Attributes That Determine the Building Information Modelling Capability Maturity of Quantity Surveying Practice

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Abstract. With more than 80% of all construction projects overrunning their budget, there is a need for more efficient management of the estimated 10% of Gross Domestic Product (GDP) that is expended annually on construction across the world. It has been proposed that better information and data management through Building Information Modelling (BIM) will lead to cost savings and greater predictability. Notwithstanding the role of quantity surveyors (QS) in modelling and managing construction cost, they remain among the least capable of assimilating BIM into their existing traditional processes. Despite the increasing need for BIM capability assessments for projects, there remains, no tool specifically developed for assessing QS firm's BIM utilisation capacity or performance. As a result, it is unclear the attributes that indicate BIM capability of QS firms as well as QS practices on projects. This study sought to address this through a review of BIM capability assessment frameworks in order to ascertain their suitability for QS practices. An expert focus group discussion was then used to identify peculiar attributes suitable for QS BIM capability assessment as a precursor to the development of a comprehensive model of QS BIM capability maturity. Findings reveal that most QS BIM capability attributes relate to processes including criteria for effective information definition and data management such that they are consistent with QS measurement standards. The BIM competence of staff also emerged as one of the key attributes highlighting the need for QSs to improve their knowledge, skills and experience in the application of BIM amidst current low levels of adoption. The proposed attributes would assist the development of performance and maturity indicators that would help QS firms better understand their own capability as well as the requirements for delivering costing services through BIM on projects.

Keywords: costing, information modelling, quantity surveying, projects, competence, maturity

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1 Introduction

The majority (circa 80%) of construction projects overrun their budget [1, 2], thereby making it imperative for more efficient management of financial resources expended annually for the delivery of construction. Global initiatives on IT adoption for construction envisage significant cost savings from the implementation of novel digitally driven processes. For instance in the UK Government hopes to achieve up to 33% cost savings through the digitisation of processes with Building Information Modelling (BIM) [3]. Notwithstanding the role of Quantity Surveyors (QS) in modelling and managing construction cost, they remain among the least capable of assimilating BIM into their existing traditional processes: only a meagre 10% of the mostly SME QS firms are reported to be using digitised BIM-based practices[4]. Despite the increasing need for BIM capability assessments for projects, there remains, no tool specifically developed for assessing QS firm's BIM utilisation capacity or performance. Emerging tools and frameworks have been designed for organisations with high design responsibility (such as architects) rather than for QS who directly manage and control spending on projects [5-12].

The aim of this study is, therefore, to develop a BIM capability assessment framework specifically for QS BIM utilisation, benchmarking and performance. This will aid the development of a set of metrics for evaluating the ability of QSs to deliver services through BIM as well as serve as an evaluation tool to aid alignment of QS BIM implementation with performance expectations. In this article, the attributes that determine a QS organisation's BIM capability is explored as a precursor for the development of a comprehensive capability maturity model.

2 Quantity Surveying Practice and the Use of BIM and Related Technologies

The major role of QSs in construction projects is costing and managing cost-related activities, this requires expertise in the measurement of quantities of building elements with procedures such as quantity take-off (QTO), cost modelling as well as other contract administration and commercial management functions. The traditional approaches to QS rely on traditional paper-based tools [13, 14]. The potential of BIM to create efficient working approach among construction professionals has however been proven by the wide adoption of 3D BIM by architects and engineers in optimising design visualization and evaluation of design choices [15]. Building contractors have also adopted 4D BIM for construction planning and scheduling but the adoption of 5D (use of BIM for costing and commercial applications) is relatively low [4]. According to Ustinovičius et al. [16], 5D BIM is a critical element of building lifecycle management through precise cost estimation as well as the elimination of human-related errors. Furthermore, Reizgevicus et al. [17] have highlighted the importance of QS practices such as life cycle costing and reliable cost analysis of different construction scenarios in the attainment of sustainability through BIM use.

The Industry Foundation Classes (IFC) has increased the opportunities for QSs to collaborate with all other industry professionals through the facilitation of open data formats for the transfer of information across various applications [4]. BIM offers a faster and effective approach to generate relevant data for QS functions in order to develop cost estimates through automated extraction of quantities from building models, it also enables parametric links for automatic updates of quantities when design changes occur [18]. The efficiency of delivering cost-effective projects has been greatly influenced by innovative technology thus critical processes such as cost planning, cost control, cost estimating and analysis can now be achieved more effectively using BIM application and platforms (i.e. 5D BIM) [4, 14]. There are more opportunities offered by innovative technology towards

improving the efficiency of project costing and QS practice overall. Most QS functions can, therefore, be more easily achieved with the application of digital technology and data analytics [4, 15].

