

Understanding of Essential BIM Skills through BIM Guidelines

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The use of Building Information Modeling (BIM) has been growing in the construction industry because of various advantages. Several projects, which utilized BIM during design and construction, demonstrated the reduction of project cost and duration. Acknowledging these benefits, many building owners are now expecting their contractors to use BIM for their new building projects. However, not all owners are good at BIM and often times they have hard time figuring out which contractor would actually be able to meet their expectation in terms of using BIM for productivity improvement. For those building owners who do not have practical experiences in BIM may not be able to determine which BIM skills their contractors should be good at. For some owners and contractors who are new to BIM, therefore, reviewing BIM manuals issued by various organizations may help to figure out what BIM skills they should pay attention to in order to best utilize BIM. This paper explorers eleven BIM manuals to understand essential BIM skills and applications demanded by these BIM manuals. These BIM skills and applications presented in this paper could be utilized to evaluate someone's level of proficiency on BIM.

Key Words: BIM, Contractor's Proficiency, BIM Manual, Assessment, BIM Requirements

Introduction

Construction has evolved through new technologies, adoption of new methods, and maturity of management skills. Outstanding among the new technologies, Building Information Modeling (BIM) is the most effective technology that contributes to further developing and enhancing the construction process (Azhar, 2011; e.g. Eastman, et al., 2011). There are many advantages from using BIM, such as increased building performance, reduced financial risk, reduced project schedule, reliable and accurate cost estimates, program compliance, optimized facility management and maintenance (e.g. Eastman, et al., 2011; McGraw-Hill, 2009). Cost, schedule, productivity, and facility management (FM) are the major areas that have direct correlation to the use of BIM technology. Since there are many benefits of BIM usage from the pre-construction through the post-construction phase, the use of BIM is increasing exponentially in the construction industry (Azhar, 2011). According to McGraw-Hill Construction Company (McGraw-Hill, 2012), level of BIM adoption in North America was 28% in 2007. It increased to 49% in 2009 and to 71% in 2012, revealing dramatic surge from 2007 to 2012. Several top companies, as well as mid-size companies, have now adopted BIM for their construction projects.

According to the BIM handbook (e.g. Eastman, et al., 2011), owners receive advantages in project quality, cost, and operation of the facility. With BIM-based processes, each phase increases the value of project information, which helps improve the efficiency of the project team. It allows for better team collaboration and encourages unity during construction given sufficient required information (McGraw-Hill, 2009). It implies that not only is the overall project productivity is increased but also cost and time are saved to reduce rework. The owners can find optimized facilities management techniques by exporting relevant BIM data to start the systems and maintain them over the lifecycle of the facilities (e.g. Eastman, et al., 2011). Thus, BIM improves the processes of project and owners can get greater returns on their investments. Because of this and many other benefits, several companies are implementing BIM in their project and prospective owners show interest in administering BIM for their project as well (McGraw-Hill, 2009).

Construction, presently, is getting increasingly complex and is in need of many special skills (e.g. Eastman, et al., 2011). That is the reason why finding a qualified contractor is very important and is the basic requirement to success of a project (Fong & Choi, 2000). However, the owner could find selecting a competent contractor challenging or confusing because the owner may not have enough information and background in BIM. Most projects these days select contractors based on a low tender bid rather than qualification based selection (e.g. Eastman, et al., 2011; Fong & Choi, 2000; Singh & Tiong, 2005; e.g. Wong, et al., 2001). The project has a high probability of failure when the contractors are selected on the basis of low tender price rather than their qualifications (Singh & Tiong, 2005). It is crucial that a general contractor who has the high level of proficiency in construction should be determined for the project for its success (Fong & Choi, 2000).

