AiC

The BIM Body of Knowledge (BOK): A Delphi Study

2017

AiC BIM Body of Knowledge Delphi Study

A Report Submitted to the Academic interoperability Coalition

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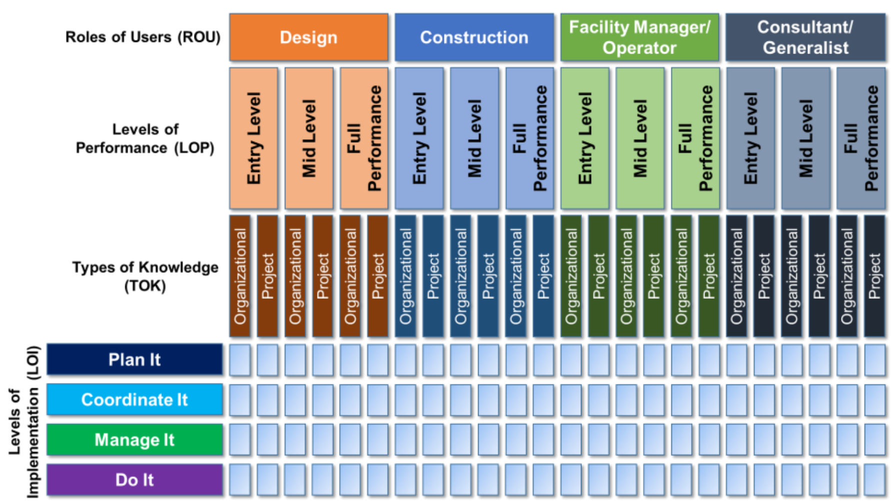
EXECUTIVE SUMMARY

The Academic Interoperability Coalition (AiC) has been a vehicle for communication and discussion concerning how academics around the world, with a focus on the United States, have been introducing BIM to their students for over ten years. BIM education has been difficult to introduce because the continuous challenge of providing students with the whole body of knowledge (BOK) they need to meet the expectations of the workplace. Because of this difficulty and a lack of coordination, a plethora of approaches have been explored. These range from training on how to use BIM tools to educating students in BIM concepts and strategies.

Educational institutions are tasked with graduating students who are prepared to be productive for the firms hiring them after successfully completing their studies. This has had varying levels of success at schools around the country and the world. Academics have been coming together and sharing their positive and negative experiences on teaching BIM through the AiC and its predecessors on an annual basis for more than a decade. It was found that nearly every educator had a different approach that was focused on different aspects of BIM education. A key aspect of BIM is that it is intended to be a collaborative tool for all practitioners, and it was found that on most campuses there was little or no collaboration among the academic units teaching BIM.

Since the accreditation boards have not yet identified criteria for credentialing BIM, it was felt that the AiC could help mitigate the apparent divergence across programs. The AiC proposed that before BIM education could move forward, some common values should be established through a BOK that both curriculum developers and corporate trainers could use as a focus and as a foundational step.

The AiC initiated this grand effort of exploring the first-ever BIM BOK in early April 2015 with a BIM Job Task Analysis (JTA) mini workshop in Washington, DC. As the centerpiece of this research undertaking, a three-round Delphi Study for BIM BOK data collection and consensus building was conducted from mid-July, 2015 to end of July 2016. With unreserved support of the whole AiC membership and painstaking dedication of twenty-three (23) persevering Delphi Study panelists from design and construction practice, a total of sixty-seven (67) BIM BOK line items were developed and consensus levels were achieved by subject matter experts (SMEs, i.e. the Delphi Study panelists) with unprecedented granularity that address four (4) levels of implementation (LOI); four (4) roles of users (ROU); three (3) levels of performances (LOP); and two (2) types of knowledge (TOK), resulting in a total of ninety-six (96) different scenarios. This report serves as a summary of the first milestone of the AiC's endeavor in BIM BOK research. It is noteworthy that this is accomplished with "Zero" funding and is all based upon voluntary work by the AiC members and Delphi Study panelists.



ACRONYMS

AECOO	Architecture, Engineering, Construction, Owner and Operator
AGC	Associated General Contractors of America
AIA	American Institute of Architects
AiC	Academic Interoperability Coalition
ASC	Associated Schools of Construction
BBWG	Better Building Workforce Guidelines
BIM	Building Information Modeling
BOK	Body of Knowledge
BXP	BIM Execution Plan
CIFE	Center for Integrated Facility Engineering
CMAA	Construction Management Association of America
CWCC	Commercial Workforce Credentialing Council
DBIA	Design Build Institute of America
DOE	Department of Energy
IP	Intellectual Property
IQR	Interquartile Range
ISO	International Organization for Standardization
JTA	Job Task Analysis
KM	Knowledge Management
KPI	Key Performance Indicator
KSA	Knowledge, Skills and Abilities
LOI	Level of Implementation
LOP	Level of Performance
NGO	Non-Governmental Organization
NBIMS	National BIM Standard
NIBS	National Institute of Building Sciences
NREL	National Renewable Energy Laboratory
ROI	Return on Investment
ROU	Role of User
SLO	Student Learning Outcome
SME	Subject Matter Expert
TOK	Type of Knowledge
VDC	Virtual Design and Construction

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INTRODUCTION – CALL FOR THE BIM BOK

Building information modeling (BIM) has been gaining exponential growth and become a standard practice in global architecture, engineering, construction and owner/operator (AECOO) industry (McGraw-Hill Construction 2012). As with any new technology innovation, the industry began to examine the market for how a technology is used and how to supply the required levels of expertise needed to facilitate its adoption and diffusion (Gu and London 2010; Peansupap and Walker 2005; Rogers 1995). As several countries (e.g. the UK and China) have sanctioned BIM mandates, the adoption and implementation of BIM is approaching a critical mass. The market demand for BIM talent is thus growing steadily and rapidly. The projected supply/demand equation for BIM-savvy employees will place acute pressure on companies to acquire BIM talent externally or cultivate in-house BIM competency to increase knowledge worker productivity and stay competitive in business (Smith and Tardif 2009).

Traditionally, education, training, and certification have been playing significant roles in preparing and fostering industry in innovation-driven market transformation (McGraw-Hill Construction 2012; Wu and Issa 2014). Nevertheless, the pervasiveness of BIM adoption and implementation is unprecedented, and accordingly, there is significant variance in knowledge aggregation, skill sets development and standardization of best practices across industry sectors under disparate technological, socio-economic and cultural contexts. In other words, there is a lack of systematic understanding and absence of established core knowledge, skills and abilities for successful BIM deployment. Specifically, the gaps that currently exist for articulating BIM knowledge include the lack of validated articulation of BIM job descriptions and qualifications for BIM-oriented job positions (Wu and Issa 2014). There is also a lack of breadth and depth in knowledge structure, performance standards and assessment metrics regarding the qualifications to address the progression of intellectual needs at the task, project, and organizational levels. Job task descriptions and performance levels will aid an employer with the capability of advertising for positions and additionally in assessing potential candidates for talent acquisition. Essentially, what the community of BIM practitioners, educators and service users need is a body of knowledge (BOK), which can be defined as the complete set of concepts, terms, values, principles, activities and outcomes that make up a professional domain (Ören 2005; Wideman 1995). Thus, the proposed BIM BOK can be leveraged to aggregate, manage, disseminate and advance fundamental understanding and best practices, facilitate continuous discovery, encourage self-reflective growth, and foster validation and standardization pertaining to BIM and its implementation in a holistic and systematic manner.

The exploratory BIM BOK project was directed as the first of its kind to investigate expectations and perceptions towards the multidimensionality in documenting and benchmarking professional BIM practices and performance outcomes. This project was directed under the leadership of the Academic Interoperability Coalition (AiC), which has been a vehicle for communication and discussion concerning how academics around the world have been introducing BIM to their students for over ten years (McCuen 2014). The overarching goals of the BIM BOK project include:

A) To establish contemporary and comprehensive metrics of BIM competency assessment for workforce across the AECOO industry under a broad variety of contexts. Existing literature and metrics developed so far lack the dimensionality to address the integrative performance of individuals, projects and organizations in BIM implementation under one unified and holistic framework;
B) To create a common curriculum and roadmap to bridge the gap between college education outcomes and workplace performance requirements; to advance understanding of BIM's business value and foster further development of BIM use cases, and to prioritize BIM education and intellectual preparation in sustaining the BIM market transformation; and
C) To standardize the level of expectation and benchmark job task performance for emerging BIM job titles (e.g. BIM/VDC Engineer, BIM/VDC Manager, BIM/VDC Coordinator, and BIM/VDC Director), and create the baseline performance measurement for BIM education accreditation, professional credentialing and certification.

BACKGROUND

BIM Maturity and Performance Assessment

BIM maturity and performance assessment are necessary to evaluate the effectiveness of strategies and actual performance of BIM adoption and implementation by individuals, projects, and organizations. BIM maturity refers to "the quality, repeatability and degrees of excellence within a BIM capability/competency" Succar (2010). Maturity assessment typically applies to the whole spectrum of competency levels of individuals, projects and organizations, while performance assessment is usually used in organizational and project settings. BIM maturity and performance assessment can help stakeholders prioritize the management of impact factors towards specific business goals in BIM adoption and implementation. One of the earliest efforts on BIM maturity assessment framework was documented in the National BIM Standards (NBIMS), Part 1-Version 1 and demonstrated through the NBIMS Capability Maturity Model (CMM) and its application version, the Interactive Capability Maturity Model (I-CMM) (McCuen et al. 2012; NIBS 2007). Succar (2010) established a comprehensive BIM Maturity Matrix (BIm^3) based upon the BIM Excellence framework created in Succar (2009). BIm^3 was built as a knowledge tool with an expandable database that incorporates five major metrics: BIM capability stages (Pre-BIM, Modeling, Collaboration and Integration), BIM maturity levels (Initial/Ad-hoc, Defined, Managed, Integrated and Optimized), BIM competency sets (Technology, Process and Policy), Organizational Scales (Macro: markets and industries; Meso: projects and teams; and Micro: organizations, units and teams/members) and Granularity levels (e.g. Technology, Software, Data). BIm^3 was expected to be applied across the construction industry at different scales but its current uses were focusing on individual competency assessment within organizations (Succar et al. 2012; Succar et al. 2013). Likewise, Stanford's Center for Integrated Facility Engineering (CIFE) initiated the *VDC Scorecard* program in 2009 to evaluate and benchmark the maturity of VDC/BIM practices, and later was commercialized through the *bimSCORE* program (Kam et al. 2013). Another similar effort was the BIM Quickscan, developed by the Netherlands Organization for Applied Scientific Research (TNO) in 2009, which was a benchmarking instrument used to assess the BIM performance of companies executing BIM services based upon questionnaire-like scores of weighted key performance indicators (KPIs) (Sebastian and van Berlo 2010). Most recently, Giel and Issa (2016) proposed and developed a framework for evaluating BIM competencies exclusively for facility owners with specifically tailored competency categories using the Delphi technique. Only a few cases (Pikas et al. 2013; Succar and Sher 2014) introduced the conceptual workflow to identify, classify, and aggregate BIM competency items that need to be taught at educational institutions or trained on the workplace to equip current and future industry professionals with the necessary knowledge and skills to engage in collaborative workflows and integrated project delivery.

