The impact of Building Information Modelling on Construction Cost estimation

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Abstract

Construction, and of course, estimation processes are vulnerable to the limitations of spatiality in design and fragmented processes in entity-based CAD and manual design procedures. Whilst this challenge often leads to some tragic consequences, building information modelling (BIM) provides platforms for innovative and integrated design processes, and automated measurement. This development triggers the need for exceptional skills for intensive collaboration, project simulation, electronic data management, manipulation and handling of automated quantity measurement, simultaneous access to BIM design server and object-oriented design procedures wherein robust, clear and comprehensive information are underlain into project components. This study explores the impact of BIM on construction cost estimation. Samples of auto-measured BIM models are compared with existing standards and estimation procedures. Misconceptions about automated capacities of BIM and cost estimation are discussed. Recommendations are focused on further areas of research on the expectations of estimators on BIM models.

Keywords: building information modelling (BIM), estimation, measurement, models
1. Introduction and background of study

Cost and time estimates are imperative to the success of any construction project, both during construction and throughout the project life. According to (Serpell 2005), effective estimates are based on processes and procedures which are stipulated in the conventions and standards being used in the estimating industry. These standards (e.g. Standard Method of Measurement for Building Works, Editions 1 to 8, Civil Engineering Standard of Measurement, Editions 1 to 3, Heavy Engineering Standard Method of Measurement, Edition 1, and Building and Engineering Standard Method of Measurement) were developed to guide and improve professional judgments regarding indicators of value and accuracy in quantity measurement. (Akintoye and Fitzgerald 2000) have summarized some of estimating methods being used in the UK. The goal of estimating includes systematic reflection on inherent risks such that they are comprehensively quantified and analysed in manners that control and entrench balance between tangible and intangible variables of project costs. The Association for the Advancement of Cost Estimating (AACE 2003) defines construction cost estimation procedures as the comprehensive consideration of stochastic and deterministic variables, which include the evaluation of risks (indirect) and direct costs involved in the procurement and application of materials, labour, management and professional services, the cost of finance and other factors deemed necessary in a project.

Evidently however, construction and facilities management industries still grapple with inefficient estimation procedures and standards (Penttilä et al. 2008). Several reports present cases of project abandonment due to poor cost performance, crises in contractual relationships, infrastructure collapse due to shoddy execution of projects, cost overruns, delays in project delivery, various concerns on ethical dilemmas, as well as misplaced philosophies of drivers of value in construction project delivery. These have clearly been linked to inadequacies in processes and procedures of designing, estimation, planning and controlling construction (Gould 1998; Gruneberg and Hughes 2006; Yeoman et al. 1998; Yiu and Cheung 2005). While (Latham 1994) and (Egan 1998 ) argue that construction costs are rather too high, inconsistent and inefficient to create value for money; (Masidah and Khairuddin 2005) claim that some professional services offered by estimators are unnecessary and counter-productive. Moreover, (Williams 2008) and (Souza 2008) report that the industry has not witnessed major improvements in the accuracy of project cost estimation tools and competitive procedures in securing value for money. Consequently, the industry is in dire need of major systemic improvements that would facilitate accuracy in quantification, value measurement and risk assessment.

The construction industry is familiar with manual and computer-aided estimation (CAE) procedures (Oyediran and Odusami 2005). The limitations of manual estimation processes are evident in the extensive time estimators spend on certain energy-sapping procedures. Regrettably, the accuracy of estimates generated using manual processes leaves more to be desired (Endut et al. 2005). (Cheong 1991) observes the range of accuracy of manually estimated projects. Whilst comparing several estimation models, the author claims that estimates are mostly generated by Bill of Quantities (BoQ), the accuracy of which is estimated to range from 8 – 30%. Other studies have shown that estimation may be seen as the Achilles heel of construction processes as project success is at the mercy of
avoidable crises, which result from variations, disputes and other effects of subjectivity in professional judgments. In Ogunsemi and Jagboro’s (2006) opinion, it is yet practically impossible to determine the cost of construction until all aspects of the project has been concluded. However, Ogunlana (1989) - cited in (Lowe 1998 ) argues that the reliability of estimators’ judgments is more likely to improve as the quality and quantity of their experience improves. Interestingly, there is limited empirical evidence to justify extensive trade-off in efficiencies of computer-aided estimation over manual estimation procedures.

