users report that design effort increases at an earlier phase in the project but decreases later on. This pattern was forecast by Patrick MacLeamy, CEO of HOK (a firm that is a keen user of BIM) in 2004 when he compared historical workflow and integrated project delivery workflow. As the cost of making design changes rises over time, so the ability to improve the design and reduce costs decreases. The four factors are plotted in a diagram that is now known as the MacLeamy curve (see figure 4.3). If this concept is correct, integrated working (whatever contractual form it takes) will save money by taking design change to an earlier, less costly phase of the project.

Figure 4.2 BIM uptake: areas where the benefits of BIM are being felt



Source: Dinesen and Thompson, 2009

Management of construction

The ability to simulate construction activities through BIM will help with sequencing and scheduling in the construction phase. A model may be broken down into packages and work methods. Site-based skills may be applied to the model to resolve process clashes, where one trade may inhibit another. Earned value, cash flow and equipment or human resource peaks and troughs can be analysed and resolved.

Benefits to the other parties

Parties all along the supply chain can participate and derive benefit. Cost consultants, for example, can use BIM to take off quantities and get prices. Fabricators can make an important contribution to the project while gaining benefit themselves. Manufacturers of off-the-shelf building products can benefit by supplying their data in interoperable forms for use in design, construction and management systems. Electronic product data – held in catalogues that designers and specifiers can access seamlessly – offers great promise. Components that are engineered to order, such as structural steel, precast concrete and curtain walling elements, often have long lead times in a process that is labour intensive and prone to error. Linking the project BIM to the fabricator's system leads to savings in time and cost as well as improved accuracy and communication. The structural steel industry has been progressive in its approach to 3D modelling and BIM – see, for example, the GM plant extension case study in figure 4.1.

