Chapter 2
Measurement and Design

Part 1

For which of you, intending to build a tower, sitteth not down first, and counteth the cost, whether he have sufficient to finish it?

Luke 14.28

The Holy Bible: King James Version (1769)

Suppose one of you wants to build a tower. He will first sit down and estimate the cost to see whether he has enough money to finish it, won't he?

Luke 14.28

The Holy Bible: International Standard Version

This oft misquoted parable is allegorical, of course, and has nothing to do with building towers, but it is illustrative of the long association between design and measurement in the cost management of construction.

The need to control the cost of building and infrastructure projects is not likely to diminish in the future, but in the digital age that the construction industry is beginning to embrace, the system of doing so will undoubtedly be revolutionised.

In the United Kingdom, for example, the Government Construction Strategy (2011) makes a clear statement that efficiency, innovation, cost reduction, value for money and new procurement methods are prerequisites when it comes to spending public money and that the industry must provide integrated solutions to required outcomes and do so in a collaborative rather than adversarial manner.

This strategy document challenges established industry cultures, business models and practices and demands that cost reduction and innovation shall be achieved by focussing on the supply chain rather than on the bidding process. The UK government has also challenged the industry by mandating a minimum requirement for Level 2 BIM on all public sector projects by 2016.

Managing Measurement Risk in Building and Civil Engineering, First Edition. Peter Williams.

Part 1

2.1 Introduction

History provides many well-documented examples of the formal quantification of materials and labour as a means of establishing the cost of building medieval castles and the like.

In 1378, for example, a contract was entered into to carry out building works at Bolton Castle in Yorkshire whereby *John Lewyn agrees to build for Sir Richard Scrape, at Bolton:*

The design	Comments
• *A kitchen tower, 10 ells by 8 ells and 50 feet high, with walls 2 ells thick* • *Between this and the gate, a vaulted room with three storeys over it, 12 ells by 5½ ells and 40 feet high, the outer walls being 2 ells and the inner 4 feet thick* • *A tower 50 feet high, containing a gateway, with three storeys over it* • *In this tower, south of the gate, a four-storey building* • *West of the gate, a vaulted room with another over it and a chamber above, 10 ells by 5½ ells and 40 feet in height* • *All the rooms having doors, windows, fireplaces, privies, etc.* • *Also a vice in the kitchen tower and two in the gate tower* • *All inner walls to be 3 or 4 feet thick*	• No *form* of construction is mentioned so this must have been well understood and fairly prescriptive in the fourteenth century • *Various* units of measurements are used • *Ells to* delineate areas • *Feet* for wall thicknesses and heights
The contract (or Works Information if the ECC had been used!)	
• *Sir Richard shall provide carriage for the materials timber for scaffolding and wood for the limekiln*	• Risk undertaken by the party best able to bear it
• *For all this work, John Lewyn shall have 50 marks and 100 s. for every perch, of 20 feet, of construction* (Salzman, 1968)	• Clear payment terms stated • Interim payment determined by measuring progress to date • The dictionary understanding of 'perch' as a unit of measurement approximates to 16½ feet and not 20 feet as stated in the payment terms

Notes:
1 ell = 1.25 yards = 1.14 m.
A perch (also called a pole or rod) was a measure of length, especially for land, equal to a quarter of a chain or 5½ yards (~5.029 m) (see Oxford Dictionary).

2.2 Design

2.2.1 Design process

Traditionally, design develops from an initial concept through to final production drawings and the ability to take measurements follows this development. Process models illustrate how this development progresses over time, the best known of which is the RIBA Plan of Work.

There are other models, the OGC Gateway and Construction Industry Council models, for example, but the RIBA model depicts not only the design and construction process but also the contributions made to the process by various participants and the exchange of information between them.

By understanding the design process, it is easier to understand where measurement fits into the picture and how models that seek to measure or quantify the design develop as the design develops. Different procurement methods dictate when, in the design process, measurement takes place and who performs the measurement function. In some cases, contractors undertake measurement tasks that were once the sole province of the professional quantity surveyor.

2.2.2 RIBA Plan of Work

The RIBA Plan of Work was first published in 1964 and has been held by many as the exemplar of standard practice over the ensuing 50 years.

In more recent times, the RIBA Plan of Work 'process model' has undergone a number of revisions. It originally comprised the RIBA Outline Plan of Work and the Work Stage Procedures which expanded the model in great detail. The RIBA Plan of Work was substantially reworked in 1998, and the 2007 edition was amended in 2008. In order to help the industry to accommodate the latest in Building Information Modelling (BIM) thinking, the 2007 edition (revised 2008) had a BIM Overlay and an additional stage (Stage M), concerned with Model Maintenance and Development.

Following a period of consultation, the RIBA published the RIBA Plan of Work 2013 (RIBA, 2013), which is substantially different from the outgoing model. The 2013 version has redefined the project stages and emphasised the role of procurement, programme and information exchange in the process model.

The RIBA Plan of Work 2013 stresses that procurement strategy does not fundamentally alter the progression of the design but that the information exchange points will vary according to the method of procurement chosen. Now that the Plan of Work is available digitally, bespoke models can be created for individual practices and individual projects so that the model more closely resembles the specific work in hand.

