PREPARING FOR THE BIM REVOLUTION

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ABSTRACT

The use of BIM technologies is rapidly achieving widespread commercial use in the design of buildings. It has the potential to make current forms of practice more efficient and to enhance the design of buildings by both allowing more complex forms and better evaluation of the technical performance of the building. In addition to this there is the potential to enable more efficient construction through the adoption of virtual prototyping techniques. There are significant challenges and opportunities for quantity surveying practice as effective 4D and 5d software becomes commercially available. These changes are centred on the greater availability of detailed information for costing purposes coupled with the computing power to work with more information.

Keywords: Building Information Modelling, 5D, Quantity Surveying practice.

1. INTRODUCTION

In the past two to three years BIM technologies have emerged from the research and development arena to become a commercial reality. This is causing a revolution in the way design practices work and the type and extent of design information they generate. It will almost certainly in turn engender significant change in construction practice through the use of 4D modelling and virtual construction. Changes in design and construction practice must in turn impact on quantity surveying practice and provide both challenges and new opportunities.

This paper first describes the current state of the use of BIM in the commercial environment and then the potential benefits to the industry and its clients of BIM. The likely impacts of BIM on the quantity surveying profession are then discussed.

For the purposes of this paper the American General Contractors (2006) definition of BIM has been adopted:

> *Building Information Modelling is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model. A Building Information Model is a data rich, object oriented, intelligent and parametric representation of the facility from where views and data appropriate to various users' needs can be extracted and analysed to generate information that can be used to make decisions and improve the process of delivering the facility.*

Eastman, Teicholz, Sacks and Liston (2008) say that the concept of parametric objects is central to understanding BIM and define them as:

- *Consist of geometric definitions and associated data and rules.*
- *Geometry is integrated non-redundantly, and allows for no inconsistencies. When an object is shown in 3D, the shape cannot be represented internally redundantly, for example as multiple 2D views. A plan and elevation of a given object must always be consistent. Dimensions cannot be 'fudged'.*
- *Parametric rules for objects automatically modify associate geometries when inserted into a building model or when changes are made to associated objects. For example, a door will fit automatically into a wall, a light will automatically locate to the proper side of a door, a wall will automatically resize itself to automatically butt to a ceiling or roof, etc.*
- *Objects can be defined at different levels of aggregation, so we can define a wall as well as its related components. Objects can be defined and managed at any number of hierarchy levels. For example, if the weight of a wall subcomponent changes, the weight of the wall would also change*

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- *Object rules can identify when a particular change violates object feasibility regarding size, manufacturability etc.*
- *Objects have the ability to link to receive, broadcast or export sets of attributes, e.g. structural materials, acoustic data, energy data, etc. to other applications and models.*

This paper has adopted the common terminology of referring to the attachment of time related information (scheduling) to the model as 4D and cost related information as 5D.

1.2 Research Methodology

This paper is based substantially on a literature review supplemented by information gathered at industry forums in Auckland New Zealand to discuss BIM. Information on the uptake of BIM in New Zealand was gathered through a telephone survey of Auckland companies. This survey captured a quick snapshot of New Zealand practice as at June 2009 but does not pretend to be statistically reliable research.

2. BIM AS A COMMERCIAL REALITY

Eastman et al (2008) describe building modelling based on 3D solid modelling as being under development since the late 1970s however it is only since about 2003 that commercial 3D BIM tools have been available. Examples includeAutodesk Revit, Bentley Architecture, Graphisoft Archicad and Gehry Technology’s Digital Project. Early adoption as reported in the literature was mainly on large scale complex projects often involving complex architectural forms that required the use of 3D imaging and structural computation to make them possible. One of the more spectacular examples is the Beijing Olympics Aquatic Centre (Water Cube) (Yukun 2008) Other examples include the One Island East Office Tower (Riese 2008) and the Federal office Building San Francisco (Eastman et al 2008).

BIM or at least the use of 3D tools now appears to have reached the point where its use has moved beyond leading edge projects to more universal adoption. A survey in the USA by McGraw Hill (2008) showed that 43% of architects surveyed were heavy users of BIM (they used it on more than 60% of their projects) in 2008. This number was expected to move to 54% in 2009. Other professions and contractors were less advanced in their take up but also expected to significantly increase usage in 2009.