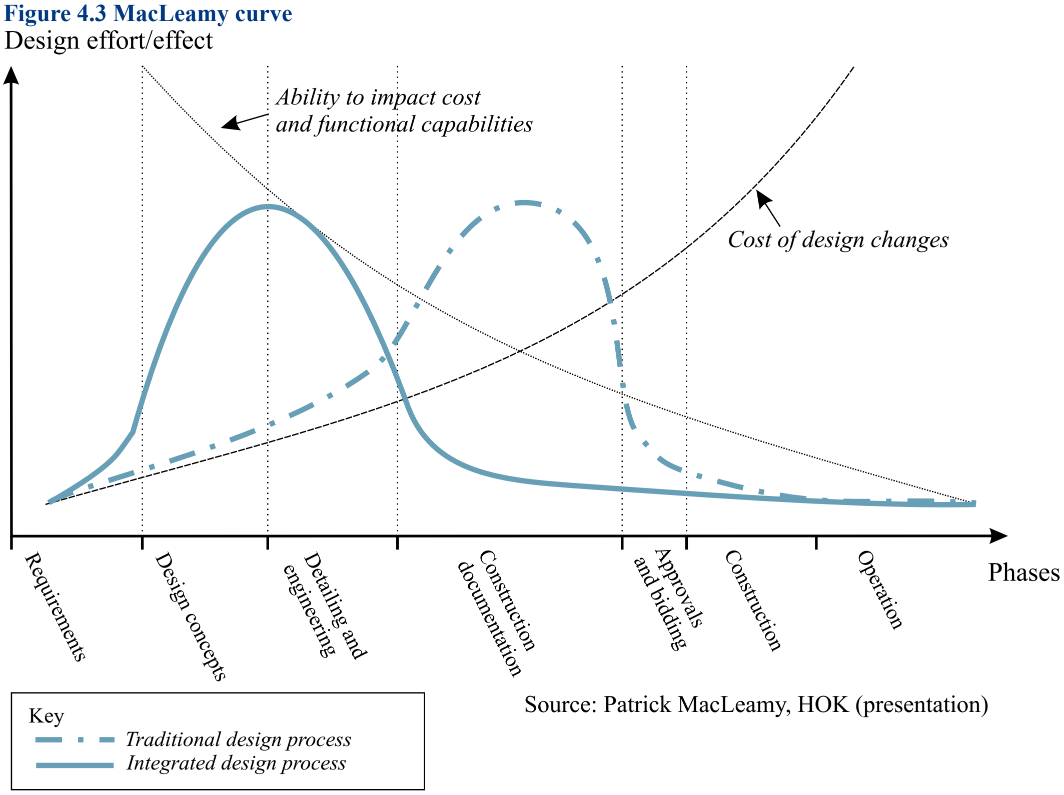
The cost of progress

Progress has to be worked at. Moving from a 2D environment to a 3D BIM environment, or more precisely from a document-based environment to a databased environment, is a step change which needs careful management. Using the technology, developing the human resources and selecting the right projects for roll-out all play a part in successful implementation. Adopting BIM is likely to have a ripple effect throughout the firm.

More effort is required upfront to create individual models and the integrated BIM. BIM also requires more active management than CAD. Information development, integration, sharing and use may require the development of new information management skills and policies. Creating new internal BIM procedures and using BIM to support value creation require effort and cost.

Training may also be required to build capability. All the disciplines may need training in BIM techniques, from understanding the concepts and using the software right down to document control.

Figure 4.3 MacLeamy curve



Source: Patrick MacLeamy, HOK (presentation)

Trainers themselves may need training. One large multidisciplinary practice is planning to develop 'BIM super-users' in each of its office locations.

Software and its limitations

BIM software may have to be bought, presenting a barrier to smaller firms. More serious, perhaps, is the fact that not all applications are interoperable. Functionality is sometimes inadequate or inappropriate for certain users. Feature that are likely to be useful have still to be developed. There are gaps in coverage and users are frustrated at having to work around them. There is for example an urgent need for manufacturers to adopt a single standard when they supply information about their products – shape, connections, properties and operating requirements.

At the start of a project, unless the client sets out the platform to be used, participants will need to establish how compatible their applications are. Using software that complies with open standard formats such as the IFC standard is fairest to all and does not impose costs on others.

BuildingSMART, the organization that defined the IFC standard and promotes BIM uptake, also offers a service to the industry, known as Aquarium. In an 'Aquarium' initiative, a project client or supplier can take a significant problem – one of high value – to a panel of industry and software experts that is assembled to resolve it. Industry and software representatives may take part or observe and the process is transparent (hence 'Aquarium').

BIM as a tool for sustainability

BIM has great potential for improving the sustainability of a building – potential that has still, for the most part, to be realized. Once a building model has been created, energy and thermal analysis can be carried out. At this stage, design changes can swiftly be made and the analysis rerun, so that the design achieves optimum efficiency.

BIM allows a facility to be analysed both for its energy consumption and its other impacts on carbon generation thoughout its life cycle. Assessments can also track other environmental impacts, including water consumption and pollution.

Aurora II – a mixed-use facility at the University of Joensuu in Finland – was built using BIM, with software packages that included ArchiCAD (architecture), BSLCC (life-cycle costs) and Riuska (energy simulation). It became clear during design that the building was not energy-efficient but the flexibility of the model meant that design changes could be easily accommodated.

The sustainability aspects of BIM are being underused. The 2009 McGraw-Hill survey in the US found that so far only 15% of BIM users were getting a high level of value from BIM in energy analysis. By contrast, US practitioners are upbeat about the future use of BIM in sustainable building projects and forecast growth in BIM use for green building in the next five years.

Users have argued that interoperability of energy modelling and analysis software is inadequate and are eager for improvement. The software houses are taking this on-board. In 2009 Graphisoft launched its EcoDesigner – an energy evaluation tool that is fully integrated with a BIM application – while the other major software companies have also improved their offerings.

