Changes in the BIM Service Provision of Top BIM Companies: A Five-Year Longitudinal Study

Namcheol Jung[a] and Ghang Lee[b]

[a,b]Department of Architecture and Architectural Engineering, Yonsei University, South Korea.
E-mail: [a]chuliee@nate.com. Corresponding author: [b]glee@yonsei.ac.kr.

Abstract –

This paper presents the results of a five-year longitudinal study conducted to analyze the changes in the building information modeling (BIM) services provided by top contractors from 2011 to 2015. Many previous studies analyzed the trend of BIM adoption through questionnaires, case studies, or interviews, all methods that are subject to respondents' perspectives. To objectively analyze the changes in BIM services throughout the years, the research team tracked the BIM services provided by top contractors, which were selected using the 2011 to 2015 Giants 300 reports. The BIM services that each company provided were collected in 2011, 2013, and 2015 from the company's websites, brochures, and/or reports about its BIM projects. The collected BIM services were regrouped using the BIM use classification suggested by Pennsylvania State University. The frequency of BIM services and the correlations between the BIM service types were analyzed. The results showed that the average number of BIM services provided by one company increased from 5.16 in 2011 to 10.91 in 2015. The top five BIM services provided by the top BIM companies include phase planning, 3D coordination, design reviews, cost estimation, and site utilization. While about 70% of the top BIM companies provided these services in 2011, these services were provided by most companies (approximately 85%) in 2015. It is expected that the results of this study will help the industry to overview trends in the BIM market and decide which technologies they need to adopt in order to keep pace with major BIM companies.

Keywords –

Building information modeling (BIM); BIM service; BIM use; Longitudinal study

1 Introduction

For over a decade, many companies in the architecture, engineering, and construction industry have been adopting building information modeling (BIM). Many studies have been conducted to understand the current status of BIM adoption as well as its future implementation and direction. This study aims to identify the ways in which leading construction companies' utilization of BIM has changed since 2011 through a five-year longitudinal study.

Previous studies depended on interviews or surveys, both of which are methods that study the perceptions of participants. To minimize the subjective judgment in the analysis, this study tracked the changes in the BIM services of the top BIM contractors by analyzing their websites, brochures, reports about their BIM projects in 2011, 2013, and 2015, respectively. The top BIM contractors were selected from Giants 300 reports, which are annually published reports on the rankings of design firms and contractors that conduct BIM projects [1]. A content analysis was conducted to analyze the changes in the BIM services provided. By analyzing the BIM services that each company provides rather than analyzing surveys, this study attempted to capture the companies' commitment to BIM rather than BIM users' personal views. The eventual goal is to understand the changes in the practical uses of BIM rather than those in the perceived uses of BIM. Also the methodology utilized in this study will improves time-consuming works to investigate the BIM trend.

This paper is divided into six sections. The next section reviews previous studies related to BIM trends. The third section describes this study's research questions and the data collection and analysis methods used. Section 4 reports the analytical results, and the final section concludes the paper.

2 Previous Studies on BIM Adoption

Many studies have been conducted to research the statuses of BIM adoption and implementation around the world. Yalcinkaya and Singh conducted a research pattern analysis and derived three main research areas from 220 publications directly relevant to BIM implementation and adoption [2]: 1) adoption and implementation processes, 2) project delivery methods, and 3) benefit realization. Azhar and Cochran also conducted a survey to determine the adoption status of

BIM in the electrical construction industry in the United States [3]. They conducted a survey using questionnaires to determine the popular BIM uses of and obstacles involved in BIM adoption. In addition, Kiziltas and Akinci conducted interviews and surveys with BIM experts to understand the lessons learned from BIM projects [4]. They summarized the results using three phases of construction—before construction, during construction, and after construction— and categorized BIM services according to these three phases.

Further, Becerik-Gerber et al. investigated the connection between BIM and facility management [5], and Alin et al. conducted a study on the inter-firm processes involved in implementing BIM [6]. Won et al. conducted an international survey to discover the critical success factors involved in the successful adoption of BIM within an organization, BIM project selection, BIM service selection, and BIM software selection [7]. Samuelson and Björk conducted a longitudinal study to investigate the adoption status of building-related information technologies (IT) in Sweden [8]. The surveys were conducted from 1998 to 2011 and utilized the IT barometer. Furthermore, Lee and Jung proposed a simplified model to evaluate and represent the level of BIM implementation in multiple countries according to four factors: 1) the depth of BIM implementation, 2) years using BIM, 3) the level of BIM proficiency, and 4) BIM adoption rate [9].

The SmartMarket Report series published by McGraw Hill Construction Research and Analytics (currently, Dodge Analytics) provides quantitative survey data related to the status of BIM adoption around the world starting from 2007 [10]. In addition, the National Building Specification (NBS) for the United Kingdom has published national BIM reports related to BIM adoption since 2011 [11].