An informal telephone survey in New Zealand conducted in early 2009 indicates that most major architectural practices are using BIM to some degree. All practices spoken to were using 3D modelling on one or more projects and expected to increase their usage in the future. In some cases engineering consultants particularly structural consultants appeared to have been earlier adopters of 3D engineering programmes. Howden (2009) describes how his practice has moved to working only in a 3D environment on all new projects and insists that engineering consultants working with them also adopted 3D modelling.

However the availability of 4D and 5D software that interacts with the common propriety 3D models is limited and generally still under development.

The major New Zealand quantity surveying practices surveyed had all experienced working on projects designed in a 3D environment however had not significantly changed their existing practice for measuring and estimating. This was not surprising given the lack of commercially available software. However all were working on updating their practice to better interact with 3D models.
Similarly most contractors surveyed had limited exposure to constructing building developed in a 3D environment and had not updated their practices to embrace the BIM environment. Use was generally limited to preparing time based videos of the construction sequence for presentation to clients at the bid stage or the modelling in 3D of specific details that were potentially construction problems. Murray (2009) describes a notable exception a contractor had modelled all construction details in 3D on a shopping mall development in order to improve the buildability of the project. This enabled them to do things such as detect structure and services clashes and identify reinforcing cages being unable to fit within beam dimensions as well as examine the sequencing of the construction work.

3. THE POTENTIAL BENEFITS OF BIM

This paper is focussed on issues of particular relevance to the quantity surveyor. However since as cost mangers the quantity surveyor has an overview of the entire project it is necessary to at least provide a broad superficial overview of the potential benefits of BIM across the spectrum of the project. For the purposes of this discussion three sub-headings are used:

- More efficient business as usual
- Enhanced design
- More efficient construction

3.1 More Efficient Business as Usual

Within this category are processes that replicate but automate or enhance current practice. Benefits in this category are summarised from Eastman et al 2008 below:

- Earlier and more accurate visualisations of a design. 3D design not only enables easier visualisation at all stages but also ensures that all views are dimensionally consistent.
- Automatic low level corrections when design changes are made. This is possible if the objects are controlled by parametric rules and makes the management of design changes easier.
- Fully consistent 2D drawings can be generated at any stage. For instance elevations are automatically consistent with plan and sections.
- Better coordination between design disciplines made possible through the merging of each disciplines model to enable dimensional inconsistencies and clashes to be detected.
- Better cost estimates during the design process enabled by the ability to extract quantities from the BIM model at any stage and in a form appropriate to the level of estimating detail required and eliminated during the design process.

3.2 Enhanced Design

Within this category progress is being made in two directions, the ability to develop buildings that have an irregular form and the ability to model in detail the technical performance of the building. At least some of the drive to develop 3D modelling has arisen from the desire to produce accurate construction details of buildings designed with complex form. Examples of these include the Mariiinsky Theatre by Dominique Perrault in St Petersburg which Grohmann & Tessmann (2008) describe as a distorted tetrahedron and the Beijing Olympic Aquatic Centre described above with its irregular polyhedron space frame structure. Grohmann & Tessmann (2008) describe how 3D engineering programme enable the structural engineering problems associated with such forms to be resolved. From a construction perspective 3D modelling enables dimensionally correct 2D drawings of components to be derived.

The other direction in which BIM is rapidly evolving within the design area is the ability to model the technical performance of the building. The parametric nature of the model enables computational based analysis and simulation to be undertaken. Eastman et al (2008) describe the following areas of technical modelling:

- Structural analysis
- Energy analysis
- Mechanical equipment simulation
- Lighting analysis / simulation
- Acoustic analysis
- Airflow / computational fluid dynamics
- Building function analysis.

Similarly Soubra (2008) discusses the ability to model “comfort” including thermal, visual , acoustic, air quality. Within the areas of functionality Soubra identifies accessibility and flexibility.

Autodesk are currently releasing their "Ecotect^{TM} Analysis 2010" suite which they claim enables designers to visualize and simulate design performance in the area of :

- Whole building energy analysis
- Carbon emissions estimates
- Water use and cost estimates
- Natural ventilation
- Wind energy
- Photovoltaic collection
- Thermal performance
- Solar radiation
- Visual impact shadows and reflections
- Daylighting
- Shading design
- Acoustic analysis.

This and other developments appear to place the industry on the verge of making commercially practical, on mundane building, what was until now considered to be advanced, complex and expensive modelling restricted to leading edge projects.