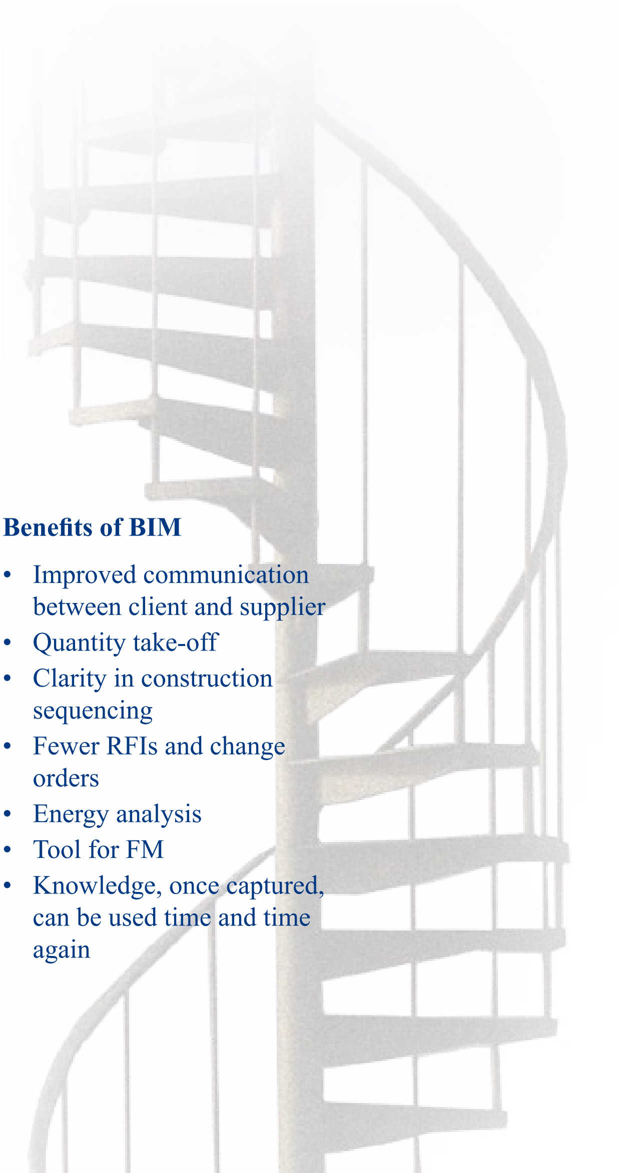
An innovative software application was developed for WS Atkins for a planned community centre in Redhill, Surrey within a BIM. The project showed how environmental impact analysis could be used at an early stage of design, using a system of 'eco-points' to measure the impact that the project would have. Environmental impact, construction cost and whole-life cost were evaluated alongside one another so that balanced decisions could be taken.

It is during occupation that a building incurs the greatest costs – energy use, operations and maintenance. Design costs comparatively less, construction comparatively more and use of the building most of all. The ratio of costs is commonly reported as 1:10:100. Therefore everything that *can* be done to lower the cost of building and occupying the asset *should* be done. Simulation of design and construction via the BIM is one way. Another is ongoing use of the BIM during the whole life of the asset.

Information about the asset contained in the BIM – the location of all the plant, the services, the materials used in construction, energy use and carbon performance – will help ensure that the building is run cost-effectively and sustainably. As sustainability demands increase, we will need to know more about the performance of products over their life cycle. Effort always has to be put into maintaining the BIM as a living tool, not a dusty archive, but there is a strong sustainability dividend to be gained here.

Competitive advantage

Expertise in BIM offers a competitive advantage. Firms are using their competence in BIM as a differentiator to seek out new business or get repeat business from existing clients. With BIM shown to cut out waste and reduce rework, BIM capability is a strong selling point.



Benefits of BIM

- Improved communication between client and supplier
- Quantity take-off
- Clarity in construction sequencing
- Fewer RFIs and change orders
- Energy analysis
- Tool for FM
- Knowledge, once captured, can be used time and time again

5 The bigger picture

As the use of BIM spreads, the benefits to the industry as a whole will be felt. The immediate benefits are likely to be in the areas of design co-ordination, reduction of errors and fewer RFIs. Better communication with clients and with other parties along the supply chain is being reported, and BIM is proving a useful tool in fabricating the engineered components and scheduling construction. This is the low-hanging fruit where early wins are being achieved.