Ashworth and Hogg [19] predicted the expansion of QS practices to cover automated measurement, environmental and sustainability analysis, facilities management, legal services, investment advice and quality management through the adoption of digital technology. Although there is a perceived threat to the QS profession with the prospect of replacing people with technology, the opportunities ahead are more than the threats [15]. Aside from the expanding opportunities in the scope of QS practice, there is an important role for QSS in the BIM development market. The skills required to drive such 5D BIM is however enormous and QS practice requires some capacity building [14, 20].

3 Organisational Capability and the Implementation of BIM

Capability Maturity Models (CMM) have been adopted for the assessment of the quality of organisational processes within software firms since the late 1970s [21]. Some of the most popular models include the quality management maturity grid by Crosby [22] and the CMM by Carnegie Mellon Software Engineering Institute (SEI) [21]. According to Eadie et al. [23], maturity models are characterised by structured elements representing key process areas as well as capability stages for progressing in these process areas. Thus, a maturity model aids the identification of critical process areas responsible for a firm's performance or capability in delivering a particular function [22]. They are popularly used in performance management to provide guidance on steps towards improving performance in key organisational process areas. Similarly, with the emergence of BIM, the maturity modelling concept has been adopted to model BIM capability [7, 12, 24]. Succar et al. [25] defined BIM maturity as "*the quality, repeatability and degree of excellence within a BIM capability*". According to Succar [24], BIM maturity is primarily used to benchmark performance improvement milestones during BIM implementation or use. The notable BIM capability maturity frameworks and toolsets include the Capability Maturity Model (CMM) by the National Institute of Building Science [7]; the Indiana University BIM proficiency matrix [26]; the BIM capability framework by Succar [24]; the BIM owners' competency framework by Giel and Issa [12]; the BIM Quickscan [6]; the BIM readiness frameworks by Gu and London [27]; BIM pre-qualification and selection framework [28] and ARUP's project maturity assessor [29]. The major limitation of these frameworks relative to QSS is, however, the fact that none of them has been specifically developed for QSS. Some generically apply to construction organisations [7, 8, 24, 28] while others apply to project scenarios [26, 29]. Giel and Issa's [12] model focussed on clients while all of the other frameworks do not specifically target particular disciplines however most suited for originations with design responsibility [28]. Some other frameworks have been developed for the assessment of the product (i.e. BIM model) maturity [11].

While these emerging standards, frameworks and tools have provided the basis for the identification of appropriate BIM capability criteria, none of them specifically address peculiar needs of QSS and QS practices. The only model with criteria for assessment cost-related BIM modelling process is the ARUP model [29]. However, this model pertains to BIM model maturity for projects rather than a QS organisation's maturity. Furthermore, it relies on a generic set of criteria that are used for assessing other disciplines such as Architecture, Mechanical and Electrical, thus, the criteria are not specific to QS. From the review of the state-of-the-art, it is clear that no BIM capability assessment tool exists for QSS, neither is it clear if the generic capability attributes proposed in existing frameworks are suitable for QS processes and organisations.

4 The Identification of Key Attributes for a BIM Capability Maturity Model for Quantity Surveying

The development of capability maturity models requires the identification of key attributes often referred to as key process areas (KPA) which represent the primary areas of performance in an organisation or system [5, 21, 23]. These capability attributes (KPA's) are distinct clusters of related activities, competencies and resources that are required for the attainment of goals [21]. The conventional notion of KPAs is that they must include processes, people and personnel, policy, systems and resources required to perform functions effectively and efficiently [24, 28]. This study, therefore, explored the attributes required for assessing a QS organisation's capability to deliver BIM as a precursor for developing a comprehensive capability and performance benchmarking framework based on capability maturity modelling principles.