The project would reach completion and success if it proceeds with a competent contractor (CIC Research Group, 2012). For this reason, the owners should select capable contractors. This has given a rise to varying research studies (e.g. Mahdi, et al., 2002; e.g. Wong, et al., 2001) about choosing a competent general contractor. There have been studies about the standard for selecting a general contractor; however, there is little research done about the questions that the owner should ask the contractors to evaluate their capabilities, especially regarding BIM. Moreover, owners, in particular those who are not proficient or have a very limited knowledge about BIM, have to make particularly difficult decisions in choosing the appropriate contractor for their projects given that they do not have the proper background knowledge. If the contractor's expertise is not good enough, it would cause problems during the project, especially when it comes to a BIM project, for which the project team selection is very important. McGraw-Hill's report (2012) mentions that "BIM capability is beginning to exert a greater influence on the process of evaluating companies for project teams. A significant 81% take it into account at some level when making project team selections." Thus, the researcher purposed to find the information about evaluating contractors' BIM proficiency. Since BIM guidelines contain fundamental BIM information, as well as essential specifications and stipulations regarding implementation of BIM project, they would be covered in the information that helps owners to select appropriate contractors.

Research Methodology

The intent of this research is to investigate if BIM guidelines include relevant information that owners can use for selecting competent contractors for their BIM projects. First, the researcher scrutinized various guidelines to find whether or not they covered the information that assist owners to select proper contractors for their BIM projects. In addition, the overviews of the guidelines were explained to better comprehend the content that was included in each guideline. Next, the guidelines were analyzed to extract the requirements using content analysis (Weber, 1990). As BIM requirements are central to constructing BIM projects, they can be used to qualify the contractors' level of proficiency. If a contractor has abundant knowledge and requirements for implementing BIM project, it implies that the contractor may have significant BIM competency. The requirements for BIM projects in various guidelines were analyzed with content analysis methodology. Qualitative content analysis is one of numerous research methods used to analyze text data because of its flexibility (Weber, 1990). The focus on discourse and its meaning separates qualitative content analysis from other research methods; it audits the language to draw implications and nuances in meaning that numbers cannot capture. The requirements were counted to verify their order of significance. In other words, frequently mentioned requirements would be valuable in implementing the BIM project. This scrutiny would allow owners to inquire about principal content and select competent contractors.

Data Collection

Their published year and publishers, due to the vast anthology of manuals, organized the collected guidelines. The researcher collected the guidelines published by public institute, such as state, university, and public corporation in the US from January 2000 to June 2014. Eleven guidelines that focused mainly on the requirements for executing BIM projects were selected. Guidelines were excluded if their manuals focused on explanation of BIM project instead of providing requirements and only covered certain aspects of BIM. The total list of BIM guidelines is shown in Table 1.

Table 1: *List of BIM Guidelines*

No.	Name of BIM guideline	Publisher
1	Building Information Modeling (BIM) A Road Map for Implementation To Support MILCON Transformation and Civil Works Projects within the U.S. Army Corps of Engineers	US Army Corps of Engineers
2	LACCD Building Information Modeling Standards	Los Angeles Community College District(LACCD)
3	Building Information Modeling(BIM) Guidelines and Standards for Architects and Engineers	State of Wisconsin
4	The VA BIM Guide	Department of Veterans Affairs
5	City of San Antonio BIM Standards v1.1	CoSA Capital Improvements Management Services(CIMS)
6	BIM Project Execution Planning Guide v2.1	CIC-The Penn state Univ.
7	Georgia Tech BIM Requirements & Guidelines for Architects, Engineers and Contractors v1.0	Georgia Tech (GT)
8	Building Information Modeling (BIM) Guidelines v1.6	USC
9	BIM Guidelines & Standards for Architects, Engineers, and Contractors	Indiana University (IU)
10	BIM Guidelines	New York City (DDC)
11	Ohio - State of Ohio Building Information Modeling Protocol	State of Ohio Department of Administrative Services(DAS)

Overviews of BIM Guidelines

Building Information Modeling (BIM) - US Army Corps of Engineers

The guideline named "A Road Map for Implementation to Support MILCON Transformation and Civil Works Projects within the U.S. Army Corps of Engineers" was published for projects under the US Army corps of engineers. According to the manual, the objective of this guideline is "to outline the strategic and implementation plans for using BIM technology to improve the planning, design, and construction processes of the U.S. Army Corps of Engineers"(US Army Corp of Engineers, 2007, p ii.). Based on BIM use experience, the key for successful BIM implementation is addressed. It displays the U.S. Army Corps of Engineer Roadmap for strategic goals. Also, detailed information such as BIM implementations plan and guidance, teamwork instructions and dataset instructions are provided in the appendices (US Army Corp of Engineers, 2007). This manual may be useful to implement BIM projects with important knowledge derived from their experience. However, it was challenging to find the information that could be helpful to evaluate contractors' level of proficiency on BIM.