In the medium and longer term, the benefits to industry will increase as the whole supply chain comes on board. Individual design firms, construction companies and clients will benefit from reduced costs and earlier delivery of projects. Risk and uncertainty are reduced. For society there are benefits too: public sector budgets will go further if waste – wasted effort and duplication – is taken out of the design, construction and FM processes.

Once we reach the level of truly integrated working, these greater gains can be realized. Using BIM tools, working collaboratively and ensuring that design/construction information is interoperable will power our progress towards the higher levels of an efficient industry. Meanwhile, there are major wins to play for, on both the client side and the industry side.

What next for clients?

Clients are often in the best position to lead the introduction of BIM. Client demand is one the most motivating factors for BIM uptake – and greater awareness is a first step to adoption. Public sector clients can take advantage of their strong position to drive change. The best way forward is to start with pilot projects. Realistically, this means taking part of a larger project and asking the supply chain to use BIM for one or two aspects of the project to keep the scope of BIM use manageable in an initial foray. Aspects such as energy assessment, clash detection, construction management or structural engineering might be selected for a pilot.

Once public sector clients have gained initial experience, they can set a timetable for the incremental adoption of BIM in their projects. At the same time, to exploit the sustainability potential of BIM, they may consider awarding bids on the basis of performance as well as price. At the moment, bids are often awarded on the basis of price and the evaluation does not sufficiently take the price/performance ratio into account.

Private sector clients also benefit by requiring the use of BIM. Large clients are already involved. Both infrastructure and pharmaceutical companies are benefiting from the holistic approach that BIM offers and are taking it forward to manage their whole property portfolios.

And for industry leaders?

Companies need leadership from the top to set the direction. BIM is just as likely to be deployed on a project at the instigation of the design firm or the main contractor. As contractors reinvent their contribution and take on a long-term role managing the building asset, they recognize the benefits of a complete as-built BIM and should expect to be asked for BIM to be used on the project.

Clarifying and agreeing the strategic shift is the first stage – BIM is more than buying the software. A new strategic framework needs to be created in which BIM implementation takes place. The knowledge and skills available in the organization need to be harnessed while others are brought up to speed with training and mentoring. It may be a case of using the company's 'A team' players to exploit the idea externally and internally and lead the implementation. This has to be carefully monitored and managed to avoid loss of billable time. Smaller firms may consider buying in modelling expertise.

Success breeds success

BIM can deliver from the start but experienced users will get a wide range of incremental benefits over time. It brings value and facilitates teamwork, collaboration and project delivery. But above all, it demands clarity of intention. Clients and supply chains need to have clear goals and then use the power of BIM to achieve them.

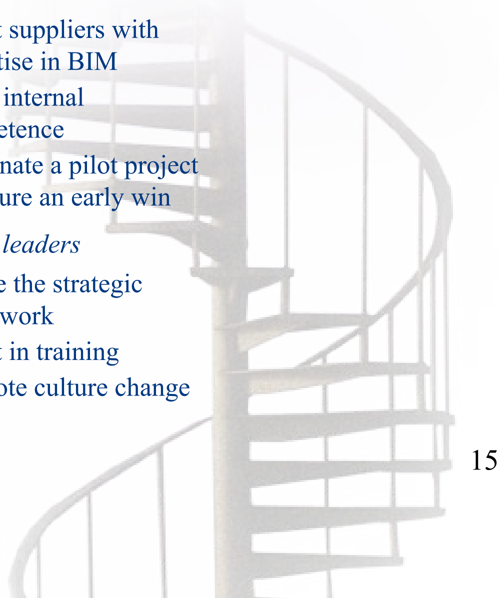
Next steps

Clients

- Select suppliers with expertise in BIM
- Build internal competence
- Designate a pilot project to secure an early win

Industry leaders

- Create the strategic framework
- Invest in training
- Promote culture change



References

Avanti case studies: source material supplied by Mervyn Richards, MR1 Consulting Ltd, and Jason Underwood, University of Salford; see also Constructing Excellence website

Constructing Excellence: Demonstration projects – The Bridge Academy (March 2009) (available on website)

Construction Users Roundtable (CURT), *Collaboration, Integrated Information and the Project Life Cycle in Building Design, Construction and Operation* (CURT White Paper 1202, August 2004)