5 Methodology

A focus group discussion (FGD) involving experts in the application of BIM for QS was used to identify a list of attributes that denote QS organisations ability to use BIM. This process allowed experts to propose criteria as well as review generic criteria derived from a review of the literature and existing BIM capability frameworks. The FGD further aided the exploration of expert views on the potential of BIM for transforming QS practices as well as review the current capacity and capability issues in the industry. A total of seven experts were engaged in the FGD. The FGD participants comprised mainly of QSSs, BIM Managers, BIM Consultants and a QS software developer. All participants had a vast experience in the application of digital technologies for construction as well as QS practice in general. They were recruited from reputable organisations with departments or projects responsible for the digitisation of QS functions. High level of expertise was a criterion for selecting participants and was also in order to meet the requirements for selecting participants when using expert group methods for data collection [30]. The following criteria were specifically relied on in selecting participants: senior professional or academic in BIM and QS; a minimum of five years of industry experience; and possession of professional QS or BIM qualifications. The background information of FGD participants is presented in Table 1. FGDs normally involves a small group of participants to ensure effective management of the data collection by the researchers [31]. Focus group methods are the preferred approach for interrogation of the phenomenon to high levels of detail and depth while reducing interviewer-domination [31, 32]. FDGs have been previously used for the identification of capability attributes in the development of capability maturity models [33]. The FGD was adopted to allow the participants to draw from each other's expertise and experience regarding QS BIM capability in order to enrichen the discussions.

Table 1. Background of FGD Participants.

ID	Role/Position	Experience in Construction	Experience in Digital Construction	Qualification
1	BIM Manager	20	7	BSc
2	Director - QS Software Development (*MICE)	40	12	BSc
3	Associate Director - QS and Commercial Management (*MRICS)	15	5	BSc
4	Construction Manager	10	2	MSc
5	Digital Construction Consultant	16	15	BSc

6	Associate Director - QS and Commercial Management (*MRICS)	14	3	BSc
7	Academic and Professional QS (*MRICS)	30	10	MSc
*Notes: BSc = Bachelors Degree; MSc = Masters Degree; MRICS = Member, Royal Institution of Chartered Surveyors; MICE = Member, Institution of Civil Engineering				

6 Findings and Discussions

The QS BIM capability attributes derived from the FGD is presented in Table 2. In total 18 key capability attributes were proposed. Some of the attributes proposed are similar to proposed attributes in BIM capability and maturity frameworks but uniquely differ given its focus on the QS practice. The criteria that are similar to previously proposed BIM capability are: Staff competence; Organisations experience; Organisation’s qualifications; Hardware; Software; Network capacity; Leadership; Policy; and Roles and responsibilities [10, 24, 28]. The criteria peculiar to QS BIM use include: Scope of QS services rendered digitally; Commercial and cost data security; Commercial data security; Cost model progression specification; Cost data exchange protocols; and 5D BIM execution planning.

Table 2. Summary of Quantity Surveying BIM capability attributes.

No.	QS BIM Capability Attributes	Key process area (KPA) category			
		People	Policy	Technology	Process
1	Staff Competence Skills, knowledge, experience and expertise among staff. Professional and academic qualifications relevant to 5D BIM and digital technology application.	X			
2	Organisations experience Historical/previous use of 5D BIM and digital technologies within the organisation and on projects.	X			
3	Organisations qualifications and certification Formal certifications indicating BIM capability, maturity, competence, standards and use of protocols.	X			X
4	Scope of QS services rendered digitally Delivery of core costing and QS functions through BIM, advanced digital technologies and data analytics.				X
5	Hardware Hardware to support 5D BIM, data capture, storage, analytics and advanced visualisation.			X	
6	Software Software to support 5D BIM, data capture, storage, analytics and advanced visualisation.			X	
7	Network capacity Adequate and secure network infrastructure to support 5D BIM through centralised or cloud-based interoperable data exchange.			X	
8	Workflow management Process maturity within the organisation for object-based, model-based or network-based integration of cost services into BIM (5D).				X

9	Commercial and cost data security Protocols, infrastructure and services that ensure commercial data privacy, protection and integrity.	X			
10	Cost model progression specification Model progression specifications for 5D BIM modelling within the team and for specifying to other project consultants.	X			
11	Cost data exchange protocols Protocols that ensure interoperable use of information from other consultants for 5D BIM (i.e. Data naming conventions and model element breakdown structures that conform or are mapped unto the classifications in QS and measurement standards such as NRM, ICMS, SMM)	X			
12	Quality assurance Availability and use of quality assurance protocols and tools to ensure data integrity, accuracy and conformance in 5D/BIM models and outputs.	X	X		
13	5D BIM execution planning Project-based execution planning and protocols for strategic implementing 5D BIM.	X			
14	Roles and responsibilities Availability of specific BIM roles within the organisational hierarchy	X			
15	Leadership Availability of executive sponsorship, champions and dedicated implementation committees for 5D BIM implementation	X			
16	Policy Clear statement of purpose and objectives for BIM use within the organisation as well as the level of importance placed on digitisation within broader company vision, mission or policies.	X			
17	Research and development Directed work and resources for innovation and improvement of products and processes for 5D BIM	X	X		
18	Digital culture Demonstrated culture of preference for technology- oriented processes in organisation or willingness to use innovative technologies for QS functions.	X			
Related KPA frequency		5	3	4	9

