EXPLORING THE BENEFITS OF EARLY CONTRACTOR INVOLVEMENT (ECI) AND THE MECHANISM FOR AUTOMATED 5D BIM QUANTIFICATION PROCESS IN OFFSITE MODULAR CONSTRUCTION

Tochukwu MOSES[1*], David HEESOM[2], David OLOKE[3], and Martin CROUCH[4]

[1]PhD Doctoral Researcher, School of Architecture and Built Environment, University of Wolverhampton, United Kingdom
[2]Reader in BIM (Dr), School of Architecture and Built Environment, University of Wolverhampton, United Kingdom
[3]Senior Research and Development Consultant (Dr), School of Architecture and Built Environment, University of Wolverhampton, United Kingdom
[4]Design Manager, Hargreaves Ductwork Ltd, United Kingdom
[*]Corresponding author's e-mail: t.g.moses@icloud.com

ABSTRACT

The UK Construction Industry through its Government Construction Strategy has recently been mandated to implement Level 2 Building Information Modelling (BIM) on public sector projects. This move, along with other initiatives is key to driving a requirement for 25% cost reduction (establishing the most cost-effective means) on. Other key deliverables within the strategy include reduction in overall project time, early contractor involvement, improved sustainability and enhanced product quality. Collaboration and integrated project delivery is central to the level 2 implementation strategy yet the key protocols or standards relative to cost within BIM processes is not well defined. As offsite construction becomes more prolific within the UK construction sector, this construction approach coupled with BIM, particularly 5D automated quantification process, and early contractor involvement provides significant opportunities for the sector to meet government targets.

Early contractor involvement is supported by both the industry and the successive Governments as a credible means to avoid and manage project risks, encourage innovation and value add, making cost and project time predictable, and improving outcomes. The contractor is seen as an expert in construction and could be counter intuitive to exclude such valuable expertise from the pre-construction phase especially with the BIM intent of 'build it twice', once virtually and once physically. In particular when offsite construction is used, the contractor's construction expertise should be leveraged for the virtual build in BIM-designed projects to ensure a fully streamlined process. Building in a layer of automated costing through 5D BIM will bring about a more robust method of quantification and can help to deliver the 25% reduction in overall cost of a project.

Using a literature review and a case study, this paper will look into the benefits of Early Contractor Involvement (ECI) and the impact of 5D BIM on the offsite construction process.

KEYWORDS – *BIM, Level 2 BIM, ECI, 5D BIM, Digital Quantification, Offsite Construction.*

INTRODUCTION

Accurate design information and adequate planning is considered necessary for offsite component fabrication or manufacturing. Woo (2007) points out the benefits of generating correct and accurate design information in the first place, arguing that the information extracted from the component model is only ever as good as that which is inputted. The drive contained in the UK Government Construction Strategy (2011) to reduce associated risks in projects, improve sustainability and product quality, reduce cost and overall project time in delivering projects to employers is creating common ground for innovation among contractors. The increasing pressure for the UK construction industry to remain innovative in their technological pursuits and processes, promote solutions that create construction cost efficiencies and delivering expected construction outputs is still at the front line of the Government mandate. BIM Level 2 has a significant effect on the existing traditional construction processes demanding a shift to a more collaborative way of working and a digitally integrated system where data integrity could be trusted and access and sharing of such data among project participants is made easier. According to Moses et al (2015), offsite manufacturers with their supply chain are expected to demonstrate credible innovative solutions to redefine project value delivered through the use of offsite solutions on the bases that it enhances product quality, improves cost saving benefits and facilitate overall product performance.

Today in the United Kingdom many types of facility components are fabricated and assembled in offsite factories and subsequently delivered to site for installation. The Level 2 BIM approach provides an information repository for contractors to input manufacturers BIM component details directly. This includes 3D geometry, material specifications, finishing requirements, delivery sequence and timing before and during the fabrication process (Eastman 2011) and a 5D automated approach to regulate the initial cost estimates and detailed cost plan of a project. The key element to BIM (Figure 1) is the process and if all offsite fabricators or modular project participants are set up correctly for the alignment of BIM implementation plans, protocols and processes then offsite projects and manufacturing processes will begin to realise a huge cost saving benefits.