LACCD Building Information Modeling Standards - LACCD

Los Angeles Community College District (LACCD) (2011) published the guideline titled LACCD Building Information Modeling Standards. This manual had been developed to enable the use of BIM technology for improving system coordination, utilization of 4D and 5D technology, and sustainable construction. Also, the LACCD had tried to establish requirements procedures in the various stages of their projects in terms of using BIM. This guideline consists of four main chapters: Introduction, BIM project requirements, BIM process and implementation, and Quality assurance and Implementation. Introductory chapter states the overview and main objectives of the manual. The BIM project requirements chapter contains the obligatory requirements for their BIM projects and the management of project files. BIM workflow process, team collaboration procedure, BIM execution plan, and roles and responsibilities are mentioned in chapter 3. Lastly, the process of quality assurance and validation are included in chapter 4 (LACCD, 2011). This manual thoroughly focuses on the requirements for their projects. However, it does not mention any information about selecting a competent contractor.

Building Information Modeling (BIM) Guidelines and Standards for Architects and Engineers - Division of State Facilities State of Wisconsin

The guideline classified the requirements with the perspective of Architects and Engineers (A/E) (State of Wisconsin, 2009). It states the requirements for implementing BIM project such as roles and responsibilities of A/E, BIM authoring software, model quality and submittal, and model elements. This manual briefly states requirements that A/E should perform for a project to be considered utilizing BIM, and not the overview or analysis of BIM. It would be valuable for the readers who need the list of requirements for implementing BIM projects.

The VA BIM Guide - Department of Veterans Affairs

The purpose of the VA BIM guide is "to deliver higher value and maximize lifecycle building performance to support VA's mission to deliver excellent medical services" (Department of VA, 2010, p.4). The VA's office of Construction and Facilities Management (CFM) had tried to enhance technology and change a process to deliver high quality and cost effective facilities by digitization and standardization of building data. This guideline introduces the process of implementing a project with BIM and the appropriate requirements. It describes the specifications about BIM Management Plan (BMP) and roles and responsibilities of BIM managers. VA requirements, format, structure, usages of model and the way to share the model for communicating collaboratively were also stated in the VA guideline (Department of VA, 2010). Most of the contents were the requirements and information for their projects and not for general owners. In this guide, it may help to get a general idea for implementing BIM projects, but it was difficult to find specific information for owners to select right contractors.

Building Information Modeling (BIM) Development Criteria and Standards for Design & Construction Projects - City of San Antonio (CoSA) CIMS

According to the guideline, "the goal of CoSA's implementation of BIM is to deliver higher value projects and maximize lifecycle building maintenance and performance" (City of San Antonio, 2011, p.4). CoSA had tried to standardize and digitize the building data to better implement BIM project. Five main articles are included in this manual: 1.Introduction, 2. BIM project requirements, standards, performance criteria, information integration, 3.Builiding information model protocol, 4.Independent information manager responsibilities, and 5.General contractor's BIM responsibilities during construction (City of San Antonio, 2011). This manual did not contain any information for qualifying contractors' level of proficiency on BIM.

BIM Project Execution Planning Guide v2.1 - The Computer Integrated Construction Research Group - The Penn. state Univ.