Figure 2.1 illustrates a two-stage tender process, where the preferred bidder is appointed during Work Stage 3, who then contributes to the development of the cost plan; this culminates in a bill of quantities being measured, priced and agreed prior to the contractor's appointment for the construction stage.

2.2.3 Design intent

In the days when buildings were constructed with simple 'natural' materials (stone, timber, slate, etc.), it was easy for architects to convey what they wanted to the builder. The architect understood the materials and the construction process, and the builder knew the materials and the construction process intimately, and enough about design, to understand what the architect wanted (Crotty, 2012).

In modern times, life is more complex. Buildings are largely constructed from manufactured materials, components and specialist equipment and, therefore, the job of the designer is much more conceptual. Great reliance is placed by designers on communicating the design to the builder via technical literature, such as product catalogues and data sheets, and the builder, or specialist installer, interprets this information in the context of the designer's drawings.

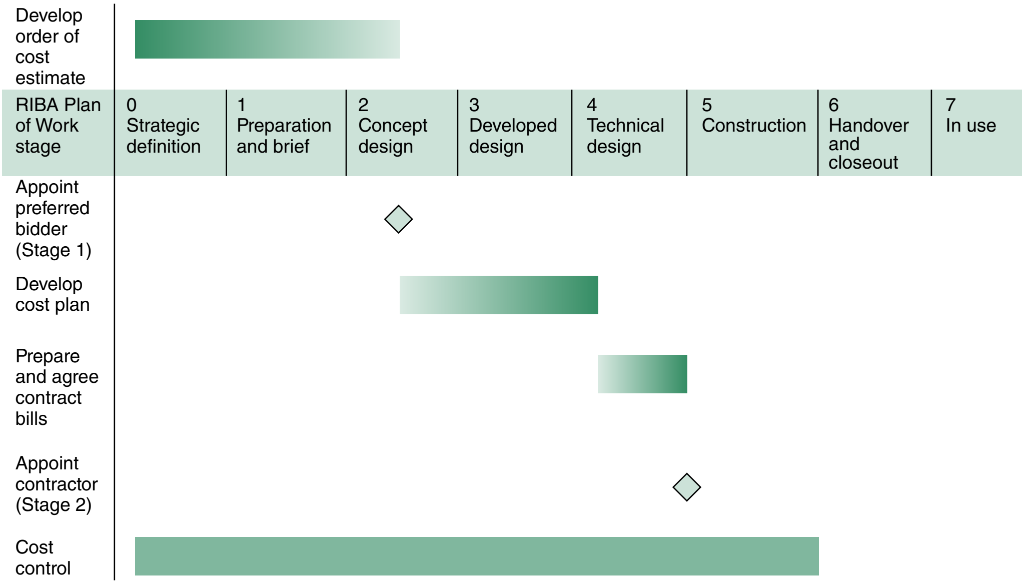

Figure 2.1 Cost control: two-stage tender.

This is not to imply that designs are not developed to a technical level of detail, far from it, but even at Work Stage 4 (Technical Design), the design is incomplete. The design may even be so incomplete that elements of the design are passed over to the contractor in a partial contractor design arrangement. This is common practice now.

As a result of all of these, the design communicated to the contractor is complete enough to be built from, but imprecise in terms of how this should be done, and building components are specified but not detailed to sufficiently accurate tolerances and specifications to be manufactured and fabricated. 2D CAD, for instance, is capable of conveying a design but, beyond the lines and circles on the drawings, the geometry of the design does not hold sufficient design information for construction purposes.

What the builder receives, therefore, is the 'design intent'.

In fact, the RIBA Plan of Work for Employer's Requirements (design and build) specifically recognises 'design intent' as an integral part of the make-up of the Employer's Requirement document.

There may be some purposefulness, or 'intended ambiguity', in a completed design which leaves the final construction decision-making to the contractor and specialist contractors. This might be to limit liability should something go wrong during construction or may be a way to tap into the collective knowledge of builders, specialists, manufacturers and tradespeople by involving them in the design process.

Examples of design intent:

- Where the standard of materials and workmanship are to be to the satisfaction of the architect, they are often stated in the contract to be to his *reasonable satisfaction*.
- In a performance specification, where the designer describes the effect that the contractor is required to achieve (such as xm^3 of air flow per minute), but not the ways and means by which this is to be achieved.
- Where a structural engineering design for roll-formed roof sheeting or engineered building products, such as prestressed concrete units, is stated in the contract as being expressed in detailed shop drawings and method statements to be provided by a specialist contractor.

All of these are examples of intended ambiguity.

Where there is purposeful ambiguity in a design, this influences the design information available (whether analogue or digital) and hence influences what is to be measured, how it is to be measured and what risk is attached to the measurements.

Consequently, the architect may conceptualise a complex roof but leave the design of that element to the contractor. This might be done through a partial contractor design arrangement whereby the tenderer prices a single bill of quantities item inclusive of the design of that item. This way of billing the item means that the tenderer has to design the roof, measure the quantities, price the work and undertake responsibility for the design.