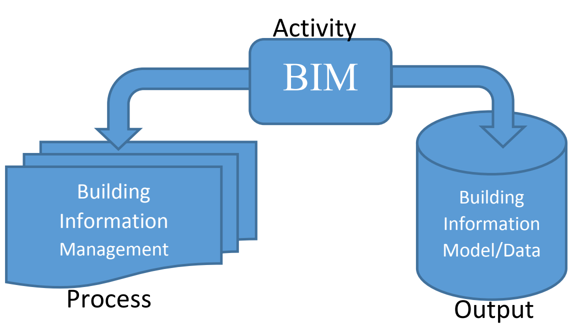

Figure 1: Showing the key elements of BIM (Adapted from RICS, 2015)

TRADITIONAL QS AND 5D BIM QS

Traditionally, the QS function is mainly associated with cost estimating and cost planning, production of bill of quantities (BoQs), interrogation of tender processes and documentation, procurement inputs, payments, construction cost control advice, valuation preparation, contractual claims and final accounts. This includes commercial management of construction projects broken into two distinct aspects: planning and control of project costs and the management of terms and conditions of the agreed form of contract between the client and the contractor (Kirkham, 2015). However the changes in procurement strategies with the developing construction standards and RIBA Plan of Works has expanded the role and responsibilities of the QS to cover whole lifecycle costing, value management, risk analysis and resolution and project management enabling the profession fulfil market demands (Ashworth and Hogg, 2007). With the emergence of level 2 BIM and the modern technological advancements in the construction industry today, Ashworth and Hogg (2007) note QS roles and responsibilities are expanded further to include automated measurement, digital quantification, sustainability, environmental analysis, investment advice, quality management etc requiring expanded QS functions and an increase of BIM skills. To increase cost efficiency and drive huge value for construction processes, UK clients (employers) expect QS practitioners to embrace BIM (BCIS, 2011), integrating this into their current practice, understand its potentials, develop and deploy effective means, tools, framework, standards, models to support their Level 2 BIM practice (Cartlidge, 2011).

'BIM is essentially value creating collaboration through the entire life-cycle of an asset, underpinned by the creation, collation and exchange of shared 3D models and intelligent, structured data attached to them' (RICS, 2015). The robust cost management of modular construction will be a fundamental measure and attract large amounts of stakeholder scrutiny. To initiate and complete offsite fabrication within time and budget will be the blending of collaborative behaviour, new technology and the communication between the systems, people and data.

'5D' BIM as used in the industry is referred to as the linking of 3D model components to a fifth dimension '5D' (cost) within a digital data environment. The 5D BIM QS key responsibility will therefore be to understand how a model and its attributes plus other data will be created and conveyed at different stages of a project in order to initiate suitable adjustment to quantities, rates and other ancillary costs and modifications at each work stage as appropriate. The almost exclusive use of spreadsheets for cost management of large complex projects is unproductive and highly inefficient. Engaging traditional process for design reviews, QTOs, inputting quantities into spreadsheet, and subsequent application of rates to produce an estimate will certainly require various different applications and data manipulations to generate accuracy if any and will have multiple negative effect when applied across a spectrum of cost consultants thus increasing risks probability. A step change from the current traditional practice is the use of integrated technological software approaches using automated digital quantification 5D BIM enabling the team members work on the same data set.

Offsite manufacturers should aim to develop a cost information model that supports specific business objectives covering inception and feasibility (brief and strategic definition), design through to tendering process, construction and even asset maintenance producing an electronic data for project life-cycle. UK offsite manufacturers are working towards automating a costing process that reflects the Government Soft Landing (GSL) which aims to consider the life-cycle costing (LCC) of a facility at the brief and design stage through to post commissioning (Pittard and Sell, 2016). Modular construction adoption of BIM will deliver and manage data in a spatially related and consistent format that encourages interoperability, allowing information to be shared by individual disciplines participating in a project and also between different stages of project design, construction and operation. Working from the same consistent and coordinated data set supports virtual construction hence the BIM intent of 'build it twice', once virtually and once physically. Key to 5D BIM is the assurance of correct data structure and unification of data with standardised and rigid naming classes and the identification of relationships between them (RICS, 2014). The uniformity of data language allow efficient consensus dialogue around cost related functions, facilitating robust understanding of the design requirements reflecting employers information requirement (EIR). This will enable the team to have a high reliability on the model for estimates, procurement functions, operations and maintenance costs. The offsite manufacturers should therefore move towards an interactive approach that uses cost software and other intelligence to extract data directly from design information allowing the project team and stakeholders to grapple a comprehensive overview of a whole life costs of a project.