3.2 More Efficient Construction

The third area within which there are potential benefits from BIM is in more efficient construction. The potential arises in a number of areas including:

3.2.1 Better Visualisation: A 3D model enables the construction team to better visualise what it is they are required to build. This can apply at the macro level to the construction management team concerned with the organisation of the entire project or at the micro level of the individual operative concerned with the fabrication of a particular detail.

3.2.3 Coordination of Information: Eatsman et al (2008) describe the dimensional stability that is inherently embedded in 2D drawing derived from 3D models. The plans, sections and elevations are derived form the same data and therefore cannot differ.

Howden (2009) a New Zealand architect with experience of working within this BIM environment report changing practice in the coordination between consultants. Instead of coordination being conducted at the completion of phases or sub-phases of the design process it is practical to merge the engineers and architects models as often as required (down to a daily routine). The various consultants models are merged and routines run to identify non- coordinated dimensions and clashes (structure with services etc).

In a similar manner the shop drawings of sub-contractors and suppliers such as structural steel and ductwork specialists developed in the same 3D environment can be taken into the base model for the project and checked for dimensional coordination fit and clash.

These developments alone can be expected to have significant effect on construction efficiency as this will reduce both lost time while dimensional and clash issues are resolved on site and rework that arises from these issues when they are not identified in advance of construction.

3.2.4 4D Modelling: This is the term used when the 3D model is linked to software that enables:

- Information contained in the base model to be extracted into the scheduling software and construction scheduling developed. This has the potential to enable the base scheduling data to be obtained efficiently and automatically updated as the design is modified. In addition objects contained in the 3D model but omitted from the schedule may be identified. This does not yet appear to be a commercial reality in the New Zealand context.
- The construction schedule once developed can be linked with the 3D model to produce an animation of the construction sequence. The potential benefits of this include:
    - The ability to identify and then analyse and improve critical areas. This may involve resequencing or altering construction details.

- The ability to identify and address issues of work space clash where multiple trades may be scheduled to work in the same space at the same time.
- Health and safety problems may be identified such as lifting activities taking place over another crew or a crew being scheduled to be in area before safety barriers are erected. (Hannon 2007)

3.2.5 Virtual Prototyping: Within the literature the activities of information coordination and 4D modelling described above are sometimes included under the heading of virtual prototyping. However additional processes also exist within this heading. These include:

- 3D modelling in detail of particularly complex construction details to ensure the components when brought together will fit. New Zealand examples identified include modelling complex reinforced concrete beam and column junctions where it was demonstrated it was not possible to fit all the reinforcing within the beam and column dimensions and provide space for the concrete (Murray 2009). The modelling of complex wall details to examine weatherproofing issues.
- Craneage modelling. The location and dimensions etc of cranes can be inserted into the 3D model and planned lifting activities checked to ensure they are feasible and safe (Baldwin et al 2008).
- Work process analysis. The 3D modelling of specific processes can be taken to the point where the location and activities of specific workers can be modelled to ensure there is sufficient safe working space for the propose activity (Baldwin et al 2008).

4. BIM AND THE QUANTITY SURVEYING PROFESSION

The potential impact of the developments in BIM described above on the quantity surveying profession, are discussed under the headings of:

- Multiple options and
- Increased information
- Procurement advice.

4.1 Multiple Options

The nature of the potential of BIM described above suggest that in order for that potential to be realised in improved buildings it will be necessary to do more work during the design process partly to improve the technical performance of the building and partly to improve the efficiency of the construction phase. Architects and engineers now have the tools and computing power to efficiently produce more options during the design process which need to be evaluated before a preferred option can be selected.

From the consultant quantity surveyors perspective this ability of the design consultants to generate more options creates the challenge to quickly and efficiently produce advice to the design team and client of the cost of each option in a manner that enables direct comparison to be made. The answer to this challenge may be provided at least in part through the object base of the 3D models. Because the model is constructed with objects rather than lines and points 5D extensions to the 3D software can count the number of each type of object and where appropriate turn them into aggregate data (a series of objects which are internal walls of various sizes can be aggregated into m^2 of internal walls or wall components). The measurement of quantities and their transfer into an estimating package should therefore be a simple automated process. Subsequent updates should also be simple.

However there are significant difficulties to be overcome before the above deceptively simple description can become a commercial reality. Matipa, Kelliher and Keane (2008) describe the technical challenges in achieving interoperability between the software of different vendors but also note that these difficulties are being overcome through alliances between vendors. Autodesk for instance describes how data from their Revit™ software can be transferred to Exactal's CostX™ software (Autodesk 2007). Despite this optimism 5D software that interacts easily with 3D software is not yet readily available for normal commercial use.