The process of conveying a 'design intent' for the roof effectively transfers risk to the contractor whose design liability, unless qualified in the contract, is the 'fitness for purpose' liability of a contractor–designer and not the lesser standard of an architect–designer.

2.2.4 Design cost control

The problem with the biblical definition of cost control and, indeed, the historic cost accounting methods employed since medieval times is the lack of a procedure to ensure that the out-turn cost of a project is equal to or less than the amount that can be afforded by the client. The ability to do this with precision requires a system that controls cost as the design develops and, at the same time, enables the designer to make informed decisions that do not compromise the design concept.

The development of **elemental cost planning** – part of a system of cost control – enabled this to happen.

The concept was introduced in 1951 by James Nisbet (1951) and has been developed and refined over the intervening years both by private quantity surveying practices and by the Building Cost Information Service (BCIS) of the RICS.

The basic idea was to establish a budget, or cost limit, and then decide how to spend the money. This introduced a different concept of measuring buildings than hitherto.

In the initial stages of design, measurements are expressed in m^2 of gross internal floor area (GIFA) or, alternatively, as simple units of occupancy, such as hospital beds, theatre seats and school places. As the design develops, more complex measurements are produced, this time expressed as elements and sub-elements, but still with a unit of measurement of m^2 of GIFA.

More recently, the RICS initiative to introduce the *New Rules of Measurement* (NRM1, 2012) has led to a rethink about the process of design cost control such that budgets or cost limits are now referred to as *order of cost estimates* and cost plans are measured in more detail as shown in Table 2.1.

The BCIS 'Elemental Standard Form of Cost Analysis (NRM Edition)' 2012 has been developed by BCIS to work specifically with NRM1, and a 'component' level has been added to reflect the same *user-defined* component level in NRM1. It can only be supposed that this has been done to line up with the 'components' that make up BIM models.

Table 2.1 NRM1 elements.

Ref.	**Group element**						
2	Superstructure	Ref.	**Element**				
		2.5	External walls	Ref.	**Sub-element**		
				2.5.3	Solar/rain screening	Ref.	**Component**
						2.5.3.1	Overcladding

2.2.5 Measurement

Measurement and design are closely connected.

Measurement is a by-product of the design process, and the stage to which the design has been developed determines what measurements can be taken both in extent and in detail. In the early stages of design, little information is available from which to measure, but as the design develops, more becomes known about the designer's intentions, representations of the design are produced in the form of sketches, drawings and/or models and consequently more detailed measurements can be taken.

Measurement is inextricably linked to the work of designers. For instance, the volume of concrete in a reinforced concrete column cannot be determined without:

- Firstly, identifying the cross-sectional dimensions from a plan.
- Secondly, finding the height of the column by reference to a cross section of the building.

Not only does this process require the use of more than one drawing, but it may also require human judgement and interpretation.

If, for example, there are no dimensions on the drawings, they must be:

- Calculated from other dimensions.
- Measured using a traditional scale rule.
- Measured using one of several types of electronic digitiser.
- Measured from a true scale drawing on a computer screen.

This effort is required because the lines on the drawings are 'dumb' and do not contain information, so their length must be determined from written dimensions or by scaling or otherwise measuring them physically, usually to a predetermined scale.

It is only at the level of BIM-based 3D models where smart digital information is available such that little or no human interpretation is required in order to establish dimensions for measurement purposes.

2.3 BIM

We live in a world of acronyms – SMM, NRM, CESMM, MMHW, POM(I), PDF, CAD, etc. – and now we have BIM! This stands for Building Information Modelling, albeit there is no universal acceptance of this.

Unlike other acronyms, BIM offers a new world of amazing information technology that will (eventually) transform construction, as it has in other industries (such as aerospace, auto manufacturing, etc.) and measurement.

There is no question that BIM presents enormous challenges and opportunities for the construction industry and that the industry is facing a period of major change in its working practices over the next decade.

There is a great deal of mystique surrounding BIM, however. What is it? How does it work? Who is using it? How will it develop? What are the implications for measurement and quantity surveying?

Adding to the mystique is the technical jargon employed by those involved with BIM which, to most non-IT people, is confusing at best and alien and something of a 'turn-off' at worst.

In fact, it takes a fair amount of 'delving', research and surfing to really get to grips with BIM, to appreciate what it means for the construction industry and to understand the answers to the questions posed at a construction practitioner, as opposed to a 'computer-buff' level. Thankfully, there are some excellent and up-to-date reference books available on the subject but none of these focus to any great extent on measurement or, in BIMspeak, 'quantity take-off'.

2.3.1 Definitions

There are a number of definitions of 'BIM' on the Internet and in the books referenced to in this chapter. Whilst researching this book, however, the author looked high and low for a clear, concise and understandable definition of BIM. Typical, though by no means the most unintelligible, of those available is:

> [BIM] is a *digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it and forming a reliable basis for decisions during its life cycle, from earliest conception to demolition*[1].