Evidence from previous reports shows that quality of information, project documentation, efficiency of designs and depth of interaction between project teams are significant to the reliability, accuracy and quality of cost estimates in construction processes (Acharya et al. 2006). Interestingly, CAD and BIM applications are two successive techniques that are being deployed to redress certain inadequacies in manual drafting and design methods. However, while CAD drafting applications are limited to two-dimensional or three-dimensional (2D or 3D) drawings which are based on geometric-data only; BIM combines both geometric and non-graphic information on design components. Although, there are other capabilities promised in BIM, there are certain features in BIM processes which relate to cost estimation in construction. Such features include automated measurement of quantities contained in BIM models, simultaneous access to design database, improved framework for communication between project teams, project visualization and simulation (Aranda-M. et al. 2008; French and Fischer 2000; Gu et al. 2008; Lee et al. 2005; Tse et al. 2005). This study aims to explore the impact of embedded information in BIM on cost estimation.

2. Auto-quantification of BIM models and estimation

Several studies have provided comprehensive definitions of BIM (Lee et al. 2005; Maher 2008; Méndez 2006). According to (Succar 2009), the applications of BIM transcend discipline or institutional boundaries, and its definitions are being tailored to multidisciplinary concepts. It can be adapted and expressed in relation to different perspectives, stage of maturity and depth of application. Nevertheless, in the context of this study, general applications of BIM in relation to estimation will be considered. Therefore, BIM is defined as a combination of computer-aided drafting and design (CADD) techniques and allied technologies, which extend beyond rendering designs in 2D or 3D with lines, arcs, splines and other rigid “unintelligent” features, but includes procedures and frameworks for enhancing object-oriented productivity and creativity in design processes through simultaneous creation, access, management, storage, use, update and sequencing of both geometric and non-geometric data to simplify project life-cycle information management. Given this premise, BIM facilitates sharing of data between different applications between project teams such that conflicts and insufficient information could be avoided. Interestingly, collaboration and value integration had been the bane of effective estimation in manual and conventional CAD applications.

BIM provides strong platforms for collaboration and process integration both for construction and facilities management. It also applies object-oriented design processes with features like simulation, project visualization, collaboration, value intelligence, thorough integration and data sharing. Aside these, BIM’s auto-quantification tools are relative to effective estimation processes as estimators
require drawing-based accuracy to trigger succinct description of cost variables in relation to accurate judgments on quantities, prices and risks. However, while so much has been said about the potential of BIM regarding process integration involving design, component specification and costing databases; the current level of achievement is fragmented as those systems are still independent. Figure 1 shows the taxonomy of interactions between CAD applications, specification documentation and cost estimation rather than full integration promised in BIM. Considering BIM as a platform for project stakeholders to collaborate, share data and sort discipline-related data on projects, it is expedient to explore the capacities of BIM models to satisfy procedural expectations that are relative to estimation.

![Figure 1: The Taxonomy of Interactions between CAD Applications, Specification Documentation and Cost Estimation (Dean and McClendon 2007)](image)

Interestingly, BIM allows multi-dimensional manipulation of drawings from higher dimensions to lower dimensions, and vice versa (nD to 2D and 2D to nD). Moreover, estimators are better off when they are able to visualise and rotate designs in 3D. This does not only show details that conventional presentations in 2D CAD cannot expressly reflect; this phenomenon facilitates more accurate judgment about construction realities. In addition to this, project visualization provides platforms that eliminate design conflicts and inefficient multi-discipline integration in design and construction processes. The implications of effective collaboration promised in BIM include systemic improvement of processes, as though when project teams integrate at earliest stages, issues or opinions that bother on economic risks and limitations are better conceptualized and comprehensively mitigated than in conventional fragmented processes.

Object-orientated modelling improves spatiotemporal capability of estimators. This is because they do not just relate with design components as quasi-real objects; embedded information that underlay model objects is very value-adding. As a way of limiting limitations of calculation errors, BIM models are auto-measured. This is a major advantage, especially with complex and irregular shapes. Moreover, BIM provides platforms for individual disciplines to use discipline-specific applications such that would enhance accuracy, innovative service delivery and value integration. It will therefore
be very helpful when estimators are provided with environments that permit workable relationship with information from other disciplines in the project team and vice versa.

Auto-quantification features in BIM both as Industry Foundation Classes (IFCs) formats and graphic dimensions, and those have been used to simplify control and planning of construction activities. According to (Sher 1996), the integration of procurement documentation and construction simulation has been a major challenge in the industry for decades as contractors often find it difficult to extract quantity data from tender documents. In many cases they need to confirm measured quantities in BoQs, extract information on construction risks and analyse work program digitally. Auto-quantification does not only reduce the time that contractors spent on quantity extraction, it saves them time for sourcing and management of price data as well as reduces inconsistencies of design data and measurements. (Sutrisna et al. 2005) have demonstrated how these issues often trigger crisis in civil engineering projects as working within limited time in bid-pricing frequently impel misinformation, conflicts, omissions and inaccuracy of judgments.