Chuck Eastman et al, *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors* (Wiley 2008)

M.P. Gallaher et al, *Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry*, NIST GCR 04-867, 2004

SmartMarket**,** *The Business Value of BIM: Getting Building Information Modeling to the Bottom Line* (McGraw-Hill Construction, 2009)

The Stand-inn Handbook: Standards for Innovation and Sustainability in Construction and Facilities Management (Stand-inn/Europe Innova, 2008)

Websites

http://shop.bsigroup.com/constructionstandards
http://www.buildingsmart.org.uk
http://www.buildingsmart.com
http://www.constructingexcellence.org.uk (also contains Avanti material)

Image credits

BuildingSMART (figs 1.1, 2.2); Nick Nisbet, AEC3 (figs 1.2, 1.3, 1.5); Mark Bew and Mervyn Richards (fig 1.4); AEC3 (fig 2.1); Betzy Dinesen and Jane Thompson (figs 3.1, 4.2); Patrick MacLeamy (fig 4.3); Jane Thompson (photography – spiral staircase).

Note on the case studies

The figures in the case studies have been verified where it was feasible and possible to do so, but buildingSMART – and external colleagues who provided assistance – cannot accept responsibility for any of the claims that have been made on cost and time savings.

Acknowledgments

Thanks are due to the members of the British Standards Institution Committee B/555, Construction Design, Modelling and Data Exchange, for their input and guidance; to Constructing Excellence for reviewing the penultimate draft; to Mervyn Richards of MR1 Consulting Ltd for the Avanti case study material; and to Christopher Groome and Beryl Garcka for help and advice on successive drafts.

About BSI

BSI is a global independent business services organization that inspires confidence and delivers assurance to over 80,000 customers with standards-based solutions. Originating as the world's first national standards body, BSI has over 2,300 staff operating in over 120 countries through more than 50 global offices. BSI's key offerings are:

- The development and sale of private, national and international standards and supporting information that promote and share best practice
- Second and third-party management systems assessment and certification in all critical areas of management disciplines
- Testing and certification of services and products for Kitemark and CE marking to UK, European and international standards. BSI is a Notified Body for 15 New Approach EU Directives
- Certification of high-risk, complex medical devices
- Performance management software solutions
- Training services in support of standards implementation and business best practice.

For further information please visit http://www.bsigroup.com

About buildingSMART UK

BuildingSMART is a cross-industry alliance dedicated to improving the efficiency and cost effectiveness of the design, construction and facilities industries. Through the development of open standards and information sharing, used together with Building Information Models (BIM), the organization is contributing to the delivery of policies, processes and people training to help firms adopt improved ways of working. The rewards for clients, investors and building users are cost savings, better return on investment and more sustainable construction.

About the authors

Nick Nisbet is technical co-ordinator for buildingSMART UK. For the consultancy AEC3, he leads work on software development, notably on IFC applications. He was a key contributor to BS 1192:2007 standard for managing CAD/BIM information.

Betzy Dinesen is a writer and editor working in construction, consumer goods and chemicals. She is author of the *Stand-Inn Handbook* on standards and innovation in construction and FM and is buildingSMART UK's editor.