BIM Job Task Analysis

At a time when BIM job titles are just emerging, and when desirable knowledge, skills, and abilities (KSAs) pertaining to BIM are yet to be defined, a Job Task Analysis (JTA) is an appropriate and valuable undertaking to provide insights into the intellectual gaps in organizations and strategize for talent acquisition to catalyze BIM competency development and maturity growth. The JTA also encompasses education and training, which is the desired pinpoint for extending industry workforce development to college education. By definition, a JTA is "a formal, industry-accepted study, validated by a group of subject matter experts (SMEs), that defines competencies in terms of knowledge, skills, and attitudes (KSAs) as the basis for education/training curricula" (Wolfe et al. 1991). To perform the JTA, a small group of SMEs are assembled as a representative sample within the profession/occupation under study. The group may either be strictly incumbents in the job under study, supervisors and managers who directly interact with the job under consideration or a combination of both. The procedure to conduct a JTA according to (Studer and Kemkar 2012) can be summarized in the following seven (7) steps:

1. Identify a JTA development method.
2. Retain a group of subject matter experts.
3. Hold the development workshops.
4. Create JTA drafts.

5. Facilitate a public comment period.
6. Survey validation.
7. Incorporate comments and publish final JTAs.

AiC BIM Job Task Analysis Mini Workshop

The AiC BIM BOK endeavor was initiated at the 9th BIM Academic Symposium via a BIM Job Task Analysis (JTA) mini workshop in Washington DC on April 8th, 2015. The BIM Academic Symposium is the official annual meeting of the AiC and is regarded as a think tank meeting that convenes knowledge and wisdom of BIM education and best practices in both educational and professional communities. The AiC BIM JTA provided the ideal vehicle to deliver the foundational work for establishing the BOK. It offered a holistic approach to define and develop strategies for conducting BIM competency assessment and creating education and training curriculum as well as certification and credentialing programs. The long-term objectives of the AiC BIM JTA included:

- Identify industry trends in workforce development driven by BIM implementation;
- Create a comprehensive competency model that comprises of foundational BIM KSAs with SMEs inputs and rigorous validation;
- Develop a matrix of learning objectives for BIM training and education curricula with integration of effective assessment measures; and
- Develop BIM competency and cultivate a BIM culture across organizations and academic programs.

Ideally, the AiC could have taken the JTA approach to its full extent to explore and develop the BIM BOK, should there be sufficient funding, time commitment and other resources that had been identified as critical to the success of comparable JTA projects conducted by National Renewable Energy Laboratory (NREL) for energy auditors (Kurnik and Woodley 2011) and National Institute of Building Science (NIBS) for building commissioning professional (Woodley and DePascale 2015) and building operations professional (Woodley 2015). Therefore, as a voluntary-based research project with zero financial budget, more affordable solutions such as a web-based Delphi Study instead of the co-located multi-day workshop seemed to be more viable.

AiC BIM JTA Mini Workshop Outcomes

The AiC BIM JTA mini workshop was designed and conducted as a brainstorming session. The audience represented a well-balanced participation from both academia and industry with domestic and international footprints (see Appendix A). This collaborative brainstorming session included extensive discussions on BIM use cases across industry sectors under varied organizational and project contexts. Distinct competency requirements and desired personnel qualifications associated with job tasks at various phases of the whole project life cycle were identified with reference to existing guidelines and standards including the OmniClass Table 31 (OmniClass 2006) and the ISO 15686-10: 2010 (ISO 2010) standard. To identify a starting list of BIM uses, the workshop participants reviewed the BIM Project Execution Planning Guide, Version 2 (CICRP 2010). Meanwhile, buildingSMART International also established a list of forty BIM use cases which are categorized based on processes such as design, procure, assemble and operate (NIBS 2015). It is worth mentioning that the workshop did not attempt to benchmark BIM competency for specific job titles/positions in a particular industry sector. Instead, the goal was set to build a foundational research framework to explore the BIM body of knowledge (BOK) with broad involvement of stakeholders in the AECOO industry. At the conclusion of the workshop, the **AiC BIM BOK Executive Committee** (hereinafter "**the Committee**", see Appendix B) was formed and charged with responsibilities to carry out next-step research endeavors in further developing the BIM BOK.

There were two major deliverables of the AiC BIM JTA mini workshop. First, a preliminary list of sixty-seven (67) potential BIM BOK line items was proposed by the participants and was subject to further verification and development (Figure 1). Second, a system architecture was created to classify and categorize the proposed and future BIM BOK line items (Figure 2). The classification and categorization criteria employed in this system architecture were based upon a discussion on macro and micro levels of BIM uses, and discretion drawn from project management literature:

Plan It (27)

- Organizational mission statement
- BXP: Process mapping
- BXP: Information exchange
- BXP: Goals
- BXP: BIM usage
- BXP: Procurement strategy
- ISO 15686-10: Life cycle functional performance
- Infrastructure planning
- Quality assurance effort
- Business process mapping
- Employer information requirements
- Benchmarking practices
- Security policy
- Risk management
- Facility management needs
- Enterprise architecture
- Life cycle assessment
- Corporate/organizational learning
- Organizational training of others
- Professional development
- Internal standards across the organization
- Develop guides
- Building performance targets
- Commissioning plan
- Staffing projects
- Budget (VDC/BIM)
- Software selection & upgrade strategy

Coordinate It (6)

- Technical support for interoperability
- Model coordination
- Pre-construction issue resolution
- Software version coordination
- Providing traininig
- Understand the roles of all phases of the life cycle

Manage It (21)

- Model quality control
- Manage BXP
- Refine BXP
- Performance measurement
- Model validation
- Standards compliance checking
- Buy-in from stakeholders throughout the organization
- Contract language
- Manage workforce
- Project controls - budgeting /cost
- Project controls - scheduling /time
- Project lifecycle data collection - feedback loop
- Leadership - team building
- Contract administration
- Change management
- Project administration
- Manage information exchange
- Pre-construction issue resolution
- Evaluate metrics
- Protecting IP of digital assets
- Professional ethics

Do It (13)

- Rendering for marketing
- Individual effort
- Understands just your own model
- Ability to build a model
- Aggregate a model
- Software usage
- Solving problems and gaining knowledge
- Estimating
- Site logistics
- List of BIM uses
- Knowledge of scripting
- Knowledge of programing
- Technical writing

Figure 3. Preliminary BIM BOK Line Items by LOI Developed in the JTA Mini Workshop.

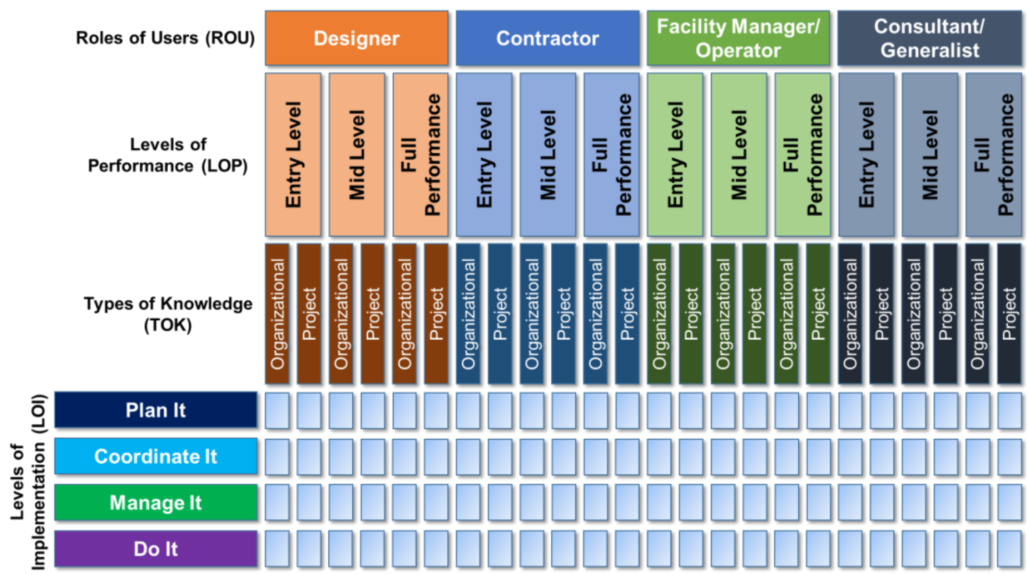


Figure 4. The Dimensionality of the BIM BOK Classification and Categorization.

- **Levels of Implementation (LOI)**: LOI address the business decision-making hierarchy on BIM uptake and utilization, descending from *Plan It* and *Coordinate It* (macro level, inter- and intra-organizational level) to *Manage It* and *Do It* (micro level, project and task level).
- **Roles of Users (ROU)**: ROU acknowledge the commonality and disparity of BIM uses across the AECOO industry sectors in reference to the OmniClass Table 33 – Disciplines (OmniClass 2006), and regroup BIM users into four representative categories including *Designers* (architecture and engineering), *Contractors* (general and specialty), *Facility Managers/Operators*, as well as *Consultant/Generalist*.
- **Levels of Performance (LOP)**: LOP indicates the stratification of performance depending on educational background and professional experience, and suggest the progression of performance from *Entry, Middle* to *Full* via college education and professional training. To facilitate the development of BIM curriculum, LOP also aligns BIM learning/training outcomes with Bloom's Taxonomy of Learning (Krathwohl 2002) (see Table 1).
- **Types of Knowledge (TOK)**: TOK inherits the concepts of Knowledge Management (KM) in the AECOO industry, and highlight its project-based nature. As a matter of fact, projects are also identified as temporary organizations (Howard 1991; Turner and Müller 2003). Therefore, *organizational general* knowledge and *project specific* knowledge are both critical constituents of the BIM BOK.

Table 1. Align the Level of Performance with Bloom's Taxonomy of Learning.

Level of Performance	Performance Expectation	Bloom Taxonomy
Entry Level	Performance expected for users with a Bachelor's degree or equivalent technical education	Remembering Understanding
Middle Level	Performance expected for users that meet *Entry Level* qualifications plus 3-5 years of experience in BIM practices	Applying Analyzing
Full Performance	Performance expected for users that meet *Middle Level* qualifications plus 5 or greater years of experience in BIM practices	Evaluating Creating

To put it into perspective, a research framework can be established upon this BIM BOK system architecture to allow and facilitate inclusive investigation on BIM competency with the broadest stakeholder involvement by addressing the depth and breadth of BIM uses among professional and educational communities from a total of *4 (LOI) x 4 (ROU) x 3 (LOP) x 2 (TOK) = 96* scenarios.