Note: 5D BIM as used in the description of attributes refers to all applications of BIM to costing and quantity surveying functions.

Abbreviations: CPD Continuous Professional Development; ICMS- International Construction Measurement Standards; NRM- New Rules of Measurement; QS- Quantity Surveying/Surveyor; and SMM- Standard Method of Measurement.

Based on the categorisation of BIM maturity elements by Succar et al. [25], the attributes were reclassified into four distinct categories. The classification of attributes was as follows: technology, process, people and policy. The technology category describes specific abilities related to physical artefacts including software, hardware and data or networks. The process category is used to describe activities, workflows, services, procedures for delivering BIM. The people category describes knowledge skills and competence possessed within an organisation or by individuals for the delivery of BIM objectives. Finally, the policy dimension describes the guidance and principles of action adopted for the attainment of BIM implementation goals.

The majority of attributes ($n=9$) were ‘process’ related though unsurprising and supports the primary definition of BIM which emphasizes its process laden nature [5]. Capability maturity models are also premised on a philosophy that process improvement is responsible

for the attainment of objectives in digital technology use [21]. A significant amount of the process criteria were related to the management of information and data exchange. This finding brings into focus the role of interoperability in the effective delivery of QS functions through BIM [4]. While the IFC has increased the opportunities for Qs to collaborate with other disciplines, there remains a need for protocols to facilitate the process and organisational interoperability [4]. The attributes proposed thus highlight the need for capacities in the definition and classification of data such that they are consistent with QS and measurement standards such as Standard Method of Measurement (SMM), International Construction Measurement Standards (ICMS) and the New Rules of Measurement (NRM). The majority of proposed QS BIM capability attributes align with a systems and hard technology deterministic view of BIM capability [28]. The category with the second-highest number of attributes (n=5) was the 'people' category with emphasis on competence and experience of individuals and the organisation as a whole in delivering QS related services through BIM. According to Succar et al. [9], the ability to adopt BIM-related processes is dependent on proficiency among staff, as well as its aggregated effect on the entire organisation through collective learning as well as the distribution of roles and responsibilities. Existing BIM frameworks and toolsets [5, 6, 8-10, 12] have similarly recognised people-centric competency measures as influential determinants of BIM capability. The concern is, however, the low level of QS BIM adoption which will invariably delay the process of developing a critical mass of Qs experienced in the use of BIM-related process and technology.

The findings reveal critical QS BIM capability attributes as well as dominant categories of attributes. The dominance of particular types of the QS BIM capability attributes does not, however, indicate their importance thus there is a need for further research to determine the relative importance of criteria.

7 Conclusion

The use of BIM within QS practice is becoming more necessary as a result of high levels of BIM use and diffusion across other segments of the construction industry. Despite the potential of BIM, however, Qs continue to lag behind in adoption as a result of capability issues among other reasons. A review of studies reveals that the majority of emerging tools and frameworks have been developed for organisations with high design responsibility (such as architects) rather than for Qs who directly manage and control spending on projects. Consequently, there are serious limitations regarding the suitability of criteria in existing BIM capability and maturity frameworks for use in QS scenarios. This study thus sought to address this by proposing QS specific BIM capability attributes. Findings reveal that most QS BIM capability relates to 'process' including criteria for effective information definition and data management such that they are consistent with QS and measurement standards. The proposed QS BIM capability attributes highlight the key process areas for the development of performance and maturity indicators that would assist QS firms to better understand capability issues as well as BIM implementation priorities. A limitation of this study is the lack of prioritisation of attributes to determine which is the most important. The subsequent phase of this study will, however, address this and prioritise these attributes as well as identify definitions of maturity levels for each. This study relied only on expert judgement, thus future studies could adopt longitudinal, ethnographic approach or case studies to explore further, the attributes identified in the current study as well their relative importance in practice.

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