According to BIM project execution planning guide from the Computer Integrated Construction research program at Pennsylvania State University (2011), "a project team must perform detailed and have appropriate responsibilities with well documented BIM project execution plan which are clearly defined in terms of implementing BIM project" (CIC Research Group, 2011, p.4). This guide covers not only procedures for creating a BIM project execution plan but also a way to perform BIM project successfully. Eight chapters are contained in this guideline. The first chapter outlines the general idea of BIM, the importance of BIM project Execution plan (BEP), BEP procedure, and the information that should be included in BEP. The second chapter discusses the plan for setting up BIM goals and selecting BIM uses for each phase. The third chapter covers the BEP process for designing, such as mapping, detailed BIM use map, and usage of symbols for process map representation. In the fourth chapter, the information regarding exchanging the data during a project was mentioned. Chapter five covered the overview of BEP for infrastructure. It details the requirements for a project team and items that should be included in BEP. Chapter six explains how to develop the BEP and what should be done in the collaboration meetings for finalizing the BEP. Chapter seven describes the organization in developing BEP effectively. The requirements for organization, such as mission statement and goals, definition of BIM uses, process map, establish of standards for information exchanges were included. Lastly, the conclusion and some recommendations for BIM project execution planning procedures are delivered in chapter eight (CIC Research Group, 2011).

Georgia Tech BIM Requirements & Guidelines for Architects, Engineers and Contractors v1.0 - Georgia Tech (GT)

Georgia Tech (GT) published the guideline for encouraging team coordination among architects, engineers and contractors and for providing BIM requirements for GT projects (Georgia Tech, 2011). The information of the requirements and guidance are provided from pre-design phase through close out phase. This manual mainly focuses on the requirements of submittals, modeling contents and applications, data analysis, and deliverables in each phase. The requirements for GT projects are clearly mentioned in the manual (Georgia Tech, 2011). However, the information that assists owners to select the right contractors for their projects is not mentioned.

Building Information Modeling (BIM) Guidelines v1.6 - USC

This manual is the guidance for USC projects through the definition of work scope, deliverables for using BIM, and the requirements for USC's construction (USC, 2012). They provide the knowledge of using BIM to improve the coordination of design and construction procedures and reduce potential risks. The requirements of using BIM such as model components, level of detail, and COBie data, are mentioned concretely through design to construction phase. In the appendices, more detailed information for various models, format, worksheets, requirements, nomenclature, and specifications are stated for helping contractors implement on USC's projects. Also, they attached the template of BIM execution plan for their project (USC, 2012). This guideline contains the essential information for executing USC's projects, but it does not include any information of selecting right contractors.

BIM Guidelines & Standards for Architects, Engineers, and Contractors - Indiana University

This manual addresses the general requirements, process of the project, deliverables, and objectives and applications for performing an IU project (Indiana University, 2012a). This guideline mentions the requirements that the contractor who works with IU should follow such as BIM applications for design and cost analysis, energy modeling, BIM model, deliverables, and BIM execution plan. The objectives and application section are divided into construction phases so that the readers understand what the action items or requirements are needed in each phase. Since the contents in the guideline are mentioned through IU's perspective as an owner, this manual cannot be applied by owners for their BIM projects (Indiana University, 2012a).

BIM Proficiency Matrix (BPM) - Indiana University (IU) created their own evaluation tool called BIM Proficiency Matrix (BPM) for assessing the proficiency of the contractors' abilities in BIM (Indiana University, 2012b). BPM includes eight main categories in terms of the contractors' capabilities to perform BIM services. Each category is divided into four maturity areas. The applicant for an Indiana University project fills out the matrix on the basis of their experience and capabilities. Then, the matrix is evaluated by the consultant in IU. If the applicant earns one point in several areas, the scores are added together. The applicant's level of BIM maturity is determined by the score. By using BMP, IU can filter the applicant who has a high level of maturity in BIM (Indiana University, 2012b).

BIM Guidelines - New York City (Department of Design + Construction)

The purpose of this manual is to establish the uniformity of standards for all New York City public buildings projects in terms of using BIM. NYC DDC (2012) explains the general information and the requirements for performing BIM projects. BIM content in the manual was explained with the general knowledge and value of each section. Since the submission and deliverables part is divided by construction phase, the requirements and instructions for project implementation are addressed depending on each phase. This manual is for the contractor who works with NYC DDC to help them provide the framework for the project. Also, the owner who does not have any standard or outline for a BIM project would be able to use this manual (NYC DCC, 2012). However, it does not mention how to select the skillful contractors in terms of using BIM.