5D BIM AUTOMATED QUANTIFICATION PROCESS

Quantity measurement and classification has evolved from the traditional processes into the digital age, taking off quantities against multiple measurements digitally. This is requiring early project collaboration across the whole spectrum of construction professionals bringing in expertise in planning, cost estimation, constructability and value engineering - hence the obvious need for early contractor involvement (ECI) in delivering projects. ECI will be further discussed later on in this paper using a case study of an SME based UK Company who designs, manufactures and installs HVAC. The conventional manual interventions or interpretation of data breeds risks of inconsistency and error in costing activities whereas BIM has capabilities to quantify accurately while reducing error margins. BIM with a multi-dimensional capabilities and it's information sharing abilities enables all parties involved in a construction project to visualise the model content from a single dimensional image and provides detailed designed elements and quantification for QS use (Mena et al., 2010). To import quantities from a model into a costing software in a BIM enabled data environment, elements are selected either individually or as a group. Correct classification of elements in the model for automated BIM process are considered extremely important and names for different material/object types is to be shared for correct interpretation as appropriate naming convention is currently a challenge. Elements are defined by intelligent data-rich objects within the model and these objects contain quantities and specification details enabling automated quantification. BIM based estimating tools vary in their functionality and working processes and it is the responsibility of the Quantity Surveyors (QSs) in collaboration with the corporate level management to select and engage these tools to be part of BIM based projects and also benefit from the merits of BIM technology. Choice of costing software with abilities to interrogate product models - the responsibility of testing and validating the use of that tool adapted to suit the types of model manufacturers produce is vital in evaluating organisations software need for process automation in 5D BIM quantification. Offsite manufacturers have the responsibility to improve their internal business processes by choosing appropriately the estimating tools (liaison with software vendors), looking at the potentials and performance of these tools in handling product data and ensuring alignment in their business goal and objectives.

Figure 2 shows a typical 5D BIM automated process demonstrating an interaction between software products, processes and data required to create 5D on mass in an efficient manner. The diagram demonstrates an automated tested process with a model assembly produced by a costing software 'CostOS' designed to price works according to the RICS NRM2 method of measurement for capital building works (Craven, 2016). It should be noted that this automated process mirrors what is possible with 'CostOS' and would apparently work differently with other costing software like CostX, Vico, Bentley AECOsim, Solibri Model Viewer/Checker 8, BIM Measure 16.4 etc.

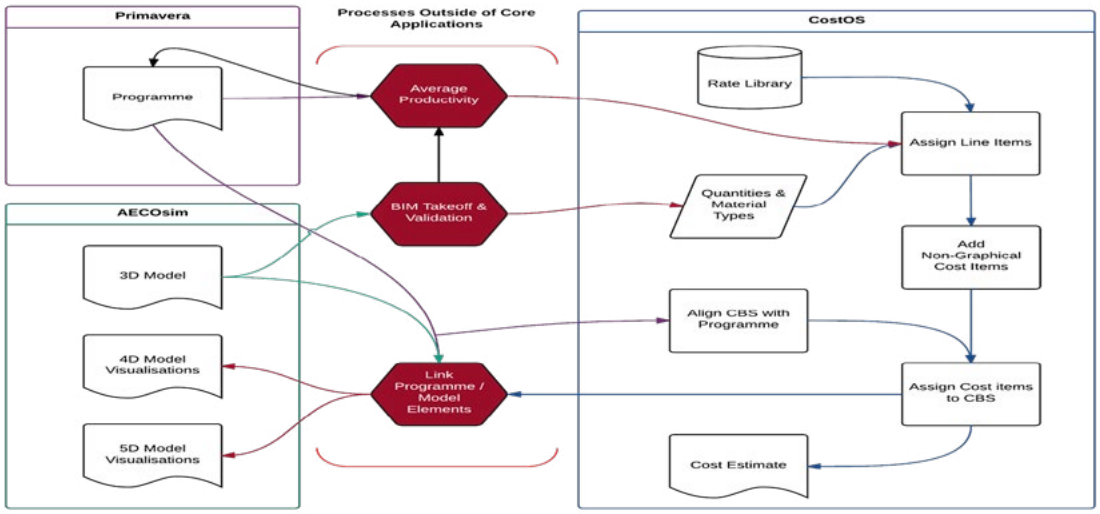

Figure 2: 5D BIM Automated Process (Source: LBA/HS2, 2016)