The AiC BIM JTA Mini Workshop laid the foundation for the subsequent Delphi Study that was directed to review, expand and verify the preliminary list of BIM BOK line items. The Committee strived for a consensus built upon perceptions of the subject matter experts (SMEs) to finalize and produce the first-ever BIM BOK of the AECOO industry.

THE AiC BIM BOK DELPHI STUDY

Immediately after the JTA mini workshop, the Committee convened a series of web conferences to plan for the next step BIM BOK project activity. The Committee concurred that it was imperative to solicit direct inputs from subject matter experts (SMEs) and have them critique, expand and establish consensus on the preliminary BIM BOK deliverables. The Committee also agreed upon the best approach to conducting this study by using the Delphi method.

The Delphi Method

The Delphi technique, mainly developed by (Dalkey and Helmer 1963) at the Rand Corporation in the 1950s, is a widely used and accepted method for achieving convergence of opinion concerning real-world knowledge solicited from experts within certain topic areas. This technique is considerably desirable to reach consensus on a field where a lack of agreement or incomplete knowledge is evident (Giannarou and Zervas 2014). It is optimum for analysis of the opinions and perceptions, and provides a means to develop a direction for an industry's existing practices and/or review of future direction (Hsu and Sandford 2007). Considering the financial constraints and lack of critical resources in the AiC BIM BOK effort, the Delphi technique is particularly valuable where the opinions and judgments of experts and practitioners are needed but time, distance, and other factors make it unlikely or impossible for the panel to work together in the same physical location (Yousuf 2007).

Procedurally, the Delphi technique is designed as a group communication process for consensus-building by using a series of questionnaires in multiple iterations to collect data from a panel of selected subjects with the researcher acting as a facilitator (Yousuf 2007). More specifically, the feedback process allows and encourages the selected Delphi participants to reassess their initial judgments about the information provided in previous iterations (Dalkey and Helmer 1963). Thus, in a Delphi study, the results of previous iterations regarding specific statements and/or items can change or be modified by individual panel members in later iterations based on their ability to review and assess the comments and feedback provided by the other Delphi panelists (Hsu and Sandford 2007). According to (ISAAC and Michael 1981), the Delphi process has six steps:

1. Identify the group members whose consensus opinions are sought.
2. Round 1, Questionnaire 1. Have each member generate a list of goals, concerns, or issues toward which consensus opinions are desired. If an established or acceptable listing of such items already exists, this first step can be bypassed.
3. Round 2, Questionnaire 2. Have each member rate or rank the resulting items.
4. Round 3, Questionnaire 3. Present the results of Questionnaire 2 in the form of Questionnaire 3, showing the preliminary level of group consensus to each item. Where the individual differs substantially from the group and chooses to remain so, the respondent should provide a brief reason or explanation.
5. Round 4, Questionnaire 4. The results of Questionnaire 3 are presented in the form of Questionnaire 4, showing the new level of group consensus for each item and repeating the member's latest rating or ranking, along with a listing by item of the major reasons members had for dissent from the prevailing group position. Each member rates or ranks each item for the third and final time, in light of the emerging pattern of group consensus and the reasons for dissent.
6. The results of Round 4 are tabulated and presented as the final statement of group consensus.

Theoretically, the Delphi process can be continuously iterated until a consensus is determined to have been achieved. However, three iterations are often sufficient to collect the needed information and to reach a consensus in most cases (Brooks 1979; Custer et al. 1999; Cyphert and Gant 1971; Ludwig 1997). The AiC BIM BOK Delphi Study followed a similar process described above with some alteration (see Figure 3):

- Due to the fact that a preliminary list of BIM BOK line items was developed in the mini-workshop, Round 1 was comprised of both the brainstorming to expand the list and a relevance check on the applicability of the existing list in the BIM BOK.
- Consensus evaluation was conducted in both Rounds 2 and 3. Round 4 was not conducted due to the stability of results between Rounds 2 and 3.
- In Round 3, based upon inputs from the Delphi Panelists, the questionnaire was broken down into 4 sub-questionnaires by ROU (i.e. *Designer, Contractor, Facility Manager/Operator* and *Consultant/Generalist*) to reduce the time burden due to the length of the questionnaire.

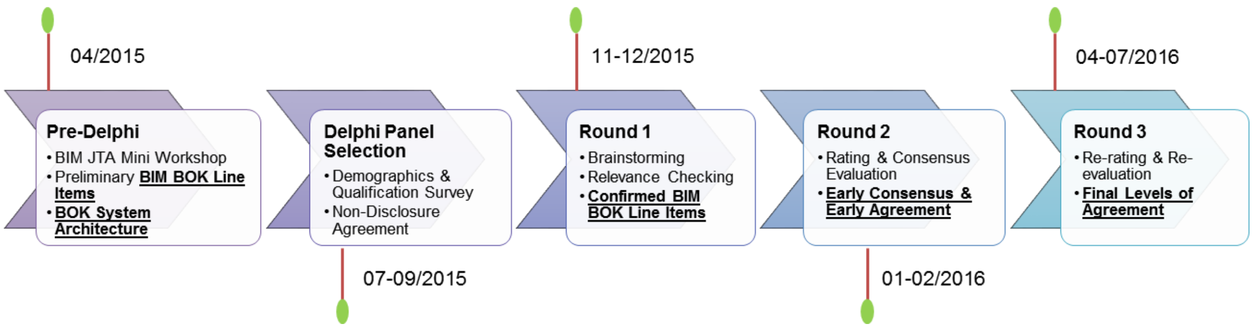


Figure 3. Steps of Conducting the BIM BOK Delphi Study.

AiC BIM BOK Delph Study: Panel Selection

In order to identify and select the subject matter experts to form the Delphi panel, a demographics survey was distributed between July and September of 2015 to several professional organizations and networks including the National Institute of Building Sciences (NIBS), Associated General Contractors of America (AGC), American Institute of Architects (AIA), Construction Management Association of America (CMAA) and Design Build Institute of America (DBIA), and the LinkedIn AECOO industry groups. The demographics survey used a combination of criteria to screen the candidates, which include:

- Current professional undertaking and job function
- Industry sector represented
- Typical phase of project delivery involvement
- Years of professional experience
- Educational background
- Geographical location

Ultimately, 29 of the 79 respondents who expressed interest in participating were selected to form the Delphi panel, which represented a good balance in job function, qualification, experience, industry sectors and life cycle phases (see Figure 4). *BIM/VDC manager* was the most common job title held by the candidates, followed by BIM/VDC Director/Integrator/Consultant/Engineer. The abundance of BIM job titles was a good indicator of the co-existence of a thriving yet unstandardized BIM business environment. Most candidates (20 or 69.0%) came from the private sector with some representation of government and other public sectors (10.3%) and non-governmental organizations (NGOs, 6.9%). Academic, training and research experts (13.8%) were also included to provide representation for BIM practices in the educational and workforce development arenas. Although the size of the company was not a qualifier, the research team worked to ensure that there was representation from all company sizes. A majority of the panel (14 or 48.3%) represented large (500+ employees) companies. The primary make-up of the panel in terms of educational level was at the Bachelor (13 or 44.8%) and Masters (12 or 41.4%) levels. The pool of candidates demonstrated extensive experience in all project disciplines and life cycle phases. Geographically, candidates were from 14 different states and represented 8 out of the 10 US standard federal regions except for Region V and Region VII. Originally, the research team considered elimination of international representation due to the possibility of a separate group for international candidates. However, there were not enough international applicants and therefore, two (2) international members were included based on their background and qualification (Figure 5).

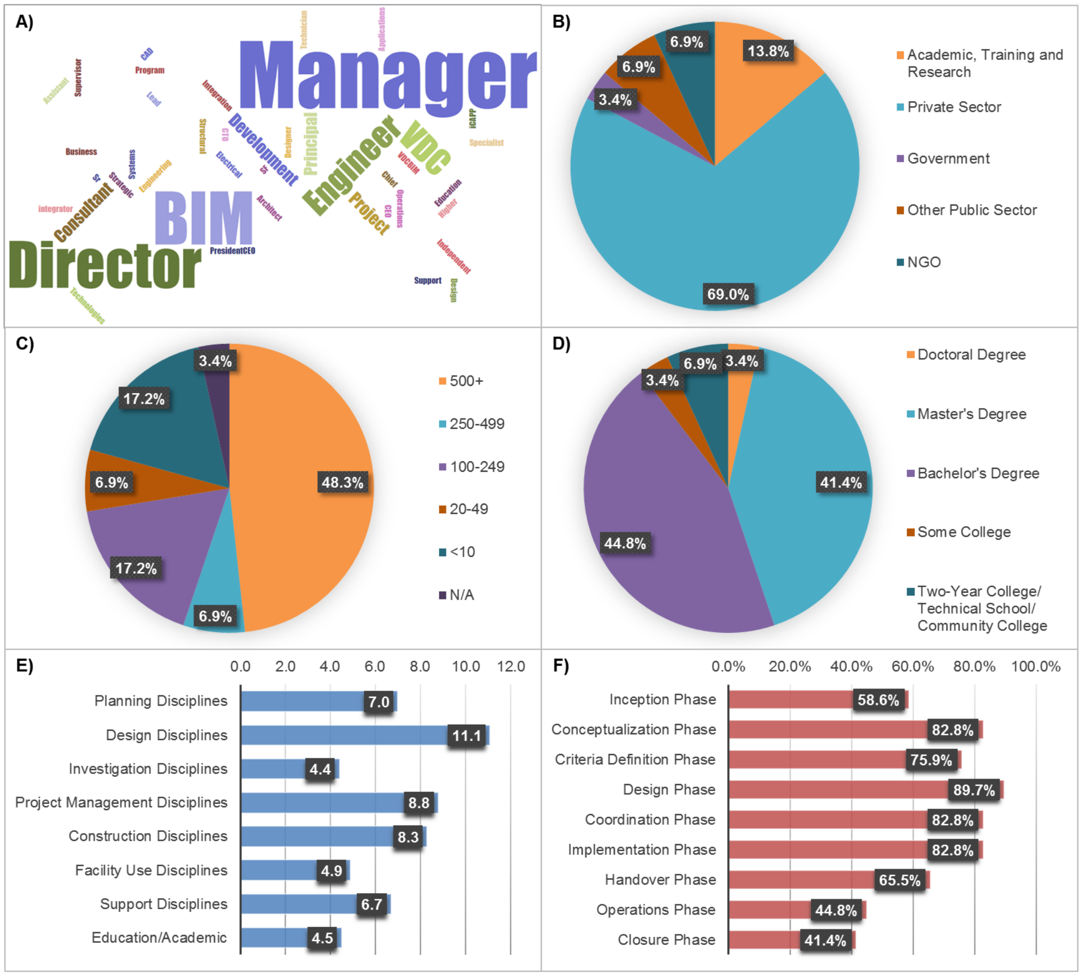


Figure 4. Qualifications of the Selected Delphi Study Panelists: A) Job Titles Currently Held; B) Industry Sectors Represented; C) Size of Company/Organization Represented; D) Highest Degree Attained; E) Years of Experience in Disciplines; and F) Project Life Cycle Phase Coverage.