To a non-designer and non-IT anorak, this definition has little meaning. Searching further, one definition stood out. It came from a local architect in Liverpool:

> *BIM is basically two things: Building an intelligent 3D model and team collaboration.*

This architect clearly understood what BIM meant at a practical level. He appreciated that BIM can create a design that readily exchanges data between contributors to the design and construction process and the client and also that, just like drawings, a BIM model is only as good as those who contribute to it and to the information upon which the model is based.

In the discussion, we did discuss the accuracy of the quantities in a BIM model, as it is open to question as to who inputs the quantities into the components in the model and how accurate they are. The impression seemed to be that the quantities are very accurate but whether this is at a QS level of accuracy remains to be seen. QSs tend to measure on centre lines and girths but it is unlikely that software people will do the same thing. One architect suggested, 'Get the QS to do a traditional take-off as a check against the BIM quants'. Good idea!

On the face of it, 'BIM' stands for Building Information Modelling; however, Race (2012), amongst others, suggests that it could equally mean Building Information Management. This view is quite persuasive because BIM models are built on 'information', and it is this information that creates the basis of a common language which can be used to exchange data, and facilitate communication, between all participants in a project that has never been seen before.

Whichever definition of BIM is preferred, the 'building' bit of the acronym is somewhat misleading because BIM models are not exclusive to building projects. They can and are created for civil engineering projects or, indeed, any construction project envisaged. The only limitation is the existence of suitable 'components' which are the building blocks of all current BIM packages.[2]

In the United States, a variety of terms and acronyms have been devised to distinguish between vertical construction (i.e. building) and horizontal construction (e.g. infrastructure) including Civil BIM, CIM, BIM for infrastructure, Heavy BIM, etc.

Whatever the label, however, the result is the same: intelligent, data-rich models in three or more dimensions that greatly enhance the quality of design, construction, collaboration and communication in the industry (The Business Value of BIM for Infrastructure, McGraw-Hill Construction SmartMarket Report, 2012).

2.3.2 BIM benefits

Once you have seen a BIM model, you will quickly appreciate the benefits to be gained from their use. Amongst the many are:

- Visualisation of the structure is 'lifelike'.
- Walking through the model is like 'being here'.

- Layers can be removed and replaced at will.
- Design becomes faster, highly customisable and flexible.
- Optimisation of schedule and cost.
- Coordination and collaboration is seamless.
- Design conflicts can be readily detected and risk mitigated.
- Easy maintenance of Building Life Cycle.

David Scott[3] believes that the benefits of BIM can be multiplied by earlier contractor engagement on a project.

Put simply, he argues, *if a project can be built virtually in a BIM world, it is possible to build it in the real world, offering guarantees on price and programme much earlier by significantly managing out risk*.

2.3.3 BIM levels

It is a little confusing, but necessary to appreciate, that BIM is not just about intelligent models. There are steps, or levels, that lead to 'full' BIM – the BIM that is slowly emerging in the industry but is not universally adopted as yet.

At this point, most articles about BIM leap to the Bew–Richards BIM Maturity Wedge[4] to visualise what the BIM levels are. Frankly, as a non-designer, the wedge 'doesn't do it' for this author and a simpler approach is preferred, as illustrated in Table 2.2.

Table 2.2 BIM levels.

Level 0	• Two-dimensional computer-aided design (2D CAD) • Replaced the old drawing board and *Rotring Rapidograph* pens	Analogue design process
Level 1	• 2D CAD with 3D conceptual models for visualising the finished product • Used by a single designer or trade contractor and thus referred to as lonely BIM • Design liability clearly with the designer • Traditional contractual and insurance arrangements	
Level 2	• 3D models produced by all key contributors of the design team • Not necessarily a single model • May eventually result in a combined (or 'federated') model • Design liability and contractual and insurance implications start to become 'blurred' • Project roles and design responsibilities need to be clarified • Design outputs (information exchanges) need to be carefully defined • Greater collaboration between the design team and designing contractors	The boundary between analogue and digital designs
Level 3	• Full digital design within a federated model • An intelligent model enabling rich data exchange • A fully collaborative design and construction process • Complex design liability and contractual and insurance issues to resolve	Digital design

2.3.4 BIM awareness

In the National BIM Report (NBS, 2012), an online survey of a variety of construction disciplines and businesses found that 21% of the 1000 respondents were neither aware of nor using BIM. A further 48% reported that they were 'just aware' of BIM, and the balance (31%) said that they were aware of and currently using BIM.

In the same report, David Philp wrote that *2011, with its cornucopia of BIM seminars, workshops and related articles, helped trigger a 'light bulb moment' for many in the UK construction industry*. This doesn't quite square with Richard Waterhouse's Introduction to the 2012 NBS Report who, whilst acknowledging the twofold increase in BIM awareness on the previous year, also made it clear that a certain degree of inertia exists in the industry despite the launch of the UK government's BIM strategy in 2011.

To those who know and understand how the construction industry works, the results of the NBS survey will not come as much of a surprise.

Construction is notoriously reactionary and Crotty (2012) is not expecting BIM to lead to the same sort of dramatic change in construction as has happened in the manufacturing industries over the last 20 years.