State of Ohio Building Information Modeling Protocol - State of Ohio Department of Administrative Services (DAS)

According to this guideline, "The state of Ohio BIM Protocol does not establish a 'standard' that requires specific software or hardware to be used by the state's venders, but provides general guidance that ensures that building owners know what they should include in their requests for qualifications, agreements, bidding requirements, contracts, and other documents affected by this new medium and process" (Ohio DAS, 2013, p2). Four sections are stated in this guideline: Statement of Purpose, The Protocol, Implementation, and Appendix. This BIM protocol addresses the necessity of the protocol, the state of Ohio DAS's findings in terms of using BIM, general awareness of the concept of BIM in BIM practitioners, and goals for developing the guideline. Also, it provides owners a foundation of BIM use on projects, BIM standard for implementation, and the requirements for project deliverables. Some information for owners, such as the model requirements for post construction, and ownership, are explained (Ohio DAS, 2013). However, the way to select the contractor who has a high level of BIM proficiency was not addressed.

Significance of BIM Requirements

The requirements for BIM project were analyzed using category counting in content analysis methods (weber, 1990). The requirements must be individually and manually counted and not counted by text quantity. In order to count these requirements, they must be accurately identified and extracted through content analysis. Normally, content analysis is run through a standard process of word or text count, but counting requirements necessitates classifying action items first. This requires a manual and cognizant look at the requirements as key words and text count alone do not sufficiently determine the requirements.