In this 'CostOS' process an IFC file is used as input and subsequently elements to price on the basis of their BIM Classification for example "Wall" are selected. From this subset the structural elements are grouped by thickness and a new Bill of Quantities (BoQ) item added for the sum of those elements with matching thickness. The unit rate library provided alongside the IFC has matching Unit Rates for the groupings which the assembly produces and allocates them accordingly. This process is repeated for all the classification types the assembly is programmed to interpret. Parametric factors are set in the assembly run interface to allow estimation of non-graphical items such as rebar content, formwork and soffits for the new line items. Non-graphical items are added automatically to the BoQ and there are pre-programmed cost line items for each of the items the assembly can import to apply prices. If elements in the model are misclassified, the assembly will not function as intended. Data could be passed into the assembly through a coding sequence to define how items are added to the BoQ or what automated non-graphical items would be added' (Craven, 2016). Classification of elements and correct naming of objects in a 5D automated process offers a better data interpretation and mitigates cost estimation risks when used in pricing. A knowledgeable QS is still required though an automated process to guide the software as in the semi-automated process while engaging 'CostOS' procedure for efficient cost 5D output. Additions of non-graphical items like site logistics, traffic control logistics etc not directly relating to the actual physical construction, would need to be added to the cost breakdown manually, or as function of total cost by a QS. Data availability and open relationships in regards to individual product data remains a big challenge facing 5D seamless automation in the built industry (Kirkham, 2015) but database / data integration supporting applications to draw data from each other's databases freely will eliminate the manual import/export of data and will enhance automation (Craven, 2016).

Manual interventions are still required for an efficient automated process to work well due to few element classification and IFC issues (Pittard and Sell, 2016). Defining the granularity of information produced during design phase supports 5D process to be fully automated and thus the very reason for early contractor involvement – the accuracy range of an estimate was based on the level of project definition in the traditional process using plans and specifications as a primary means to define a correlation between projects definition and the expected accuracy of an estimate. Traditional QS managed, organised, extracted and used cost information in the best means suited however that process shifted in BIM through early contractor involvement

(ECI) as more of the functions and cost saving advice begins in the design model phase (Garlick, 2016).

EARLY CONTRACTOR INVOLVEMENT (ECI)

Early Contractor Involvement is an aspect of the growing trend for early project collaboration across the industry allowing contractor's early involvement within the project team at the outset of a scheme bringing expertise in planning, buildability, cost estimating and value engineering (Garlick, 2016). The traditional approach within the construction industry in a Single-stage procurement and contractual models has only involved the contractor and its subcontractors only at the construction phase. However, such a model is not likely to obtain the best contributions of all parties to a successful project due to the exclusion of the main contractor and subcontractors from the early design and project planning and as a result innovative solutions, constructability, cost saving benefits, overall project timescale, health and safety planning into the design has been adversely affected. Experience has shown that value for money is not achieved in either the final cost of construction or the whole life and operational costs (Pittard and Sell, 2016). As a consequence, the industry embarked on a sustained campaign to cushion the effect of performance problems through a number of initiatives and radically different approaches to the procurement and management of construction projects with chief among them as BIM Level 2. Subsequently, emerging project delivery methods increasingly rely on collaboration between the client, designer and contractor and its subcontractor, and are aimed at developing longer term positive relationships for the benefit of all involved parties (Garlick, 2016). The traditional approach involved the team much too late in the project development and therefore providing limited scope for innovation, cost considerations, knowledgeable inputs into the design phase and the consideration of constructability issues. It is expected that the designer's team, consultants and contractor's team work together from the very beginning upon which the premise of the ECI is based. ECI supported through the BIM process is a credible means for cost savings and rewards cost-benefit ratio with respect to initial process investment for the manufacturers. It offers potential project merits in avoiding and managing project risks, predicting cost and project time, encouraging innovations and better project. Manufactures should leverage on the valuable expertise of contractors from the brief definition stage right through commissioning to ensure a maximised streamlined process and a support for automated quantification process in order to deliver a reduction in overall project cost.

An SME UK organisation, focusing on the design, offsite fabrication and installation of HVAC systems, was selected for the case study due to their maturity in the application of BIM. The study highlighted exemplar usage of 5D BIM and ECI. The early contractor involvement of the design-manufacturer company eliminated the tendering process since the cost is being derived in collaboration with the client design consultants alongside the manufacture designers. The case study highlights ECI supported the client's design consultants in designing to a correct level of detail for use of in the manufactures subsequently positively impacting cost.