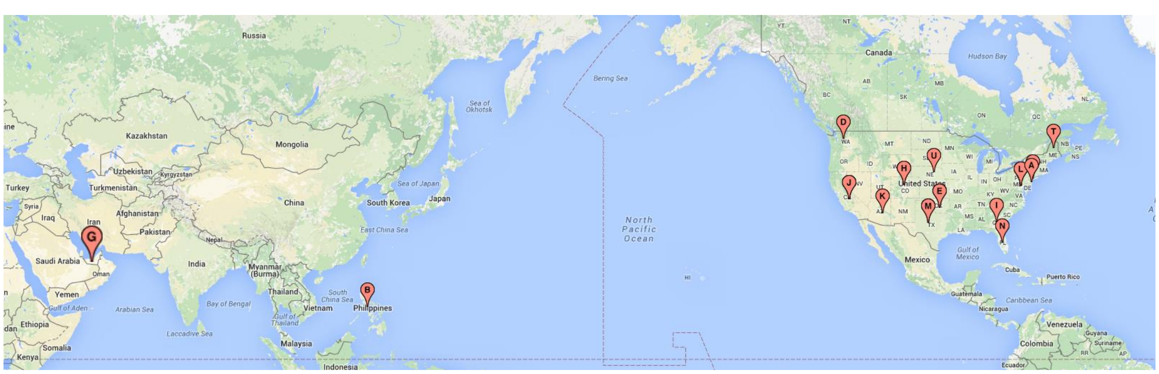


Figure 5. Geographical Distributions of the Delphi Panelists.

AiC BIM BOK Delphi Study: Round 1

In a typical Delphi study, Round 1 is used to generate a list of goals, concerns, or issues for which consensus opinions are desired. In this study, because a preliminary list of BIM BOK line items was already established through the BIM JTA mini workshop, Round 1 was used for relevance checking and expansion on existing BIM BOK line items. Round 1 was conducted via a Qualtrics online survey deployed between November and December of 2015, with a response rate of 21 out of 29, or 72.4%.

In the questionnaire, the Delphi panelists were requested to indicate if the pre-established BIM BOK line items were relevant at a specific LOI, to a specific ROU, at certain LOP, as one of the TOK options (Figure 6). Results summarized the total counts of each BIM BOK line item for its designated BIM implementation level at different performance levels across the industry sectors. These counts were not mutually exclusive. There was also a "Not Applicable" column indicating that the Panelists thought the line item did not apply to the circumstances in question. A complete summary of Round 1 results can be accessed "Here". Round 1 results suggested that all 67 BIM BOK line items should be carried forward, while no new line items were suggested by the Panelists to be added to the list.

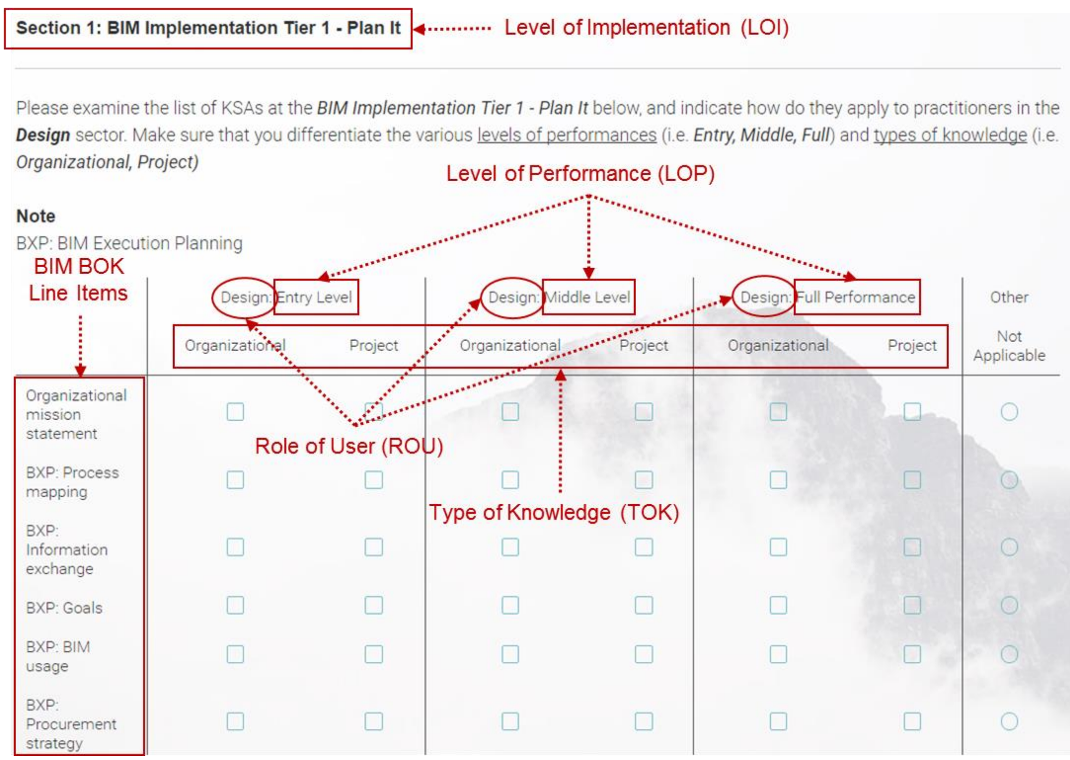


Figure 6. A Snap Shot of Round 1 Delphi Study Questionnaire via Qualtrics.

AiC BIM BOK Delphi Study: Round 2

The purpose of Round 2 was to establish the initial consensus on the BIM BOK line items among the Delphi panelists based on their ratings on the importance of each line item using a 5-point Likert-type rating scale (Likert 1932) as shown in Table 2. A "Neutral" option was eliminated to avoid convenient rating without cognitive efforts (Weijters et al. 2010). To interpret the results of the rating, as opposed to a binary indication of consensus, the investigators conducted a comprehensive review of research literature on consensus evaluation and interpretation (Giannarou and Zervas 2014; Mayo and Issa 2016; Rayens and Hahn 2000; Stitt-Gohdes and Crews 2004; von der Gracht 2012). A combinatory, multi-criteria evaluation scheme was created to establish the levels of agreement (LOA) with *Standard Deviation* (SD), *Interquartile Range* (IQR) and the *Percent Score* (PS), as shown in Table 3.

Table 2. The 5-point Likert Scales and Levels of Measurement.

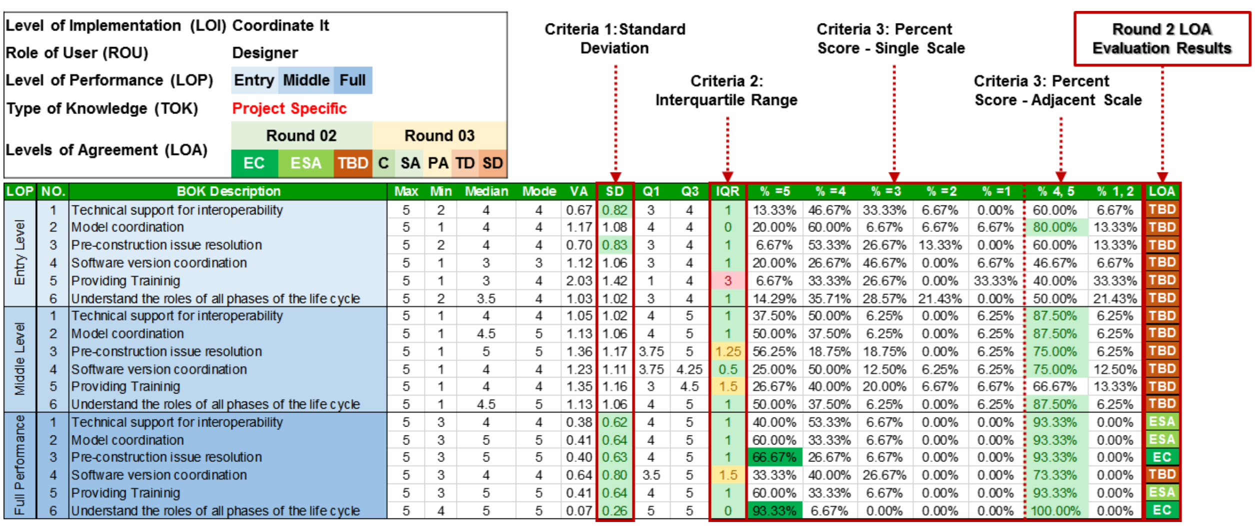
Level of Measurement	Very Important	Important	Somewhat Important	Somewhat Unimportant	Very Unimportant
Likert Scale	5	4	3	2	1

Table 3. Combinatory Multi-criteria Evaluation for Levels of Agreement with Color Coding[1].

Level of Agreement	SD		IQR Round 2	IQR Round 3		PS Single		PS Combined Adjacent
Early Consensus (EC)	≤ 1	AND	≤ 1	—	AND	≥ 60%[2]	—	
Early Strong Agreement (ESA)	≤ 1	AND	≤ 1	—	—	—	AND	≥ 70%[3]
Consensus (C)	≤ 1	AND	—	≤ 1	AND	≥ 60%	—	—
Strong Agreement (SA)	≤ 1	AND	—	≤ 1	—		AND	≥ 70%
Partial Agreement (PA)	≤ 1	AND	—	1 < IQR ≤ 2	—		AND	≥ 60%
Split Disagreement (SD)	> 1	OR	—	> 2	AND	≥ 25%[4]	—	—
Total Disagreement (TD)	> 1	OR	—	> 2	OR	< 60%	—	—

[1]Combinatory evaluation criteria were suggested by (Giannarou and Zervas 2014).
[2]Single scale Percent Score 60% threshold suggested by (Rayens and Hahn 2000; Stitt-Gohdes and Crews 2004; von der Gracht 2012).
[3]Combined adjacent scale Percent Score 70% threshold as suggested by (Mayo and Issa 2016).
[4]At polar ends of Likert scales only (i.e. 1 or 5).

