Framework for Evaluating the BIM Competencies of Building Owners

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ABSTRACT

Facility owners play a vital role in the Architecture, Engineering, Construction, and Operations (AECO) industry to improving the quality of building information modeling (BIM) execution. However, research shows that BIM adoption by owners is still in its early stages. Owners' requirements documentation, their assessment of the quality and accuracy of BIM deliverables, and their continued use of BIM during Facilities Management (FM) are critical to reaping the full life-cycle benefits of this technology. In order to improve facility owners' execution of BIM, it is critical that their BIM competency be assessed. Using the Delphi technique, this research identified and prioritized 66 critical BIM competency factors that building owners must possess using the perceptions of 21 pre-qualified BIM experts representing several diverse roles in the AECO industry. Based on the results of this study, a BIM competency evaluation framework for owners is proposed.

INTRODUCTION

In the most recent Smart Market report conducted by McGraw-Hill Construction (2012), 30% of owners surveyed indicated that they were using building information modeling (BIM) on more than 60% of their projects. However, more than 50% of those surveyed indicated their BIM expertise level to be that of beginners (McGraw-Hill 2012). Organizations like the General Service Administration, the Department of Veterans Affairs, the US Army Corps of Engineers and many higher education institutions have set exemplary standards for those looking to get started. But most efforts have been conducted during the design and construction phases (Becerik-Gerber et al. 2012; McGraw-Hill 2009). Many facility owners still lack the technical proficiency and knowledge required to manage and later utilize BIM processes downstream during Operations and Maintenance (O&M). This knowledge gap in conjunction with their recent increased demand for BIM creates a strong research need to educate facility owners and improve their BIM Competency.

LITERATURE REVIEW

Since the 2007 publication of the National BIM Standard (NBIMS v1), there have been several subsequent BIM maturity assessment tools suggested by various authors and consulting organizations. Among the most referenced include: the NBIMS *Capability Maturity Model (CMM)*, the *BIM Excellence (BIMe)* program, *BIM Quickscan*, and the *VDC Scorecard*/*bimScore*. Table 1 compares these tools

based on their intended user groups, evaluation style, rating context, measurement categories and number of maturity levels.

Table1. Leading BIM maturity tools compared

	NBIMS CMM (NIBS 2007)	BIMe (Succar 2010, 2013)	BIM QuickScan (Van Berlo 2012)	VDC Scorecard/ bimScore (CIFE 2011; Kam et al. 2013)
Intended User Group	A,E,C, O	A,E,C,O	A,E,C	A,E,C, O
Rating Context	Evaluates information management on building projects	Evaluates organizations, projects, teams, or individuals BIM maturity & performance	Evaluates BIM performance level of organizations providing BIM services	Evaluates project BIM performance and maturity
Evaluation Style	Self-evaluation of the model	Multiple types of evaluation offered	External certified evaluator or a free online *self-scan* assessment	Multiple types of evaluation offered
Measurement Categories and Weightings	*11 areas of interest* weighted based on importance	Multiple indices with different categories based on the evaluation context	*4 chapters* and *10 different aspects* based on weighted KPIs	*4 areas* across *10* different *dimensions* and several weighted measures
Number of Maturity Levels	10 maturity levels	5 maturity/ competency levels across various indexes	None (evaluation is based on weighted KPIS)	5 percentile ranges of increasing innovation

In an effort to synthesize some of these same research efforts, Chen et al. (2012) have also developed a framework for measuring BIM maturity based on the perceptions of a sample of BIM experts inside and outside of the U.S. The authors combined some of the variables proposed by Succar (2010) and NIBS (2007) to determine 27 indices for measuring BIM maturity. They concluded that in recent years BIM maturity analysis has evolved from technical factors related to software and hardware to factors related to information processes and people (Chen et al. 2012).

Though many of these research efforts may be used to evaluate owner organizations, few address the specific needs and information requirements of facility owners as a separate entity. Most similar to the intent of this study has been the work of the CIC Research Program at Penn State University. Their *Facility Owner's Guide,* published in early 2012, has been very useful to the owner community; providing suggestions for how to begin planning for and requiring BIM processes (CIC 2012). The document provides a template maturity matrix that corresponds to the guide and its suggested execution strategies. However, little detail has been given regarding how the assessment variables were chosen and weighted. This research study expands upon their foundation and suggests a different approach to assessment which incorporates a more inclusive list of variables.

METHODOLOGY

Delphi Background. The Delphi Method, a survey technique which has been widely adapted among a number of different research disciplines, was used. The methodology is often useful when there is incomplete knowledge about a problem, when the problem addressed does not lend itself to analytical quantitative techniques and/or when collective problem solving may be useful (Skulmoski et al. 2007). Because of the novelty of using BIM during O&M and the lack of concrete use-cases on building owners identified in the literature review, this technique was chosen as a means for the development and prioritization of owner's BIM competency factors.