Based on no evidence whatsoever – simply personal instinct – it is more than likely that the NBS survey is a pretty accurate reflection of the state of affairs in the industry and that BIM is probably something of a 'black box' to many people in construction. Considering the 'hype' surrounding BIM, the confusing technical jargon used by BIM evangelists and the lack of clear and simple explanations as to what BIM is, it is no wonder that the industry has been somewhat slow to take BIM on board.

As part of the research for this book, some informal interviews were held with local architects – not huge practices – in order to learn more about BIM and try to understand how the world of architecture was dealing with this complex subject. All were 'aware' and some were using BIM, but only up to a point. Listed below are some of the observations received:

- Some practices were at the interface between Levels 1 and 2.
- Others could not justify the expense of the leap from Level 2 to Level 3.
- Some practices used BIM, but only up to planning permission stage as clients were not prepared to pay the fees for full BIM design.
- For smallish projects, the architect, as lead consultant, could/would be the project manager for the model, but for larger jobs, there would need to be a project manager who would be in charge of the model.
- Ideally, a central model would be available in cyberspace (the Cloud), but this needs a fast fibre-optic Internet connection which is not always available to all. The other option is to provide a copy of the model for others to work on. This raises an issue of syncing where changes in the copy model have to be integrated into the central model which could then detect clashes and other problems.
- Some saw problems with the legal aspects of federated models and the 'questionable' quality of input from other contributors.
- There may be limitations in existing software such as Revit (Autodesk) because model properties do not necessarily exhibit UK standards such as Building Regulations and thermal insulation standards.
- It might be difficult to measure a stepped DPC; this would be shown on the model as a single line but the detailed changes of direction would not appear as the model would become too complicated and require too much computing power.
- It was suggested that interfaces may pose a problem from a measurement point of view, for example, wall to roof at eaves, as they may not be adequately detailed in the model.

2.3.5 *Glossary of terms*

BIM has a vocabulary, if not a language, of its own, much of which has its origins in the United States. To English language 'purists', this presents yet another example of the 'Americanisation' of the 'mother tongue', but to pragmatists, this is a horse that bolted a long time ago!

Some words, phrases and acronyms are alien to the UK construction industry, and others are simply an offence to the English language (e.g. interoperability)!

BIM component

Components are the 'objects' that build the model (e.g. precast concrete wall panels, acoustic panels). They are 'parametric', being members of the same 'family' (e.g. Industry Foundation Classes (IFC)), but might have variable properties.

The components are 'smart' in that each component in the model may have all sorts of structural, thermal, sonic and physical property attributes, such as mass, dimensions, areas and volumes.

The designer chooses the desired components and drops them into the model which then takes shape and form.

IFC

IFC is a class, or family, of objects or components for BIM models that is not controlled by any particular software vendor.

IFCs have been developed by buildingSMART[5] specifically to ease the interoperability problems between software platforms. They are 'platform neutral' so it is not necessary to buy a specific piece of software to use the components in the model. Any suitable software will do the job.

Interoperability

This is where one piece of software doesn't speak the same language as another.

If one tries to open a Revit drawing in Microsoft Word, it doesn't work. In some QS software, Revit and PDF files won't open, and another piece of software (a plug-in) is needed to open and read the drawing.

Rendering

BIM models can be produced with different visual effects, and rendering is the process of turning a visually uninteresting model into something rich and lifelike.

Think of adding colour and shade to a normal paper drawing – it's similar in effect but much more impressive in the models which, when fully rendered, have astounding visual appeal and reality.

3D BIM

This is a model of a building or structure that has all the hallmarks of the 'real thing'. The model can be viewed from any angle, components can be turned off and on again, and 'walk-throughs' can be performed. Each component in the model has all sorts of attributes attached to it, including quantities.

Note the phrase 'each component in the model'. Models are like drawings. If it hasn't been designed, it's not on the drawings and it's the same with models. There is no point spending lots of time and money developing a model to the *n*th degree of detail for a planning application.

Models develop over time – from concept to technical design – but if something is not in the model, there will be no quantities available. Even when the model is well advanced, there may be aspects of the design that haven't been included in the model – just like the paper-based drawing. The QS needs to be as intuitive and inventive as ever!

4D BIM

This is a module or bolt-on to project management software, such as Asta Powerproject.

A BIM model is uploaded to the Cloud, and this can then be accessed by the software. The model is based on IFC components. The software draws IFC data from the Cloud, and the project activities in Powerproject can then be linked to the components in the model. When the model develops more detail or is revised, the changes can be seen in the Cloud and the programme revised accordingly.

5D BIM

This is to do with quantities, where a BIM model is accessed to extract quantitative data.

In some instances, it is necessary to have the architectural software (e.g. Revit) to access the quantities, but if the QS software used has a BIM reader that can import and read a BIM model, the quantities can be extracted within the software.

There is a bit of 'smoke and mirrors' here because, whilst the BIM reader can select quantities from the model and return them to the QS software, or to a spreadsheet, it isn't possible to import the quantities into an SMM-based electronic dim sheet just yet.

2.3.6 BIM systems

There are numerous individual BIM systems which can be used for a variety of purposes including architectural design, structural design and the design of engineering services such as heating and ventilating, fire protection and air conditioning.