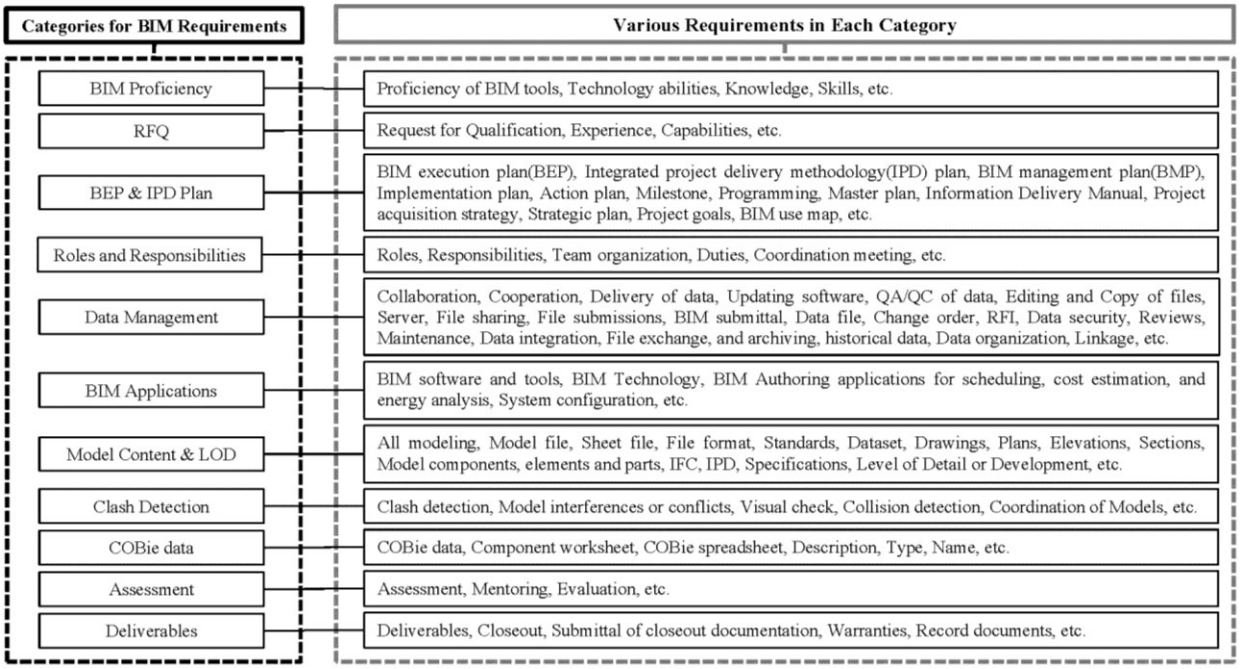

Figure 1: The organization chart for requirements categories

The requirement categories were classified and established; once the guideline requirements were counted, they were designated to the appropriate categories. The categories were arranged into eleven groups: BIM Proficiency, Request for Qualification (RFQ), BIM Execution Plan (BEP) and Integrated Project Delivery (IPD) Methodology Plan, Roles and Responsibilities, Data Management, BIM Applications, Model Content & Level of Development (LOD), Clash Detection, COBie data, Assessment, and Deliverables. Figure 1 displays the organization chart for requirements categories.

Table 2: The requirement frequency-of-mention in each BIM guideline

Publishers of BIM Guidelines	General Information										Pre-Design Phase							Design Phase							Construction Phase							Post-Construction Phase						
All BIM Guidelines	BIM Proficiency	Request for Qualification	BEP & IPD Plan	Roles and Responsibilities	Data Management	BIM Applications	Model Content & LOD	Clash Detection	COBie Data	Assessment	Roles and Responsibilities	Data Management	BIM Applications	Model Content & LOD	Clash Detection	COBie Data	Assessment	Roles and Responsibilities	Data Management	BIM Applications	Model Content & LOD	Clash Detection	COBie Data	Assessment	Roles and Responsibilities	Data Management	BIM Applications	Model Content & LOD	Clash Detection	COBie Data	Assessment	Deliverables	Data Management	BIM Applications	Model Content & LOD	COBie Data	Assessment
1. US Army Corps of Engineers			3	6	8	3	6											2	10	6	15	2																
2. LACCD	7	4	5		7	6	17				4	4	4	4				12	14	11	9	4			10	13	6	11	1			2	1		1		
3. State of Wisconsin		3			5	6	12			3	5	1	7	8				4	1	2	33	3				1		1				5	1	1	2		
4. Department of VA	6	5	9		14	10	39		1		10	5	6	14		3		12	6	5	16	5	2		10	5	1	11	4	2		11	3	1	9	4	
5. City of San Antonio CIMS	2	5	7		13	12	26				9	2	4	13				15	2	5	26	14			13	4	4	14	4			10	4	1	9		
6. CIC-The Penn. State Univ.	1		35	59	37	8	22	1		1	1	1		1	1			1	1	0	1	1			1	1		1	1			6	1				
7. Georgia Tech (GT)	3	1	7		7	1	11		2		9	5	11	19		4		6	8	6	15	3	3		9	11	4	9	4	5		5	2	2	3	4	
8. USC	2	1	12		6	2	25		3		10	6	7	16		6		14	10	6	20	4	7		12	8	6	7	3	3		2	1	2	7	4	
9. Indiana University (IU)	2	1	20		1	2	5			2	15	6	7	8	6			15	8	5	17	7	1		9	3	4	6	2	2		5	2		2	2	
10. New York City (DDC)	2	2	6	2	6	5	14				3	4	3	9				2	1		4	2			3	5	5	8	4			3	3	2	7		
11. State of Ohio DAS	1	3	10		3	2	6				3	3	2	10				3	4	2	11	4			2		1	4	2			6	5		5		
Total Number of Frequency	26	25	114	67	107	57	183	1	6	6	69	37	51	102	7	13	0	86	65	48	167	49	13	0	69	51	31	72	25	12	0	55	23	9	45	14	0

According to the analysis of requirements, the frequencies of categories for requirements in each BIM Guideline are shown in Table 2. Through the data table, the mentioned frequency of any requirement is displayed within their respective guidelines. This information is potentially crucial in informing the BIM project requirements, as repetition in the text reveals emphases on certain requirements.