Even when the interoperability problems are resolved Kraus, Watt and Larsen (2007) identify that there are significant problems in achieving the standardisation needed to enable design objects can be mapped into estimating software. In simple terms if the description of the object used by the 3D modeller does not match the description used in the estimating software the two cannot be paired off to allow a price to be attached to a quantity. Hannon (2007) also notes this difficulty of mapping data from the 3D model into various estimating formats.

Assuming these difficulties can be overcome estimating practice that aligns with the manner in which the granularity of information regarding an object evolves in the design process will need to be developed. For instance as the design evolves from concept through developed design to construction details within the same evolving 3D model the level of information regarding a internal wall will evolve from generic internal wall to describe its fore rating, thermal and acoustic properties etc and then evolve again to describe construction details, surface finishes etc. The challenge to the quantity surveying profession is to develop techniques and processes that align with this evolution of detail in an efficient manner whilst providing for the cost of details that have yet to evolve.

Such development of costing process and technique is a fairly lineal evolution of the quantity surveying profession. Aligned to the development of multiple options within which varying technical performance is measured is the opportunity to further develop the services provided to clients in the area of assessing economic benefit. The design professions have the ability to generate and present to clients a number of options that are fairly well resolved in terms of preliminary engineering and technical performance. The client now has a problem of determining which is best when each has a different:

- Capital cost
- Construction time and development finance cost
- Energy efficiency
- Comfort factors
- Operational efficiencies etc.

Estimating the life cycle benefits of each alternative taking account of future risk and inflationary scenarios is possible with existing knowledge and computing power but would take most quantity surveying practices into new territory. Given the need to deal with multiple probabilities for each factor in the life cycle cost benefit analysis, techniques such as Monte Carlo simulation may emerge as standard tools in the quantity surveyors kit.

4.2 Increased Information for Construction Phase Estimating

The combination of 3D, 4D and virtual prototyping described above has the potential to provide the estimator with much greater levels of information than is used in current practice. By linking 3, 4 &5D software it will be possible to produce quantities related to both time and location (when in the schedule will the work be done and on which floor is it located) at almost any level of granularity dependant on the information in the 3 and 4D models. The challenge to quantity surveyors is how to use such information beneficially. For the consultant quantity surveyor can they evolve techniques to use this more detailed information to provide better advice to the design team particularly on alternative forms of construction. Similarly for the contractors' quantity surveyor can they evolve estimating techniques that enable them to refine their estimates and gain competitive advantage through better evaluation of alternative construction procedures and better evaluation of risk.

The potential of the computing tools may see a resurgence in interest in activity or location based estimating which have long been described in texts but rarely used in practice.

4.3 Procurement Advice

For the potential of BIM to be realised additional work early in the design process is necessary to set up the model and develop and analyse alternative design solutions. Adjustments to fees and timing of payments may be necessary to facilitate this.

Similarly it is necessary to involve the contractor in virtual prototyping exercises for them to be meaningful. A procurement method that allows early contractor involvement is therefore necessary to realise this potential.

The use of BIM models that integrate the work of the architects, engineers in their many forms, contractor, subcontractors and suppliers creates new legal issues. Thompson and Miner (2006) identify the following:

- Who owns the BIM model and the intellectual property contained in it?
- Who controls the entry of data and who is responsible for inaccuracies?
- Who is responsible for the integration process and checking for dimensional coordination and clashes?

For quantity surveyors involved in providing procurement advice to clients these are issues they need to take account of and deal with in an arena where practice is rapidly evolving.

5. SUMMARY

The use of BIM modelling or at least the 3D components of BIM has now reached the point where its use on building projects is widespread and rapidly increasing. The evolution of 4D and 5D components is not so well advanced as a commercial reality but this may soon change.

For the quantity surveyor this presents both challenges and opportunities in a rapidly changing arena. These include:

- How can they efficiently engage in providing cost advice for the alternatives that design teams can rapidly generate?
- Can they better engage in providing clients with advice on the economic benefits as well as the cost of alternatives?
- Are there better ways of estimating at each stage of the design process given the amount and type of data BIM systems can generate? Including can estimating data be better flowed through the process of evolving design detail?
- What advice should they give their clients on procurement methods to enable them to optimise the benefits they can obtain from the use of BIM.

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