The four most notable characteristics of the Delphi technique include: anonymity, iteration, controlled feedback and statistical aggregation of expert group responses to achieve consensus based reasoning (Rowe and Wright 1999). Expert panels can range from three to 80 members and anywhere from two to six rounds can be conducted. However, Hallowell and Gambatese (2010) suggested three rounds of at least 8-12 panelists based on their review of construction engineering and management (CEM) Delphi applications. Though the suggested sample size is much smaller, maintaining a high response rate between rounds is a critical part of the process. The same sample of participants must be present through the conclusion of the study.

Procedure. Over a period of five months, a BIM expert panel was assembled and surveyed to determine the leading factors most useful to the evaluation of building owners' BIM Competency. Five separate respondent categories were targeted including: Architects/Engineers, Contractors, Owners, Consultants and Academics. Participants were required to satisfy criteria in one of the following three major categories: (1) They had to have at least five years of BIM experience working with an Architectural, Construction Management, Engineering or specialty Consulting firm and have personally worked on at least five projects in which BIM deliverables were exchanged at critical life-cycle phases with requirements by owners; or (2) They had to be employed by an owner organization which had required BIM for a period of six months or more and have had direct experience working with BIM deliverables on a minimum of five projects; or (3) They had to be a researcher in the BIM maturity or facility management domain and satisfy at least four of the criteria outlined by Hallowell and Gambatese (2010) in qualifying as a CEM expert from academia.

Solicitation for participants for the BIM expert panel were sent via email to VDC/BIM managers of the ENR's top 25 Architecture, Engineering and Construction firms, members of the Florida Chapter of the Construction Owners Association of America (COAA) and the BIM for Owners group on LinkedIn. Additionally, the research proposal was presented at the 2012 Campus FM Technology Association (CFTA) conference and the 2013 building Smart alliance (bSa) Building Innovation Conference. Using the criteria previously outlined, a ten question online survey was utilized to gauge the qualifications and BIM experience level of all potential participants. Eligible respondents were then formally invited to participate.

The expert panel participated in three rounds of anonymous electronic questionnaires delivered via email. Using a three-point Likert scale, participants were asked to suggest and rate the perceived importance of a list of BIM competency

factors derived originally from a comprehensive review of literature on the existing BIM maturity tools (Giel and Issa 2013). Consensus was considered to be reached for each factor with an Interquartile Range (IQR) < 2. Stabilization of opinion was deemed to be reached if less than 15% change occurred in the mean importance rating of a factor between two consecutive rounds. A prioritized list of 66 BIM competency factors was then developed based on the mean importance ratings awarded in the final round and a corresponding BIM Competency evaluation framework was proposed.

RESULTS

Demographics. A total of 21 qualified BIM experts were identified, representing many different perspectives within the AECO industry. Figure 1 shows the proportion of respondents within each respondent category. The sample contained: seven representatives from building owner organizations, five representatives from construction management organizations, three representatives from BIM consulting firms, two representatives from architectural firms, and four researchers with experience in the FM and BIM maturity domain.

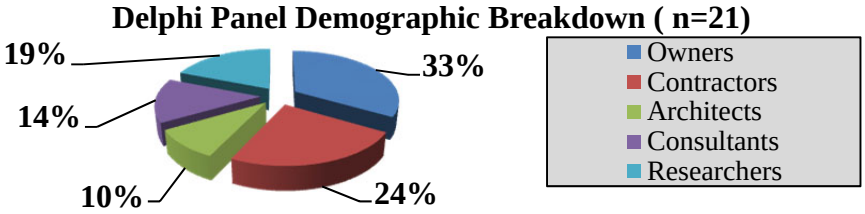

Figure 1. Breakdown of Delphi panel by respondent categories

The two Architect experts on the panel represented design firms with between 5 and 7 years of organizational experience producing BIM deliverables and personal BIM management experience on between 5 and 10 BIM-assisted projects; many of which included BIM requirements set forth by owners. The five Contractor experts on the panel represented large construction management firms with between 7 and 10 years of organizational experience producing BIM deliverables and personal BIM management experience working on anywhere from 8 to 50 BIM-assisted projects. The three Consultant experts on the panel represented organizations that provide strategic BIM and VDC consulting and production services with 5 to 7 years of organizational experience producing BIM deliverables and research. They also indicated having personal BIM experience working on anywhere from 5 to 60 BIM-assisted projects in their career portfolio. The seven Owner experts represented the interests of four University organizations, one healthcare facility provider, one federal entity and one military entity with 6 months to 7 years of organizational experience requiring BIM deliverables. They also had personal BIM management experience working on anywhere from 1 to 22 BIM-assisted projects. Lastly, the four Researchers on the panel represented between 2 and 9 years of research knowledge in this research domain and were all active members of the building Smart alliance (bSa).