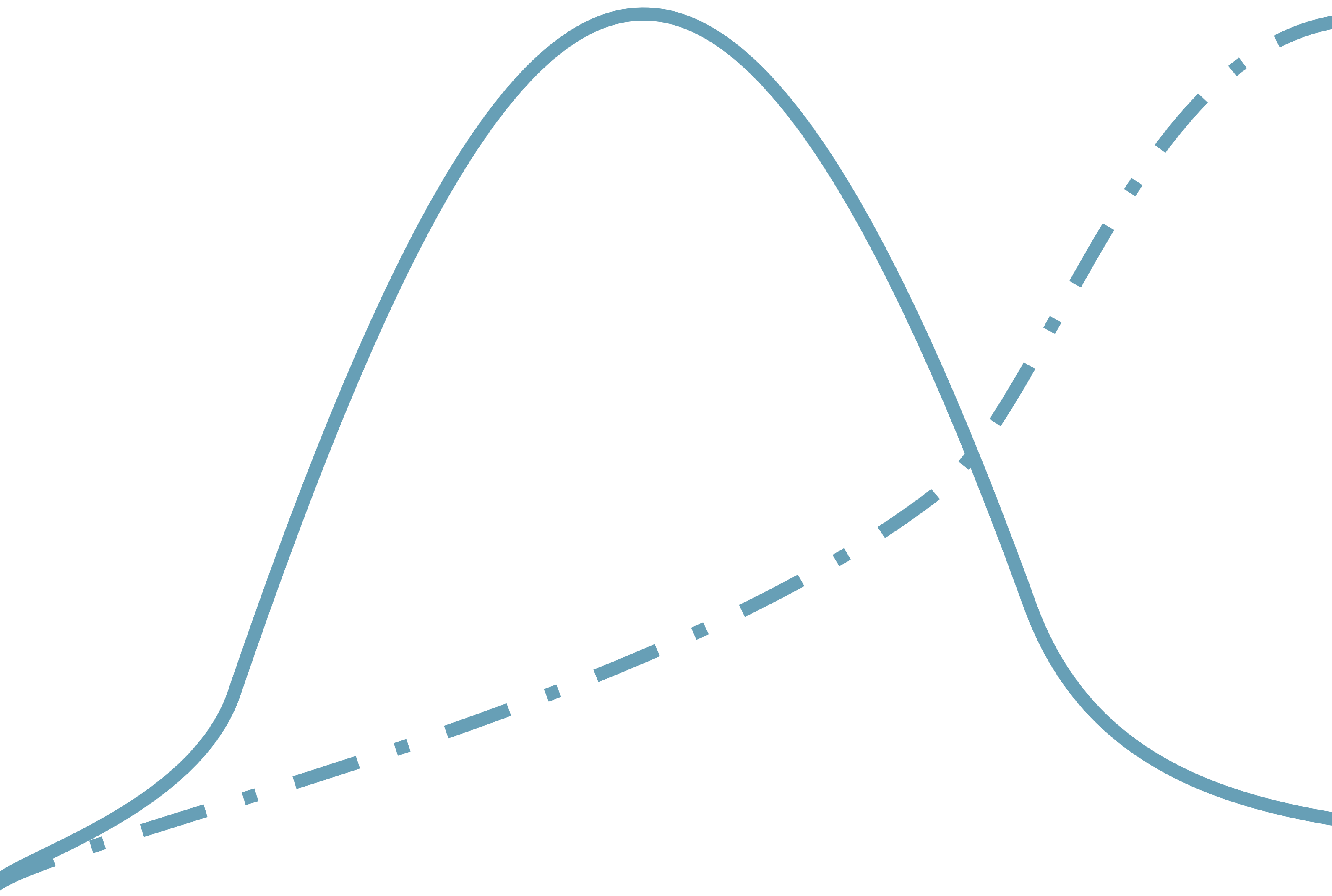
Contacts at BuildingSMART UK

Nick Nisbet, technical co-ordinator nn@buildingSMART.org.uk
Christopher Groome, business manager chris.groome@b-r-t.co.uk
Beryl Garcka, administration beryl.garcka@b-r-t.co.uk

Standards

IFC	ISO/PAS 16739:2005	Industry Foundation Classes Release 2x
IDM	ISO/DIS 29481-1:2010	Building Information Models – Information Delivery Manual (to be published during the course of 2010)
IFD	BS ISO 12006-3:2007	Building construction. Organization of information about construction works. Framework for object-oriented information
Uniclass	BS ISO 12006-2:2001	Building construction. Organization of information about construction works. Framework for classification of information information
Avanti	BS 1192:2007	Collaborative production of architectural, engineering and construction information. Code of practice

Cover design shows the BIM wheel of information sharing and the effects of BIM on design delivery (solid blue curve)



BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

Tel +44 (0)20 8996 9001
Fax +44 (0)20 8996 7001
www.bsigroup.com/standards