Round 2 was also conducted via a Qualtrics online survey between January and February of 2016, with 20 responses and 16 completed questionnaires, which yielded a response rate of 55.2%. At the end of Round 2, investigators summarized the Likert Scale ratings of each BIM BOK line item, and calculated their individual *SD*, *IQR* and *PS* accordingly. The investigators then analyzed the LOA of each BIM BOK line item against the criteria established in Table 3, with the intention to identify those line items that achieved *Early Consensus* (**EC**) or *Early Strong Agreement* (**ESA**). Figure 7 shows this evaluation process using the BIM BOK line items of *LOI: Coordinate It,* for *ROU: Designer,* on *TOK: Project Specific* at all *LOP: Entry, Middle and Full Performance*. A line item (e.g. NO.*3 Pre-construction issue resolution*) with a "*SD ≤ 1, AND* an *IQR ≤ 1, AND* a single scale *PS ≥ 60%*" was rated as **EC**, which indicated that the highest LOA could be achieved. Similarly, if a single scale PS ≥ 60% was not possible but the combined adjacent scale (either 4 and 5, or 1 and 2) PS was ≥ 70% (e.g. *NO.1 Technical support for interoperability*), then this line item would be rated as **ESA,** the second highest LOA. Round 2 only aimed to identify **EC** and **ESA** BIM BOK line items, which were exempted from Round 3 for re-rating and re-evaluation. All the rest of line items, which were temporarily marked as *to be determined* (**TBD**), would be carried forward into Round 3 for further rating by the Delphi panel and be subject to more comprehensive LOA evaluation.



Level of Implementation (LOI)	Coordinate It							
Role of User (ROU)	Designer							
Level of Performance (LOP)	Entry	Middle	Full					
Type of Knowledge (TOK)	Project Specific							
Levels of Agreement (LOA)	Round 02			Round 03				
	EC	ESA	TBD	C	SA	PA	TD	SD

LOP	NO.	BOK Description	Max	Min	Median	Mode	VA	SD	Q1	Q3	IQR	% =5	% =4	% =3	% =2	% =1	% 4, 5	% 1, 2	LOA
Entry Level	1	Technical support for interoperability	5	2	4	4	0.67	0.82	3	4	1	13.33%	46.67%	33.33%	6.67%	0.00%	60.00%	6.67%	TBD
	2	Model coordination	5	1	4	4	1.17	1.08	4	4	0	20.00%	60.00%	6.67%	6.67%	6.67%	80.00%	13.33%	TBD
	3	Pre-construction issue resolution	5	2	4	4	0.70	0.83	3	4	1	6.67%	53.33%	26.67%	13.33%	0.00%	60.00%	13.33%	TBD
	4	Software version coordination	5	1	3	3	1.12	1.06	3	4	1	20.00%	26.67%	46.67%	0.00%	6.67%	46.67%	6.67%	TBD
	5	Providing Traininig	5	1	3	4	2.03	1.42	1	4	3	6.67%	33.33%	26.67%	0.00%	33.33%	40.00%	33.33%	TBD
	6	Understand the roles of all phases of the life cycle	5	2	3.5	4	1.03	1.02	3	4	1	14.29%	35.71%	28.57%	21.43%	0.00%	50.00%	21.43%	TBD
Middle Level	1	Technical support for interoperability	5	1	4	4	1.05	1.02	4	5	1	37.50%	50.00%	6.25%	0.00%	6.25%	87.50%	6.25%	TBD
	2	Model coordination	5	1	4.5	5	1.13	1.06	4	5	1	50.00%	37.50%	6.25%	0.00%	6.25%	87.50%	6.25%	TBD
	3	Pre-construction issue resolution	5	1	5	5	1.36	1.17	3.75	5	1.25	56.25%	18.75%	18.75%	0.00%	6.25%	75.00%	6.25%	TBD
	4	Software version coordination	5	1	4	4	1.23	1.11	3.75	4.25	0.5	25.00%	50.00%	12.50%	6.25%	6.25%	75.00%	12.50%	TBD
	5	Providing Traininig	5	1	4	4	1.35	1.16	3	4.5	1.5	26.67%	40.00%	20.00%	6.67%	6.67%	66.67%	13.33%	TBD
	6	Understand the roles of all phases of the life cycle	5	1	4.5	5	1.13	1.06	4	5	1	50.00%	37.50%	6.25%	0.00%	6.25%	87.50%	6.25%	TBD
Full Performance	1	Technical support for interoperability	5	3	4	4	0.38	0.62	4	5	1	40.00%	53.33%	6.67%	0.00%	0.00%	93.33%	0.00%	ESA
	2	Model coordination	5	3	5	5	0.41	0.64	4	5	1	60.00%	33.33%	6.67%	0.00%	0.00%	93.33%	0.00%	ESA
	3	Pre-construction issue resolution	5	3	5	5	0.40	0.63	4	5	1	66.67%	26.67%	6.67%	0.00%	0.00%	93.33%	0.00%	EC
	4	Software version coordination	5	3	4	4	0.64	0.80	3.5	5	1.5	33.33%	40.00%	26.67%	0.00%	0.00%	73.33%	0.00%	TBD
	5	Providing Traininig	5	3	5	5	0.41	0.64	4	5	1	60.00%	33.33%	6.67%	0.00%	0.00%	93.33%	0.00%	ESA
	6	Understand the roles of all phases of the life cycle	5	4	5	5	0.07	0.26	5	5	0	93.33%	6.67%	0.00%	0.00%	0.00%	100.00%	0.00%	EC

Figure 7. An Example of the Combinatory Multi-Criteria LOA Evaluation Process for Round 2 Results.

AiC BIM BOK Delphi Study: Round 3

Round 3 of the Delphi Study requested the panelists to review the results of Round 2 and re-rate the remaining BIM BOK line items based on their interpretation of the aggregated perceptions of the panelists. Feedback from the panelists on Round 2 included the excessive length of the survey questionnaire and the complex dimensionality of the BIM BOK, i.e., the 96 different scenarios encapsulated by the BIM BOK classification and categorization. These inefficiencies accounted for the low response rate at Round 2. The investigators took into account this feedback when designing the Round 3 survey instrument and created a group of four (4) sub-surveys per ROU (i.e. *Designers, Contractors, Facility Managers/Operators* and *Consultants/Generalists*) to allow panelists to focus on one sub-survey at a time. This arrangement was expected to alleviate panelists from the burden of committing a large block of time to complete the rating, and reduce the confusion caused by an extremely lengthy and complicated questionnaire. Meanwhile, two panelists who were not able to contribute in Rounds 1 and 2 requested to withdraw from this Delphi Study, so the effective count of the Delphi Panel for Round 3 was 27. Round 3 was administered between April and July of 2016, with a response rate for each sub-survey at 63.0% (*Designers*), 55.6% (*Contractors*), 59.3% (*Facility Managers/Operators*) and 59.3% (*Consultants/Generalists*), respectively.

The ratings of Round 3 were summarized and analyzed in a similar manner as in Round 2 for consensus evaluation (Figure 8) with the combinatory multi-criteria established in Table 3. Round 3 was also the final round of the Delphi Study. To better present the results of Round 3, color-coded heat maps were created to provide a visual summary, as shown in Figures 9a – d. The rows of the heat maps visually represent the specific LOA achieved for each BIM BOK line item. Table 4 explains the keys used to categorize each column of the heat maps per LOP, and reiterates the LOA color codes.

Level of Implementation (LOI)	Plan It							
Role of User (ROU)	Designer							
Level of Performance (LOP)	Full							
Type of Knowledge (TOK)	Organizational General							
Level of Agreement (LOA)	Round 02			Round 03				
	EC	ESA	TBD	C	SA	PA	TD	SD

Descriptive Statistics

Final Consensus Evaluation

NO.	BOK Description	Max	Min	Mean	Median	Mode	VA	SD	Q1	Q3	IQR	% =5	% =4	% =3	% =2	% =1	% 4, 5	% 1, 2	LOA (R2)	LOA (R3)
1	Organizational mission statement	5	3	4.5	5	5	0.55	0.74	4	5	1	60.00%	26.67%	13.33%	0.00%	0.00%	86.67%	0.00%	ESA	ESA
2	BXP: Process mapping	5	3	4.4	5	5	0.54	0.74	4	5	1	53.33%	33.33%	13.33%	0.00%	0.00%	86.67%	0.00%	ESA	ESA
3	BXP: Information exchange	5	2	4.3	4	4	0.64	0.80	4	5	1	40.00%	53.33%	0.00%	6.67%	0.00%	93.33%	6.67%	ESA	ESA
4	BXP: Goals	5	4	4.7	5	5	0.21	0.46	4.5	5	0.5	73.33%	26.67%	0.00%	0.00%	0.00%	100.00%	0.00%	EC	EC
5	BXP: BIM usage	5	3	4.3	4	5	0.64	0.80	4	5	1	46.67%	33.33%	20.00%	0.00%	0.00%	80.00%	0.00%	ESA	ESA
6	BXP: Procurement strategy	5	3	4.2	4	4	0.46	0.68	4	5	1	33.33%	53.33%	13.33%	0.00%	0.00%	86.67%	0.00%	ESA	ESA
7	ISO 15686-10: Life cycle functional performance	5	2	3.9	4	4	0.56	0.75	4	4	0	17.65%	64.71%	11.76%	5.88%	0.00%	82.35%	5.88%	TBD	C
8	Infrastructure planning	5	3	4.1	4	4	0.50	0.70	4	4.5	0.5	26.67%	53.33%	20.00%	0.00%	0.00%	80.00%	0.00%	ESA	ESA
9	Quality assurance effort	5	4	4.7	5	5	0.24	0.49	4	5	1	66.67%	33.33%	0.00%	0.00%	0.00%	100.00%	0.00%	EC	EC
10	Business process mapping	5	3	4.2	4	4	0.49	0.70	4	5	1	35.71%	50.00%	14.29%	0.00%	0.00%	85.71%	0.00%	ESA	ESA
11	Employer information requirements	5	3	4.2	4	4	0.60	0.77	4	5	1	40.00%	40.00%	20.00%	0.00%	0.00%	80.00%	0.00%	ESA	ESA
12	Benchmarking practices	5	3	4.3	4	4	0.38	0.62	4	5	1	40.00%	53.33%	6.67%	0.00%	0.00%	93.33%	0.00%	ESA	ESA
13	Security policy	5	3	4.1	4	4	0.61	0.78	4	5	1	35.29%	41.18%	23.53%	0.00%	0.00%	76.47%	0.00%	TBD	SA
14	Risk management	5	3	4.3	4	4	0.50	0.70	4	5	1	40.00%	46.67%	13.33%	0.00%	0.00%	86.67%	0.00%	ESA	ESA
15	Facility management needs	5	3	4.3	4	5	0.64	0.80	4	5	1	46.67%	33.33%	20.00%	0.00%	0.00%	80.00%	0.00%	ESA	ESA
16	Enterprise architecture	5	2	4.0	4	4	0.88	0.94	3	5	2	35.29%	35.29%	23.53%	5.88%	0.00%	70.59%	5.88%	TBD	PA
17	Life cycle assessment	5	2	3.9	4	4	0.70	0.83	3.5	4	0.5	20.00%	53.33%	20.00%	6.67%	0.00%	73.33%	6.67%	ESA	ESA
18	Corporate / organizational learning	5	3	4.2	4	4	0.60	0.77	4	5	1	40.00%	40.00%	20.00%	0.00%	0.00%	80.00%	0.00%	ESA	ESA
19	Organizational training of others	5	3	4.5	5	5	0.41	0.64	4	5	1	53.33%	40.00%	6.67%	0.00%	0.00%	93.33%	0.00%	ESA	ESA
20	Professional development	5	3	4.5	5	5	0.55	0.74	4	5	1	66.67%	20.00%	13.33%	0.00%	0.00%	86.67%	0.00%	EC	EC
21	Internal standards across the organization	5	3	4.6	5	5	0.40	0.63	4	5	1	66.67%	26.67%	6.67%	0.00%	0.00%	93.33%	0.00%	EC	EC
22	Develop Guides	5	3	4.3	4	5	0.52	0.72	4	5	1	46.67%	40.00%	13.33%	0.00%	0.00%	86.67%	0.00%	ESA	ESA
23	Building performance targets	5	3	4.2	4	4	0.46	0.68	4	5	1	33.33%	53.33%	13.33%	0.00%	0.00%	86.67%	0.00%	ESA	ESA
24	Commissioning plan	5	2	3.9	4	4	0.64	0.80	4	4	0	20.00%	60.00%	13.33%	6.67%	0.00%	80.00%	6.67%	EC	EC
25	Staffing projects	5	3	4.4	5	5	0.54	0.74	4	5	1	53.33%	33.33%	13.33%	0.00%	0.00%	86.67%	0.00%	ESA	ESA
26	Budget (VDC/BIM)	5	4	4.7	5	5	0.24	0.49	4	5	1	66.67%	33.33%	0.00%	0.00%	0.00%	100.00%	0.00%	EC	EC
27	Software selection & upgrade strategy	5	2	4.2	4	4	0.60	0.77	4	5	1	33.33%	60.00%	0.00%	6.67%	0.00%	93.33%	6.67%	ESA	ESA