Round 1. The initial Round 1 (R1) questionnaire served as a brainstorming session to gauge panelists' perceptions of a preliminary list of 68 BIM maturity variables

identified from the literature review of existing BIM maturity tools (Giel and Issa 2013). It allowed respondents to suggest additional factors significant to the evaluation of building owners' BIM competency and remove any factors from the list which they felt were not relevant. Any factors selected by less than 50% of respondents in R1 were removed in R2.

Upon completion of R1, six factors were eliminated and four 4 new competency factors were suggested as additional variables for evaluation in R2. Based on suggestions made by the expert panel, the competency factors were grouped into three major categories based on semantic similarities including: Strategic Competencies, Administrative Competencies, and Operational Competencies. *Strategic Competencies* include factors which impact an owner organization's ability to plan and develop a course of action for its BIM execution efforts. Within the framework, these factors were further sub-divided into categories including: Goals and Objectives, Preparation, Documentation and Project Standards. *Administrative Competencies* include factors which impact the ability of an owner organization to manage resources and meet desired goals related to its internal BIM execution efforts. These were further sub-divided into: Policies, Personnel, and Project Procedures. Finally, *Operational Competencies* include factors that impact the ability of an owner organization to execute BIM at the organizational and project level. Factors in this area were subdivided into categories of: Technology, Staff Aptitude, and Organizational BIM Use during O&M, BIM Use Requirements, and BIM Deliverable Evaluation.

Round 2. In Round 2 (R2), participants were asked to rate the importance of each newly identified relevant factor on a 3-point Likert scale in order to validate the consolidated list of factors identified in Round 1. To provide controlled feedback, the anonymous responses of the other panelists from R1 were delivered in an appendix. Any factor which received an importance rating IQR of 0 (indicating suitable agreement) was removed in R3. During R2, the panel reached minimum consensus regarding the importance of six factors including: the presence of an organizational mission statement, a BIM vision and objectives, Research and Development efforts, the presence of a BIM Champion, the documentation of BIM roles and responsibilities for staff and the presence of a technology infrastructure improvement plan.

Round 3. Finally, in Round 3 (R3), participants were given the opportunity to reconsider their answers given the R2 mean and median importance ratings and the cumulative frequency of rating responses for each factor. Based on the suggestions of Scheibe et al. (1975), stabilization of opinion between rounds was evaluated using the percent change in mean importance rating between Rounds 2 and 3 for each competency factor. The percent change in mean remained below 15% for all but one of the final 66 factors evaluated. Data richness evaluation of disaster management requirements had an IQR which remained a value of 2 in Round 3, indicating higher dispersion among the panel's responses. For that reason, it was removed from the final list. Given that the panel reached a high level of consensus on more than 50% of the BIM competency factors evaluated and that overall the Likert scale rating results

showed suitable stabilization in Round 3, the s was concluded after Round 3. Table 2 summarizes the level of agreement for all factors in the study.

Table 2. Level of agreement in R3 among the panel

Consensus level	Criteria	No. of factors	% of total
High Agreement	0 < IQR < 1	40	61%
Average Agreement	1 < IQR < 2	25	38%
Low Agreement	IQR =2	1	1%
Total		66	100%

Discussion. The two factors perceived by the panel to be most important to evaluating building owners' BIM competency included: having adequate support from upper management and the existence of a Quality Control plan for checking BIM deliverables. Twenty members (95% of the panel) felt them to be of very high importance early in the survey process. Other factors of high importance as perceived by the panel included the existence of a BIM champion, the requirement for BIM meetings on projects and having a clearly defined BIM vision for the organization. Having specific required applications of BIM during different life cycle phases were also highly rated. Overall, the Strategic Competencies and Operational Competencies were perceived to be of higher weighting than Administrative Competencies by the expert panel. This suggests that having a defined plan of action for BIM execution at the organizational level as well as the skills, staffing and technology at the project level to execute it may be better indicators of an owner's BIM competency than more traditional construction administration factors.

Contributions. The primary contribution of this research study was the selection and prioritization of 66 factors relevant to evaluating owners' BIM Competency. Figure 2 summarizes the final list of variables which were assessed, sorted in order of their R3 mean importance rating. They are color coded based on the Competency Area in which they were categorized. As a result of this list, a proposed framework for evaluating the BIM Competency of owners is suggested and summarized in Figure 3. Based on the weighted proportion of each factor's final mean importance rating in Round 3, Operational Competencies were proportionally rated most relevant followed by Strategic Competencies and Administrative Competencies. Of the major sub-categories outlined by this research, the evaluation of BIM deliverables both in terms of geometry and data was weighted highest. Also of great perceived importance was the existence of clearly defined strategic documentation and organizational personnel's culture and practices. The next phase of this research will be to validate the utility of this framework on a sample of owner organizations.