Conversely, a major issue in the multi-disciplinary deployment of BIM is how to distinguish between BIM models as objects and activity-based processes that conventional procedures are made of. Activity-based estimation procedures are prescribed in different forms and versions of Standard Methods of Measurement (SMMs) as though composed of several element-tasks that may be described with fixable cost implications. In currently forms of BIM models, these are made in ways that neither recognize exiting guidance which are predefined in SMMs and practice notes nor proffer a better alternative. Whilst BIM only provides platforms for all stakeholders to put in information into project database and sort whatever data they need, conventional estimation practice is activity-based wherein each element task are measured and defined, not just to standards of clients and project teams’ expectations, quantities must be applied to reflect appropriate construction situations. Moreover, as BIM models superficially present auto-quantities in as-it-appear form, certain data that are vitally important to estimators might not be available in some design models. Such includes wastes, allowances for joining and lapping, in-line fittings and accessories, material contexts, treatments and other indirect inputs. Table 1 shows some examples of BIM models in auto-measured forms and the corresponding variables in estimation standards’ provisions.

Table 1: Examples of BIM Models in auto-measured Forms and the Corresponding Variables in Provisions of Estimation Standards

<table>
<thead>
<tr>
<th>Model Forms</th>
<th>Object-based description in BIM models</th>
<th>Activities-based variables of estimation standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floors</td>
<td>Floors’ core material, including surfaces and other contents defined as unitary</td>
<td>Floor cores must be separately measured because they imply different costs; then other ancillaries like reinforcements, formworks, treatment to surfaces, etc are measured according to different rules. Other factors include corresponding units, nominal sizes of materials and description details, application complexities, assemblage treatments required, lapping details, shrinkage values and application limitations; ditto finishing and protection.</td>
</tr>
</tbody>
</table>
### Walls
- **Wall models are defined according to superficial area of main materials**
- Walls are measured according to types and must be separated from other ancillaries. Other variables of measurements include spot-item related measurements, type of wall materials and treatment to components’ core, bedding and jointing details, rendering materials and treatment, special treatments needed on surfaces, coating materials, number of coats, manufacturers’ details, etc.

### Roofs
- **Roof areas measured superficially**
- Roofs are considered on the basis of materials, manufactures, application limitations, and separately detailed from other attachments. Such include carcasses, ridges, barges, eaves, flashings, etc. Carcasses are measured in relation to sizes, lapping and application details.

### Frames
- **Frames are as-they-appear**
- Frames are measured according to types and separately from ancillaries, according to height, size or weight and content. Ancillaries are considered on the bases of sizes and weights, lapping, application requirements, treatment to surfaces, etc.

### Door and Window Units
- **Measured as model units**
- They are considered in relation to different characterizations. Main units are categorized by sizes, materials and thicknesses; then accessories considered separately. This must reflect size, type, model codes and other details of each accessory.

As the level of adoption and maturity of BIM application differ in different parts of the world, there is significant empirical evidence on the need to integrate the requirements and expectations of estimators in BIM model formulation, and this will be helpful to cost-led deployment of BIM universally. It is necessary that project teams improve on their value integration skills in order to facilitate improved design and construction processes. Hence, rather than rhetoric claims on error-proof potential of auto-quantified models, BIM models should be developed to reflect value and cost-led indices in construction activities. Many studies have shown that activity-based measurement of construction works has served the industry as a lasting platform for reliable accuracy, competition, accountability, openness, generation of value for money and innovative estimation procedures in construction.

### 3. Conclusion

Effective estimation procedure depends on the interaction between project teams and the value of quality of information design processes could reflect. However, while manual and conventional CAD applications are delimited by certain limitations, BIM promises marked improvements through collaboration and integration. There are exceptional opinions on the impact of auto-quantification in BIM on estimation. Although, this and other capabilities promised in BIM markedly reduce errors and conflicts of judgments in estimation, it is evident that bridging the gap between estimation conventions and auto-quantification features on BIM models is a challenge. Therefore, while the adoption and level of maturity of BIM modelling techniques continue to improve; this study identifies...
the need for stakeholders to develop integrative codes and standards that are systemic and strategic to construction industry’s fuller understanding of activity-based work measurement. Further empirical studies are needed to justify the acceptability of other options of measurement other than activity-based measurement rather than superficial claims on product-led auto-generated data. It is also recommended that BIM model development should be relative to multi-disciplinary expectations and standards as portended in the philosophy of trans-disciplinary integration it promises.

References