An individual BIM system enables the designer to model the design in virtual reality using 'intelligent' components which, Crotty (2012) explains, are *exactly analogous to building components in the physical world*. Consequently, the designer can 'build' the design just as it would be built on-site in real life. Such models also have the capacity to be viewed from all sorts of perspectives, in many different ways and by showing or hiding features depending on the complexity or clarity desired.

Race (2012), however, suggests that the idea of a single, fully interactive and responsive BIM platform does not match reality. It is tempting to suppose that a BIM model will allow changes to be made to the design which are then reflected in all parts of the model. For example, a change in the floor–ceiling height not only will be reflected in the architectural design but also will be seen in the structural design, MEP, scheduling and quantity take-off. Race informs us that no such platform exists at the present time.

From a measurement point of view, the capability to hide all details, except the items to be measured, allows much greater clarity and accuracy when it comes to taking-off quantities. 2D and 3D CAD packages have the same capability, but the significant difference with BIM models is the richness of the information contained within the model, generated by its intelligent components. 2D and 3D CAD do not possess this capability.

The possibility that this technology can create 'fault-free' designs that can be built on-site without recourse to the usual circus of Requests for Information (RFIs), Architect's Instructions (AIs) and loss and expense claims is truly beguiling.

Crotty (2012) reports that there were only 10 *structure-related RFIs* on the £20 million Norwich Open Academy project and *no field RFIs* on the £20 million Llanelli Scarlets Rugby Stadium project, both of which were 'BIM projects'.

However convincing these examples are, reality persuades us that construction involves much activity that is not 'risk-free', such as excavating below ground level, tunnelling, installation of temporary works and so on. It is, therefore, unlikely that construction projects are capable of being completed on the basis of 'perfect' information, and without any variations to the design, no matter the extent of the intelligence contained within BIM models.

2.4 BIM quantities

As two thirds of vendors at 2013 BIM Show Live were dealing with measurement/surveying, it is tempting to imagine that a BQ can be produced at the push of a button with BIM. However, full automation is not possible with BIM models just yet, and according to Eastman et al. (2011), there is no BIM tool available that will prepare a quantity take-off suitable for preparing accurate estimates of construction work.

Additionally, quantity surveyors have to interpret BIM models just as they have to interpret drawings. If an item is not included in the model, but is clearly to be quantified, the QS will have to find another way of including relevant quantities in the BQ or schedule.

Consequently, professional insight and judgement is needed when producing quantities from models, and the traditional skill set and interpretative abilities of the QS are still required as they always have been. There is no less requirement for the QS to understand the technology of construction just because a model is available, and collaboration doesn't mean that there is no need to pick up the telephone to talk to designers.

2.4.1 Limitations

The quantities produced by models are not calibrated to methods of measurement and, therefore, whilst considerable measurement effort is saved, the BIM quantities still have to be manipulated into recognisable units and descriptions. BIM models can generate their own plans, elevations and sections, which is just as well because there is considerable need for 2D data when extracting quantities for measurement. Also, some items are not shown in models, just as they were not shown on the drawings:

- Off-site disposal.
- Earthwork support.
- Formwork.
- Reinforcement is often not modelled, but it can be.
- Subcontract attendances.

Benge (2014) suggests that *BIM is intended to address issues of process management and data retention* and that *NRM1 is linked to this, enabling the consistent collection of construction cost data that is synchronised with the design data*.

This seems to be somewhat at odds with the findings of a recent RICS Research Report which indicates that the information generated by BIM models is out of step with the NRM1 standard for order of cost estimating and elemental cost planning (RICS, 2014).

2.4.2 A word of caution

The ability to take quantitative data directly from a BIM model is an attractive proposition but the old adage must be remembered – G.I.G.O. ('Garbage In–Garbage Out').

Quantity surveyors are trained to pay attention to detail and, by their nature, tend to be careful people. Any self-respecting QS will wish to be sure where quantity-based information comes from, and most professionals will tell you to always use figured dimensions, or dimensions calculated from figured dimensions, rather than relying on scaling.

Quantities abstracted from a BIM model need to be treated with caution because the quantity surveyor cannot verify the source of the information or who has generated it. The data will have been entered in the model by someone and that someone will be a designer or an IT person and not a quantity surveyor.

Professional quantity surveyors are legally liable for the accuracy of their work, and quantities taken from BIM models should not be used out of hand without running some checks and balances to be sure that the figures 'stack up'.

2.4.3 On-screen measurement

Measurement and billing of construction work using on-screen measurement software is now fairly commonplace in the industry, and both SMM-based packages and non-SMM-based packages allow PDF and 2D and 3D CAD files to be imported into an on-screen measurement environment. Some other software packages use plug-ins that facilitate quantity take-off on-screen from imported PDF or CAD files which can then be exported to the bill production software.

In some ways, on-screen measurement software has transformed the way in which construction work is quantified, and it has certainly made the process much quicker and cost-effective both for QS practices and on the contracting side of the industry.