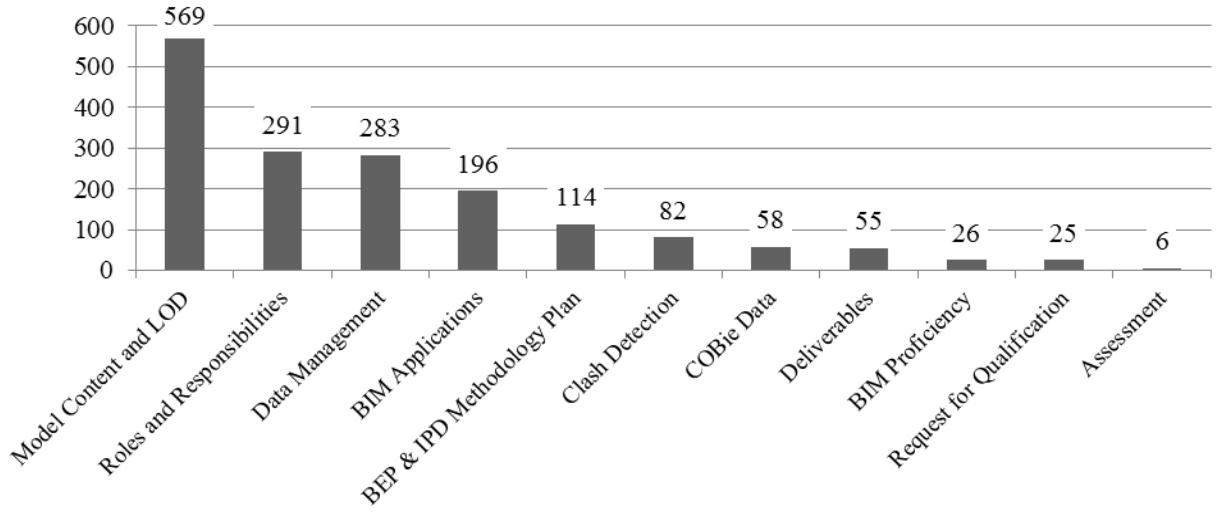

Figure 2: Descending order of requirement categories' frequency-of-mention

According to the outcome of the analysis, the requirements for Model Content and LOD were mentioned the most, followed by Roles and Responsibilities and Data Management. In BIM guidelines, Model Content and LOD regularly presented the requirements for 3-dimensional modeling, models that are needed for BIM projects, proper elements in 3-dimensional modeling, and directions on creating the model. Roles and Responsibilities is the second most recurring category. This category was generally counted by the roles, responsibilities, and duties of stakeholders, such as the BIM manager, architect, engineer, technician, and contractor when implementing BIM project. Data Management reiterated the requirements for sharing, updating, saving, and transforming data, in addition to explaining document management and coordination data between team players. Although the categories for BIM Applications, BEP, Clash Detection, COBie Data, Deliverables, BIM Proficiency, RFQ, and Assessment were mentioned fewer times than other categories in the guidelines, they still remain significant in their disparate roles. The research outcome reveals how many times each requirement was covered among various BIM guidelines, and does not assess the individual requirement's value or credibility.

Conclusion

The paper explored eleven BIM manuals issued by various entities in the U.S. to figure out essential BIM skills that some owners and contractors who are not good at BIM may need to pay attention to. From analyzing various guidelines and regulations suggested by these BIM manuals, this paper figured out what has been most mentioned in those eleven BIM manuals. The outcome of the analysis revealed that "Model Content and LOD", "Roles and Responsibilities", and "Data Management" are most frequently mentioned in any BIM manual, which may indicate that the ability of creating a 3D model for the proper level of development is critically important. It may also indicate that a successful BIM application requires good understanding of roles and responsibilities among project team, so owners may want to hire those contractors who can clearly address the roles and responsibilities of their team members in terms of using BIM for advancing their decision making process. What has been discovered from this investigation is directly related to core competencies that one needs to demonstrate to best utilize BIM for construction.

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