Figure 8. An Excerpt of the Round 3 Consensus Evaluation Results.

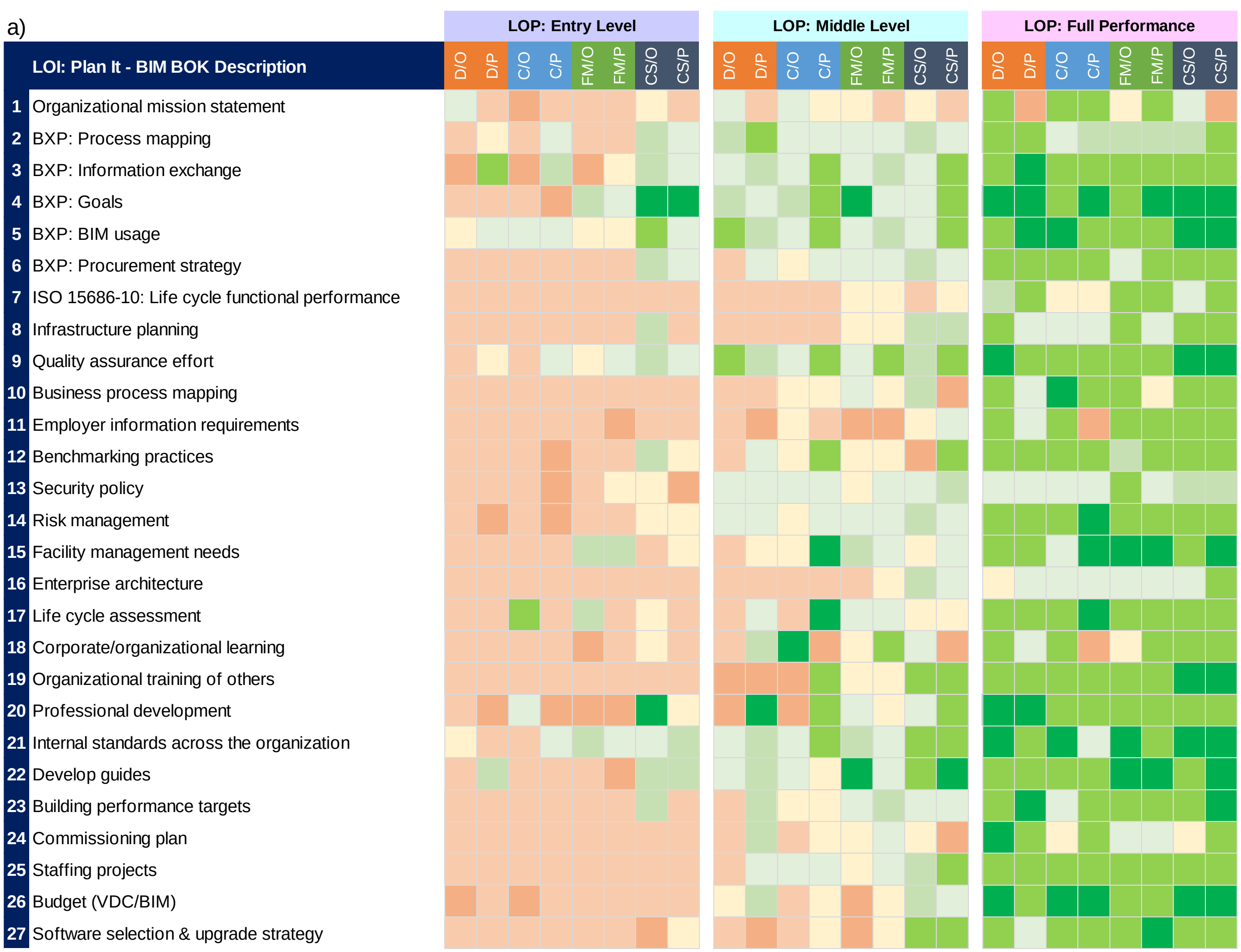
AiC BIM BOK Delphi Study Results and Findings

The heat maps in Figures 9a – d present the final consensus on the BIM BOK line items achieved among the Delphi panelists and reveal some interesting patterns/trends. An immediate observation is that the level of consensus on BOK line items increases steadily and substantially from *LOP: Entry Level* to *LOP: Middle Level* and peaks at *LOP: Full Performance*. This positive correlation is consistent across industry sectors (i.e. *Designer, Contractors, Facility Manager/Operator,* and *Consultant/Specialist*) at different levels of implementation (i.e. *Plan It, Coordinate It, Manage It,* and *Do It*). A possible interpretation is that the industry holds high expectations on what true BIM experts are capable of, yet there is a lack of understanding of the desired competencies for junior and intermediate positions. In other words, while there are industry leaders who have pushed the boundaries of BIM innovation and have accrued advanced knowledge and expertise via sophisticated BIM project experiences, such knowledge and expertise are yet to be transferred to a critical mass of companies who are still at their early stage of BIM adoption and implementation.

Table 4. Keys for Heat Map Columns and the LOA Color Codes.

LOA Color Codes		LOA Description	Heatmap Column Keys	BOK Classification/Categorization Description
Round 2	EC	Early Consensus	D/O	ROU: Designer TOK: Organizational General
	ESA	Early Strong Agreement	D/P	ROU: Designer TOK: Project Specific
Round 3	C	Consensus	C/O	ROU: Contractor TOK: Organizational General
	SA	Strong Agreement	C/P	ROU: Contractor TOK: Project Specific
	PA	Partial Agreement	FM/O	ROU: Facility Manager/Operator TOK: Organizational General
	TD	Total Disagreement	FM/P	ROU: Facility Manager/Operator TOK: Project Specific
	SD	Split Disagreement	CS/O	ROU: Consultant/Generalist TOK: Organizational General
			CS/P	ROU: Consultant/Generalist TOK: Project Specific

a)



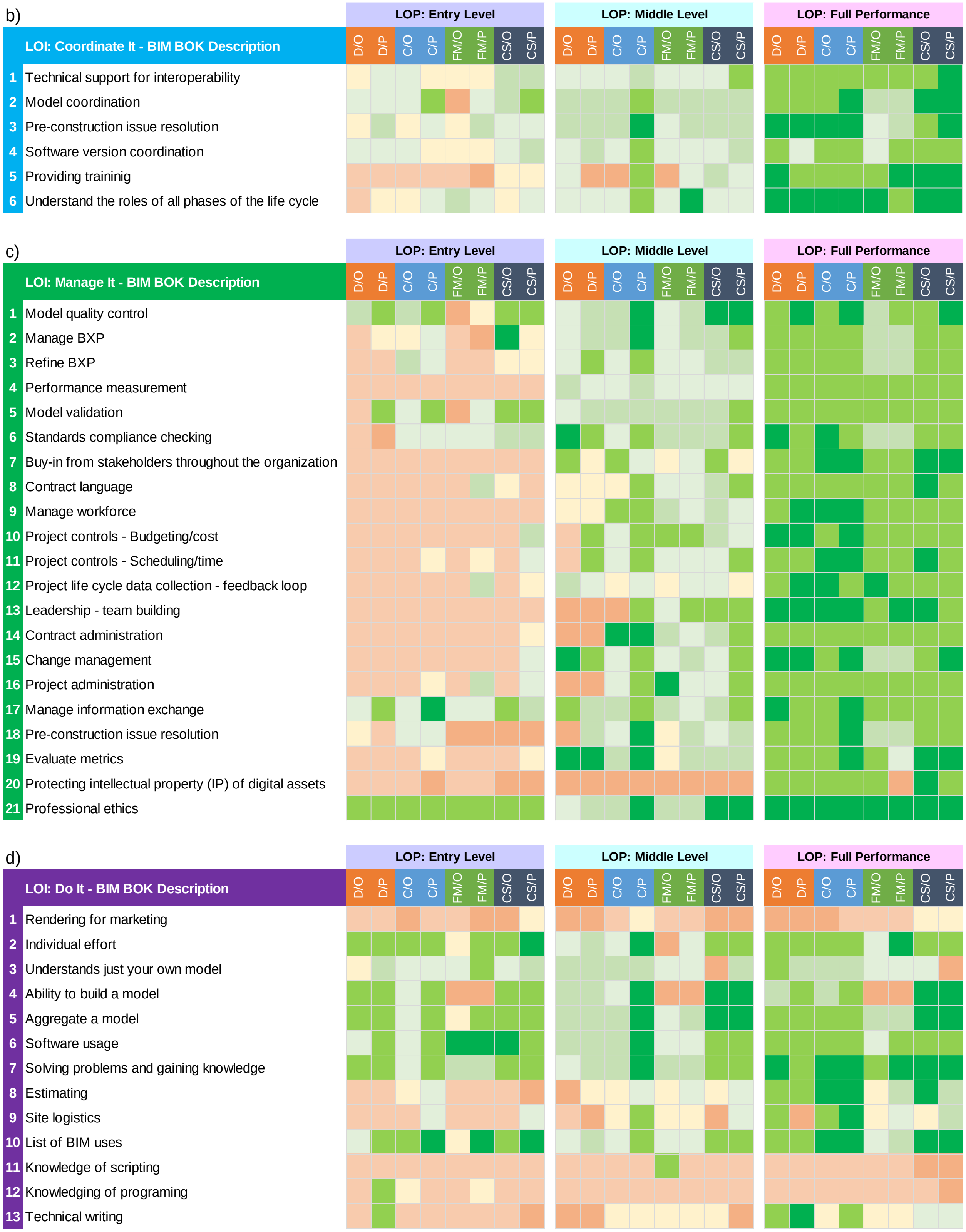


Figure 9. Round 3/Final LOA Distribution of BIM BOK per Classification/Categorization: a) LOA at LOI: Plan It; b) LOA at LOI: Coordinate It; c) LOA at LOI: Manage It; and d) LOA at LOI: Do It.