However, the step-up from CAD measurement to full BIM measurement is a significant one and requires a different mind-set compared with both traditional quantity take-off and BQ production and on-screen measurement from CAD files. Quantity take-off using BIM models is conceptually quite different to that from traditional or even on-screen measurement for a number of reasons:

- It is the model that generates the quantity data as opposed to the software when using on-screen measurement.
- Quantities from models are not necessarily in SMM units of measurement.
- There are no SMM distinctions (e.g. classifications of concrete thicknesses).
- Quantities generated by the model must be exported into suitable software in order to create bills of quantities or schedules.
- The output from CAD files is units of finished work whether SMM based or not.
- The output from BIM models is object based.

The difference is significant because BIM models consist of 'intelligent' objects that carry lots of data, including measurement data, whereas CAD files do not. As a consequence of this difference, quantity data is extracted from the model and then used, manipulated or imported into a suitable software package, whereas quantity data from CAD files has to be generated by the measurer within a software package that supports the importation of, and measurement from, CAD files. This is the case whether or not the software is SMM based.

2.4.4 Software issues

Some software packages purport to be BIM-measurement packages but this is something of a fallacy because there are no software packages available yet that can measure from full BIM models. Claims of BIM-measurement capability are not intended to be misleading, however, as there are different levels of BIM, and both 2D and 3D CAD are staging posts on the way to full BIM as illustrated in the Bew–Richards Maturity Wedge diagram.

Using quantity take-off data generated from a model may be an alien concept to some quantity surveyors, who are more used to generating the quantities themselves, either from drawings or from CAD files on-screen. Quantity surveyors may also feel a degree of scepticism regarding the reliability of quantities generated from a model because:

- The quantities produced by the model cannot be controlled by the measurer/estimator.
- The model may not generate all the quantities that the measurer/estimator needs (e.g. the quantity of concrete may be generated but not formwork or rebar).
- The measurer/estimator does not know how the quantities have been measured (e.g. does the model measure on the centre line as a QS would?).
- Objects within the model display their properties, including their dimensions, but do changes in the model generate an audit trail of change as would a change in quantity taken from a drawing or CAD file?

Having established that the BIM tool generates quantities from the model, the question arises as to how to overcome the lack of capability within the BIM tool to use and manipulate the quantity take-off for producing bills of quantities or schedules for pricing. Eastman et al. (2011) suggest three viable options:

1. Export the quantities from the BIM tool into a suitable software package (e.g. MS Excel spreadsheet).
2. Link the BIM tool with a suitable software package via a plug-in (e.g. Autodesk Quantity Take-off with Revit).
3. Import the model from the BIM tool into a specialised measurement package (e.g. Causeway BIMMeasure or Buildsoft Cubit).

The disadvantage of options 1 and 2 is that suitable software, or a plug-in, must be acquired as well as a copy of the BIM tool or software used to create the model. This may not be cost-effective in some instances. Consequently, option 3, using a software package such as Causeway BIMMeasure or Buildsoft Cubit, might be more attractive, as each allows models to be imported into the package for quantity take-off purposes.

2.4.5 Example

Figure 2.2 illustrates a model imported into Causeway BIMMeasure together with the various windows used for extracting and presenting quantities. A short and simple explanation of how the software works is provided at http://www.youtube.com/watch?v=ur2jcCPw6Ag by CATO's Tim Cook, whose YouTube channel is well worth visiting.

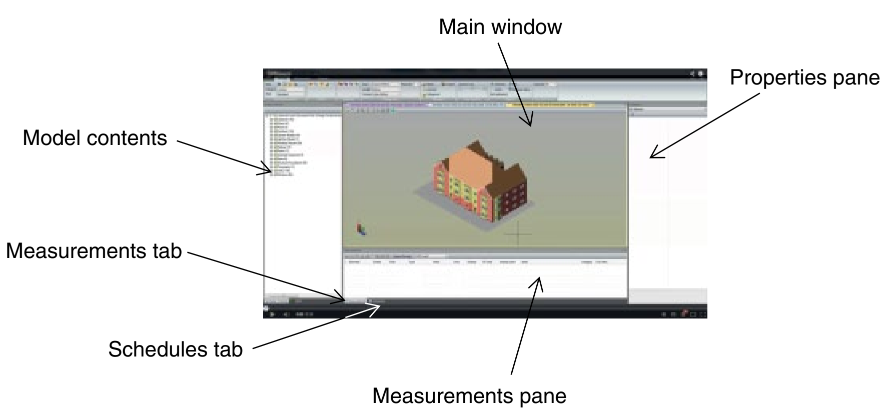

Figure 2.2 Causeway BIMMeasure (1).