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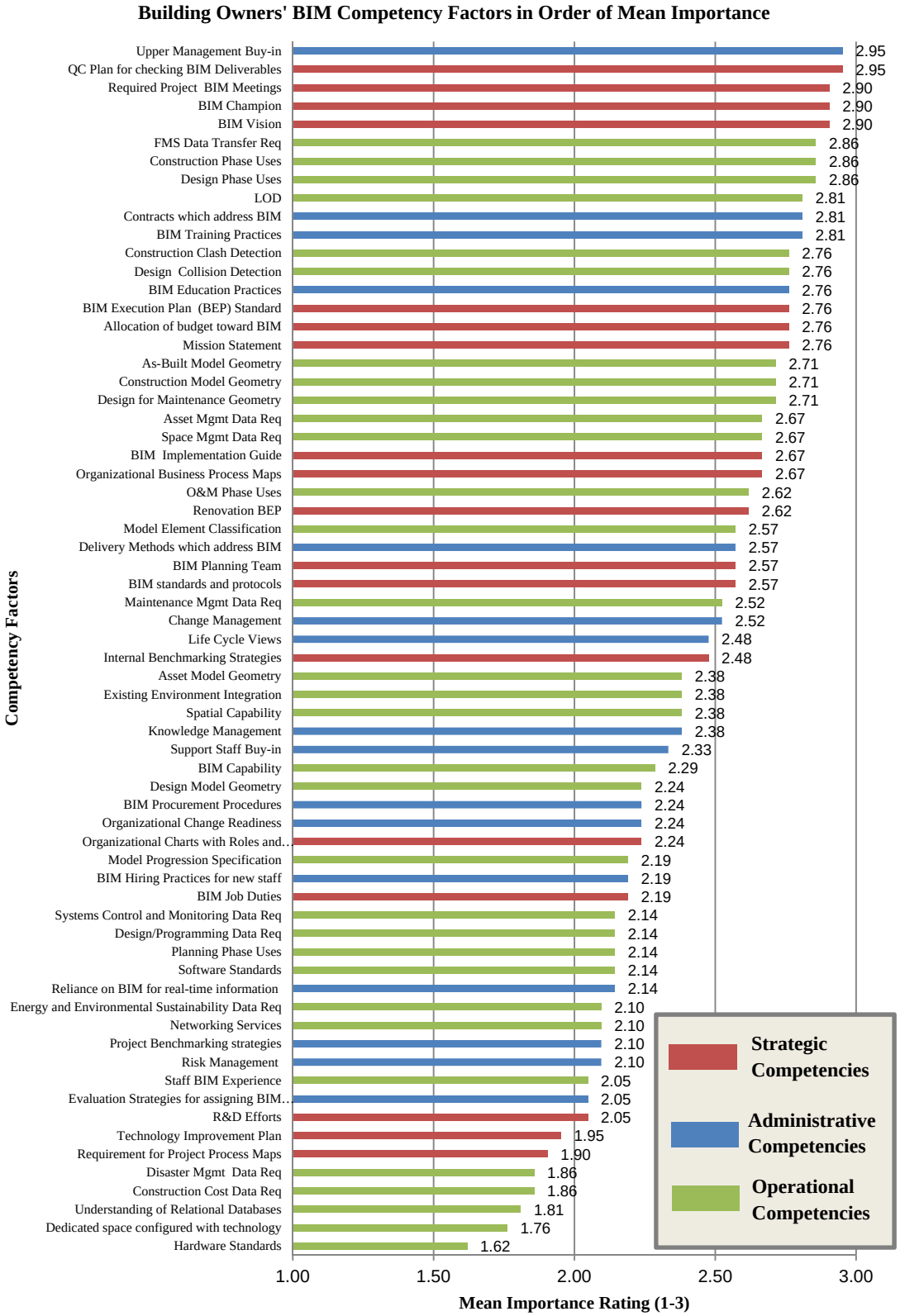

Figure 2. R3 mean importance ratings for competency factors in order of relevance

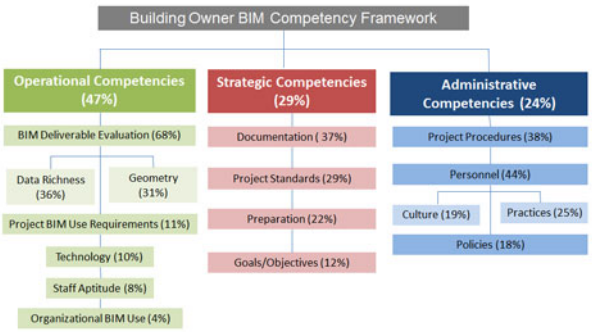

Figure 3. Proposed BIM competency framework for owners

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