Meanwhile, it is not surprising to find out that most senior VDC/BIM managers in companies today are those who have been CAD managers and long-time BIM practitioners. To them, BIM has always been there even before the term "BIM" was invented and became a trend in the AECOO industry. The pressing demand and real gap reside in the pipeline of enhanced cultivation of the future BIM workforce, especially those who are at the early stages of their professional career and are dedicated to a BIM-related career path. From that point of view, the BIM BOK heat maps clearly expose where efforts should be made to help beginners and intermediate users improve and grow into BIM champions and real experts in their companies. A sustainable intellectual supply to the pool of BIM workforce is the backbone of market transformation in advancing the BIM competency and maturity of the AECOO industry. To do so, these heat maps can be referred to as a roadmap, based upon which companies and academic programs will be able to define priorities of competency needs, and create corresponding educational and training programs.

To promote the dissemination of the BIM BOK Delphi Study results and findings, and also to facilitate better understanding and potential application of the BOK, the research team created a Tableau Public Visual Story (https://public.tableau.com/profile/wei.wu#!/vizhome/AiC_BIM_BOK/AiCBIMBOK_Story) to allow the interested parties to interact with the research data including the descriptive statistics of the survey results as well as the heat maps (Figure 10). Using the filters provided, the audience can drill down to look at specific BIM BOK line items and associated metadata that fit into their unique needs.

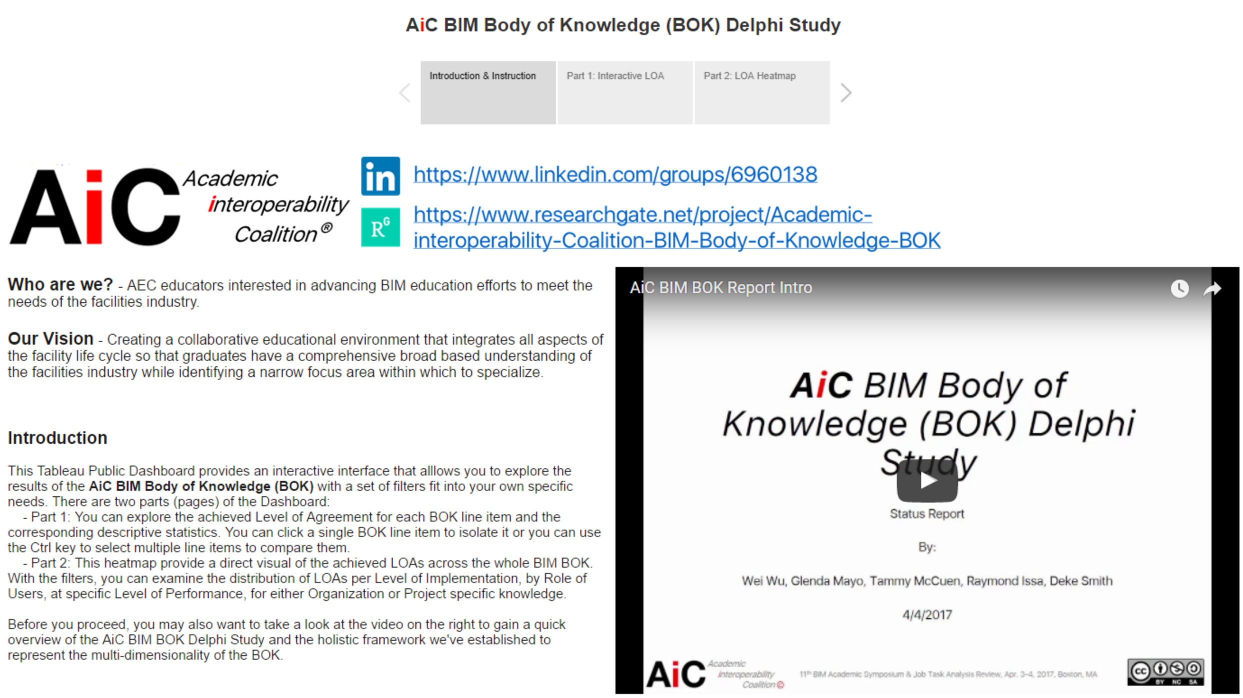


Figure 10. The Tableau Public Visual Story for Data Visualization and Interaction.

Potential Use Cases of the AiC BIM BOK

As the first of its kind, the AiC BIM BOK is anticipated to stimulate broad interest among the professional, educational, and training/credentialing communities not only as a comprehensive reference guide on BIM competency benchmarking and performance assessment, but also as a potential toolkit to help formulate strategies and create action plans for cultivating BIM talent and advancing BIM innovation. The following sections elaborate on the potential use cases of the BIM BOK in education, corporate training and hiring, and credentialing and certification arenas.

The Use Case for Education

BIM in higher education has come through a long and painstaking process. In the early days, BIM was introduced as technical electives and innovative add-ons to existing college curricula, and there were significant external (e.g. availability of textbooks, industry buy-in and professional support) and internal barriers (e.g. curriculum redesign, faculty qualification and time commitment) to its integration in higher education (Sabongi and Arch 2009). As BIM was taking off in the industry between 2007-2012, the educational community was incentivized to expand its footprint in higher education with multiple strategies (e.g. vertical and horizontal integration) being adopted to adapt college curricula to prepare students for the rising market demand for BIM talent. BIM education has ever since become ubiquitous in 2-year or 4-year architecture, engineering, construction, and facility management programs, as well as graduate programs in the US and around the world (Chegu Badrinath et al. 2016; Wu and Issa 2014).

Given the recent dedication to BIM education, higher education is facing some major challenges in meeting the market demand for a BIM-competent workforce from their industry partners. Firstly, prior scholarly works reveal that current BIM education tends to focus on specific disciplines for practicality reasons, which is indisputably critical as eventually the job tasks in BIM implementation will be largely performed by *specialists* in each industry sector. That being said, the AiC BIM BOK Delphi Study is significant because it acts as the nexus that presents the big picture of BIM competency that is essential to BIM implementation in the increasingly collaborative, common data environment in which most capital projects are delivered today. The changing nature of digital project delivery and the transforming roles played by the workforce from each industry sector encourage educators to take a holistic strategy and interdisciplinary perspective on BIM education. Secondly, there is a nontrivial competency gap between workplace performance expectations and the actual capacities of recent college graduates that have limited exposure to empirical BIM knowledge (Wu and Issa 2014). The BIM BOK will be especially valuable for education programs that are dedicated to aligning the student learning outcomes of their BIM curriculum with the career-specific BIM competencies desired by industry partners. Specifically, using a backward design model (Childre et al. 2009; Wiggins and McTighe 2005), educators may utilize the BIM BOK to establish and prioritize the end results of the student learning outcomes (SLOs) of their BIM curriculum, determine metrics for performance assessment, and lastly plan for pedagogy design (Figure 11). The backward BIM curriculum design model encourages outcome-driven, competency-based learning, and facilitates a partnership among academia, industry and subject matter experts in defining future workforce development strategies with regional priorities. It is noteworthy that the Supplemental Guidelines (hereafter *The Guidelines*) indicated in Figure 11 are currently under development. The Guidelines aim to clarify concepts and definitions, exemplify use cases, and gather assessment metrics to foster education and training curriculum development.

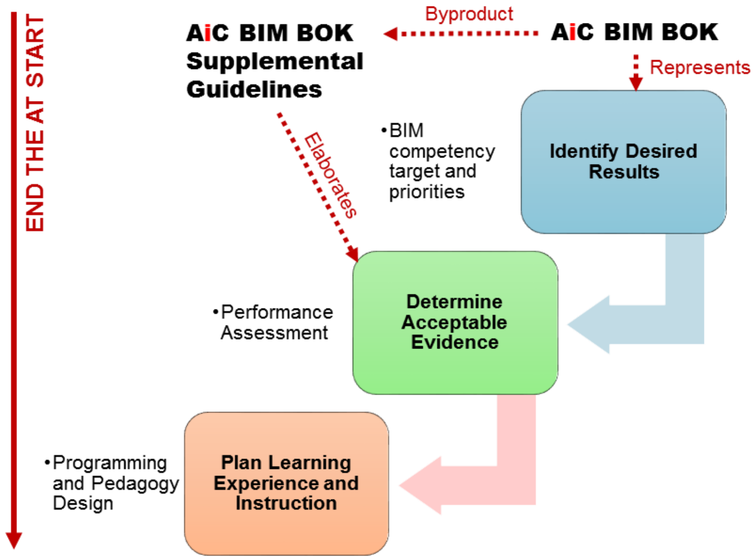


Figure 11. Backward BIM Curriculum Design with the AiC BIM BOK.

The Use Case for Talent Acquisition & Recruiting

The struggles of human resources departments in recruiting and acquiring BIM talent are well acknowledged and one particular barrier is the lack of accurate articulation on BIM job descriptions and qualifications of a BIM-oriented position (Joseph 2011). Given the fact that new job titles such as *VDC/BIM manager, VDC/BIM coordinator,* and *VDC/BIM engineer* are widely used in job advertisement (Barison and Santos 2011; Wu and Issa 2014), there is really no formal structure within the field that clarifies position-specific BIM competency requirements nor is there a standard that identifies a BIM skill set with a level of academic learning (Mathews 2015). The consequences are significant since companies may bear unnecessary risks of hiring incompetent personnel and staffing key positions on a project with inappropriate candidates who may lack the desired BIM exposure and working knowledge, and eventually fail to fulfill the requirements of the BIM workflow anticipated by the organization and clients.