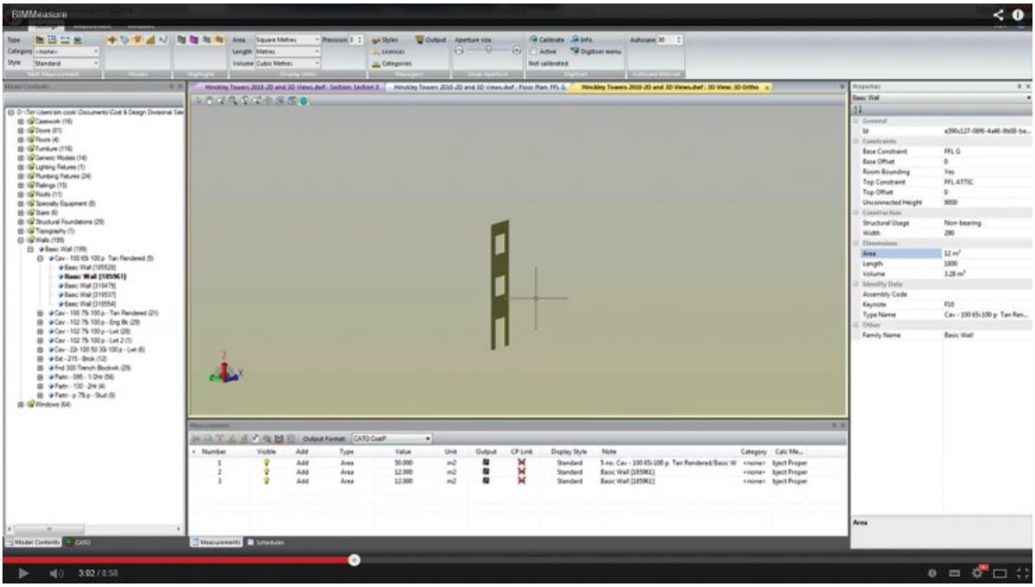

Figure 2.3 Causeway BIMMeasure (2).

In this demonstration, Tim explains four ways of producing quantities from the model:

1. Drag and drop the quantities from the list of Model Contents into the Measurements pane of the BIMMeasure window.
2. Highlight a model object in the main window and drag and drop its quantities into the Measurements pane.
3. Drag and drop the quantities for the object from the Properties pane of the BIMMeasure window.
4. Schedule the object(s) into a list by highlighting the object(s) in the main window and clicking the Schedules tab at the bottom left of the main window.

This is illustrated in Figure 2.3 which shows a model object and the selection cursor as well as object properties and measurement details.

2.4.6 Using 5D BIM

Causeway BIMMeasure allows quantities to be exported to MS Excel or they may be exported to Causeway's CATO suite. If an elemental cost plan is required, the BIM quantity take-off could be exported to the CATO Cost Planning tool.

Buildsoft Cubit, amongst whose many features are on-screen measurement and billing, also has a BIM reader in which models can be opened and quantities extracted. These quantities can then be exported from the BIM reader into Buildsoft Cubit in order to produce a bill of quantities, schedule or estimate (https://www.youtube.com/watch?v=l0IHqNZTth0).

As the Buildsoft Cubit measurement pane is basically a spreadsheet, this works very interactively, whereas, in other SMM-based take-off packages, there is no functionality between the BIM reader and the take-off dimension sheet.

Buildsoft Cubit also exports to MS Excel and the functionality of an NRM2 library is planned.

For a non-SMM-based bill of quantities, MS Excel could be used, though this is a bit long-winded compared to some other software that is available. Buildsoft Cubit is excellent for producing generic or non-SMM bills/schedules of quantities, and it can also extract BIM quantities to produce any style of bespoke measurement output.

SMM-based bills of quantities, or schedules, may be produced by deploying the CATO Take-off and Bills tool or, alternatively, with QSPro and the Bluebeam on-screen measurement plug-in.

One of the many attractions of BIM quantity take-off is the speed at which schedules of quantities can be produced. Such quantities are, however, generic and have no synergy with any of the standard methods of measurement used either in the United Kingdom or elsewhere. Consequently, further manipulation of the data is needed to produce the required output if formal bills of quantities or schedules are to be produced.

For informal use within contracting organisations and for the production of activity schedules, BIM quantity take-off is ideal. It can quickly provide the 'base' quantities required and a further benefit is that project management software such as Asta Powerproject can be linked to a 3D model in order to create a 4D programme, which can then be linked to the 5D BIM model (e.g. activity schedule) if desired.

BIM quantities are, however, generic and there is no standard method of measurement for use with BIM. Furthermore, it would appear that a common international standard method of measurement, compatible with all BIM software, is some way from being a reality (National Building Specification). Considering how long it has taken for mobile phone manufacturers to agree on a universal charging connector and notwithstanding the publication of the revised CESMM4 and the 'new' NRM2, a step in the right direction might be to move away from measurement driven by standard methods altogether and towards a more simplified approach to measurement.

Crotty (2012) subscribes to the view that a 'smart' bill of quantities, generated from a BIM model, would be able to retain all of the detailed information about a structure at the component level that is compressed in a traditional bill of quantities by the aggregation of individual items demanded by standard methods of measurement.

Perhaps Ted Skoyles was not too far wrong after all with his Operational Bills approach to measurement in the 1960s!

Notes

1. Construction Project Information Committee (CPIC).
2. Ibid.
3. Structural Engineering Discipline Lead, Laing O'Rourke, Engineering Excellence Group.
4. http://www.thenbs.com/topics/BIM/articles/whatIsCOBie.asp (accessed 20 April 2015).
5. http://www.buildingsmart.org.uk/ (accessed 20 April 2015).

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