CASE STUDY

The study focused on a single high value project within the host organization whereby clients design consultant had identified early within detailed design, that their traditional design team had little experience in coordinating traditional building services and ventilation systems. The design consultant was using BIM clash reports to manage the detailed design layouts, but was not controlling coordination or access requirements which can then move the problem further down the programme and into manufacture design. This approach would have brought about considerable reworks of the HVAC systems after the coordinated model for detailed design had been approved. In embracing the manufacture design team early and embedding the team into the traditional detailed design, enhanced the teams overall capabilities to deliver a rounded solution. The manufacture design teams brought practicality into the routing, coordinated support structure, which will save on installation time and cost.

The value transition point for this project was much earlier than has become traditional, as the drawing and routing design works was led by the manufacturer rather than the clients design consultant, as it is them that has this practicality and knowledge of the product. The early involvement of the manufacture designers added 5D cost value to the design scope at that early point of entry, challenging design liabilities, and design details that come in excess of what's required at that design phase. Again receiving a completed design model in a file format that cannot be converted (like solidworks, PDMS) by the manufacture designers is not value add, it means retracing that design information and redesigning it for appropriate use. 5D BIM automated processes with this approach brings confidence in the detailed design output and cost information; this confidence allows the project to move directly into manufacture once the detailed design gate has been achieved. Having a huge cost and time savings on the normal costly tender exercise / contract placement and quality assurance documentation/ manufacturer familiarization period as could be seen in figure 3.

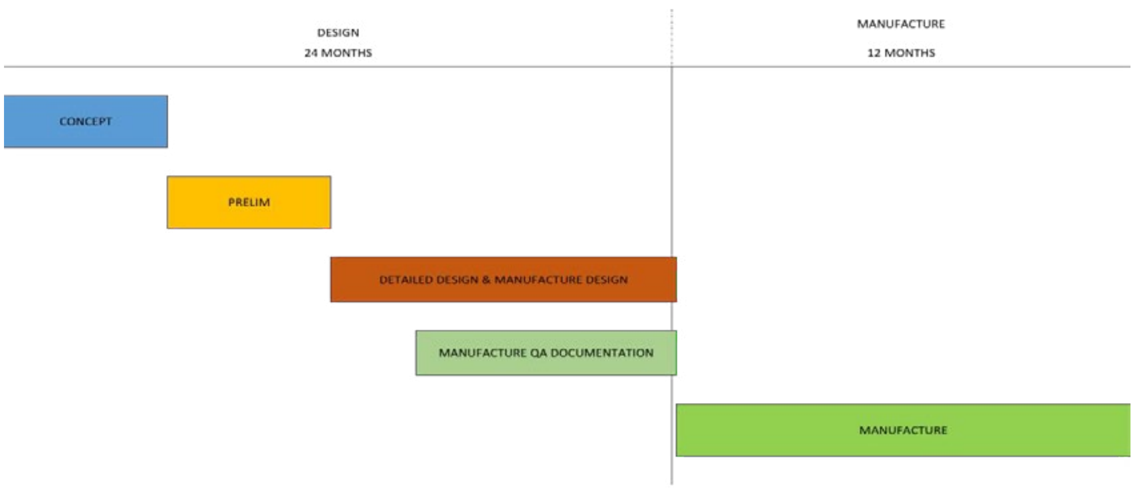

Figure 3: Early Contractor Involvement Case Study

Benefits of Early Contractor Involvement and 5D BIM

- Removes the normal costly time consuming mid-term tendering process.
- Knowledge retention through-out the whole project delivery.
- Visualisation of cost information by all parties involved
- Ability to interact with the design model with reference to cost and programme schedule
- Enhancement of project team collaboration through modelling of 5D information and generating the suitability of 3D design information.
- Project conceptualisation as 3D design information facilitated the costing of design options through ECI
- Efficient generation of quantities for cost planning as compared to the traditional QS processes during the manufacture design detailed cost plan stage
- Contract arrangement more likely to encourage a fit for purpose solution.

- Increased ability to resolve RFI's in real time, potential risks identification and clash detection possibilities
- Substantial time and cost saving exist for the project, as the Quality assurance documentation and manufacture design detail can be completed earlier - during the detailed design phase, further enhancing the benefits identified in item one above.
- Commencement of the Quality Assurance documentation can only commence in manufacture design, this documentation is quite likely to take longer than the manufacture design and in some instances delays manufacture.

CONCLUSION

To streamline construction processes, automate standards and enable collaborative working within UK construction, Level 2 BIM is currently implemented. As part of this philosophy, 5D BIM and ECI can help and manufacturers to engage with the BIM process to improve the construction process and subsequently save time and money. Currently a level of fragmentation exists within the offsite fabrication process in respect to 5D and this requires more development with respect to automated process to generate further cost saving benefits.

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