By attempting to standardize the terminology and benchmark the job task description, human resources departments will be in a better position to identify both short-term and long-term workforce development needs and prioritize BIM talent acquisition by aligning job roles with candidates' background and qualifications, and differentiating the compensation/benefits packages in accordance with corresponding levels of workplace duties. Developed upon the basis of a BIM JTA, the AiC BIM BOK fits in very well serving and assisting the industry to move toward the formalization and standardization of advertising and marketing BIM job positions with clearly delineated, highly classified/categorized competency requirements (Figure 12). Standardization will also assist companies in business development and marketing their specific BIM capabilities with a more precise language. Although companies have finally moved away from the blanket statement "we do BIM," there is still work to be done to create meaningful marketing definitions. As this committee works to define job requirements further, it is important to note that it assists in more than just the department of human resources perspective. This effort will also include assistance with the challenges set forth in the lack of understanding from hiring managers, upper management, and project managers as well with regards to getting the right people in the right positions.

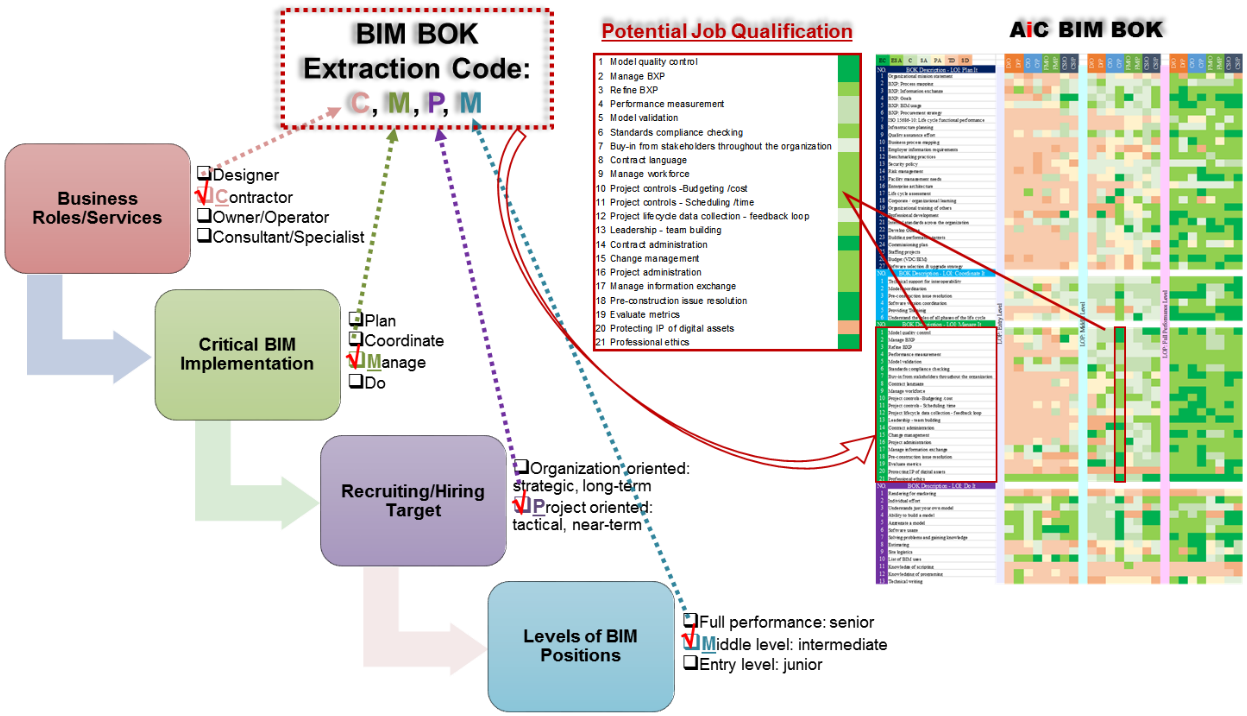


Figure 12. An Example of Benchmarking BIM Job Position Qualification Using the AiC BIM BOK.

The Use Case for Professional Certification/Credentialing

By definition, a BOK captures and structurally represents the broad spectrum of concepts, nomenclatures as well as best practices commonly acknowledged by practitioners in the field. Therefore, a BOK is often referenced as the standard and benchmark for competency evaluation and typically forms the premises and foundation of professional certification and credentialing. As more professionals and recent college graduates are committed to a career path that relates or specializes in BIM implementation, certification and credentialing become not only valuable but also imperative for the community to identify real BIM champions, endorse authentic BIM expertise and differentiate levels of competency as needed in varied organizational and project contexts. For employers and recruiters, BIM certifications/credentials may set standards for qualifications of candidates in the screening process. For job-seeking professionals and students, earning BIM certifications/credentials can help gain competitive advantages in the job market.

The Delphi Study conducted in this research preliminarily established the levels of consensus as well as levels of priorities in terms of desired BIM BOK for professionals at different performance levels. Therefore, the AiC BIM BOK establishes a comprehensive framework that can be further developed into educational and training curriculum, which will eventually lead to third-party certifications and credentials across industry sectors with differentiated levels of accomplishments (e.g. Associates vs. Professional). Success has been witnessed in a similar effort of the Better Buildings Workforce Guidelines (BBWG) program directed by NIBS and DOE through its Commercial Workforce Credentialing Council (CWCC). The BBWG program also conducted JTAs and utilized the Delphi technique to create credentialing schemes for a series of energy-related jobs including *Building Energy Auditor, Building Commissioning Professional, Energy Manager* and *Building Operations Professionals* (NIBS 2016). The AiC BIM BOK is expected to help create BIM certification/credentialing programs that match the sophistication level of BIM implementation in the industry and represents the state-of-the-art best practices.

Concluding Remarks and Future Work

The AiC investigators committed 15 months to explore the first-ever BIM BOK across the AECOO industry, with zero funding but completely relying on voluntary work. Using the Delphi technique and a consensus-building process, a panel of leading BIM experts was assembled and contributed an enormous amount of time and effort, sharing their insights in the inquiry of what knowledge, skills and abilities were critical constituents of the competencies desired in workplace for BIM uses and implementation. Established upon a comprehensive classification and categorization framework, the AiC BIM BOK represents a state-of-the-art understanding of concepts, nomenclature, standards and best practices of BIM implementation in the AECOO industry. The AiC BIM BOK is expected to make major contributions to helping curriculum/training development and competency cultivation in academia and industry, and to standardize baseline performance for future education accreditation and professional credentialing/certification.

As BIM continues to develop and the industry strives to advance, the BIM BOK is likely to evolve accordingly. It is the vision of the AiC and long-term goal of the BIM BOK project to periodically revisit and update the list of BOK line items, and gradually establish a dynamic and robust knowledge management (KM) system to serve the AECOO industry with the following BIM intelligence goals:

- Identify industry trends in workforce development driven by BIM innovation and implementation;
- Create a comprehensive competency model that comprises of foundational BIM KSAs with SME's input and rigorous validation;
- Develop a matrix of learning objectives for BIM training and education curricula with integration of effective assessment measures;
- Align BIM education with academic accreditation standards, such as NAAB, ABET, and ACCE;
- Benchmark workplace BIM performance and encourage professional BIM certification and credentialing; and
- Cultivate a BIM culture in the professional and higher education communities.

APPENDIX

Appendix A: 2015 AiC BIM JTA Mini Workshop Participants

Deke Smith	National Institute of Building Sciences
Wei Wu	California State University, Fresno
Raymond Issa	University of Florida
Tamera McCuen	University of Oklahoma
Dominique Fernandez	National Institute of Building Sciences
Gregorius Gegana	University of Indonesia (Indonesia)
Geoffey Becker	University of Southern California
Sa'id Kori	University of Liverpool (UK)
Michael Gonzalez	University of New Mexico
David Batie	East Carolina University
Fernanda Leite	University of Texas – Austin
Anne Anderson	Washington State University
Tony Graham	North Carolina A&T University
Zulfikar Adamu	Loughborough University (UK)
Rogelio Palomera-Arias	The University of Texas at San Antonio
Rui Liu	University of Florida
Maria Gomez	Worcester Polytechnic University
Julide Demirdoven	Illinois Institute of Technology
Kherun Nita Ali	Universiti Teknolgi Malaysia (UTM) (Malaysia)
Marcel Maghiar	Georgia Southern University
Tony Widjarnarso	Institute of Technology Bandung, Indonesia (Malaysia)
Kevin Miller	Brigham Young University
Lamar Henderson	Independent
John Cribbs	Arizona State University
Steven K. Ayer	Arizona State University
Tracy Stone	Woodbury University
Han Hoang	The BIM Factory (Vietnam)
James Bedrick	The BIM Factory (Vietnam)

Appendix B: AiC BIM BOK Executive Committee

R. Raymond Issa	University of Florida
Glenda Mayo	University of North Carolina – Charlotte
Tamera McCuen	University of Oklahoma
Deke Smith	National Institute of Building Sciences
Wei Wu	California State University -Fresno

Appendix C: AiC BIM BOK Delphi Study Panelists

A special “thank-you” to all Delphi Panelists! To say the process of completing the three rounds of surveys was painstaking is an understatement. They are commended for their commitment, perseverance and insights in providing valuable inputs to this grand research effort of building the first-ever BIM BOK.

Vimesh Amin	Caddell Construction
Giovanni "Gio" Carino	ProdigyAE Inc. Philippines | 3DProdigy Singapore | 5DProdigy Philippines
Mike Carroll	Dvirka & Bartilucci Engineers and Architects
Chuck Coen	Washington State University - Facilities Services, Administration
Malcolm Coetzee	JE Dunn Construction Company
Chris Cossey	United Mechanical, Inc.
Ayman Daoud	Eurosia™
Michael DuLaney	University of Colorado Health
Scott Ebert	Design BIM Group
Andrew Fisher	DPR Construction
Ram Ganapathy	DPR Construction
Brittany Giel	The Whiting-Turner Contracting Company
Sindhu Gundimeda	Austin Commercial
Maya Joannides	Morris Architects
Brian Krause	Clark Construction Group
Kurt Maldovan	Jacobs
William Manion	O'Neil & Manion Architects P.A.
Casey Martin	Jacobs
Cliff Moser	Stanford Healthcare
Stu Rich	PenBay Solutions
Todd Shackelford	Alvine and Associates
Doug Sinclair	Intemation
Darren Young	Southland Industries

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