Despite the strengths of interviews and surveys as research methods, they also have limitations in that interviewees may answer perceived facts rather than actual facts [12]. For this reason, this study longitudinally tracked the BIM services that each company declared it provided as a basis to analyze the status of BIM implementation in top BIM contractors.

3 Research Design

3.1 Research Questions

The primary aim of this research was to study the changes in the use of BIM from 2011 to 2015 by top global contractors. Based on this, the following research questions were developed.

- Q1: How has the number of BIM services provided by each company changed over time?
- Q2: Were there any changes in the main BIM services provided each year?
- Q3: What BIM services were provided for each project phase?
- Q4: What are the most popular BIM services provided by leading BIM companies?
- Q5: What BIM services were newly introduced in each year?
- Q6: Is there any correlation between BIM services?
- Q7: What are the BIM-related characteristics of the contractors that stayed on the Giants 300 reports from 2011 to 2015?

3.2 Classification of BIM Services and Data Coding

To classify the collected BIM services, the BIM use list developed by Pennsylvania State University (Penn State) [13] was used. The Penn State classification is composed of 25 BIM services throughout four project phases. The 25 BIM services are divided into two types: primary and secondary BIM uses. Each item is listed in Table 1. The Penn State classification was selected for the following reasons:

1. The BIM services are clearly categorized into primary and secondary services and by project phase.
2. The classification is simple and easy to understand.
3. The classification is already well known to the BIM community and has been used in other studies [14, 15].

Among the 25 BIM services listed, several services related to engineering analyses, such as structural analyses, lighting analyses, energy analyses, and mechanical analyses, were merged with engineering services to prevent ambiguity in their definitions. Disaster planning was also excluded from the analysis because all the contractors claimed that they did not support disaster planning. Therefore, a total of 20 BIM services from the original 25 BIM services specified by Penn State were used in this analysis.

3.3 Data Collection

We gathered texts from the webpages, brochures, and case study reports of the top BIM contractors to conduct a content analysis. The provision of a BIM service field was checked yes (1) if a company provided the BIM service and no (0) otherwise.

Table 1 BIM uses [13]

Item	Construction Phase	Type	Note
Existing Conditions Modeling	Plan, Design, Construct, Operate	Primary	
Cost Estimation	Plan, Design, Construct, Operate	Primary	
Phase Planning	Plan, Design, Construct	Primary	
Programming	Plan, Design	Primary	
Site Analysis	Plan, Design	Primary	
Design Reviews	Plan, Design	Secondary	
Design Authoring	Design	Primary	
Structural Analysis	Design	Primary	Merged
Lighting Analysis	Design	Primary	Merged
Energy Analysis	Design	Primary	Merged
Mechanical Analysis	Design	Secondary	Merged
Other Engineering Analysis	Design	Secondary	Merged
LEED Evaluation	Design	Secondary	
Code Validation	Design	Secondary	
3D Coordination	Design, Construct	Primary	
Site Utilization Planning	Construct	Primary	
Construction System Design	Construct	Secondary	
Digital Fabrication	Construct	Secondary	
3DControl and Planning	Construct	Primary	
Record Model	Construct, Operate	Primary	
Maintenance Scheduling	Operate	Primary	
Building System Analysis	Operate	Primary	
Asset Management	Operate	Secondary	
Space Management/Tracking	Operate	Secondary	
Disaster Planning	Operate	Secondary	Not used

The contractors used in the content analysis were selected from the top 100 BIM contractors listed in the Giants 300 reports published by Building Design and Construction. Giants 300 reports have been published every year since 2010. Each year, the report ranks the leading companies in the architecture, engineering, and construction industry by sector based on their annual revenues.

The 2011 Giants 300 report listed leading BIM companies in two sectors: design firms and contractors. The 2012 Giants 300 report listed leading BIM companies in three sectors: architecture firms, engineering firms, and construction firms. The following reports used the same categorization. This study conducted an analysis focusing on leading contractors using information from their webpages, brochures, and reports. A list of the companies included in the analysis is given in Table 2.

For data collection from 2011, we used the Giants 300 report published on December 16, 2010 that investigated revenue of the top companies in 2009 [16]. From the report, 32 companies were selected as target companies based on their provision of the proper materials. For 2013, we used the Giants 300 report published on September 20, 2012 to collect data on 34 companies [17]. Similarly, in 2015, we used the Giants 300 report published on August 4, 2014 to collect data on 65 companies [18].

3.4 Data Analysis

To answer the seven sub-questions, we conducted a frequency analysis and a cross-tabulation analysis.

To answer Q1 (how has the number of BIM services provided by each company changed over time?), we tracked and analyzed the average amount of BIM services provided by each company in 2011, 2013, and 2015, respectively.

To answer Q2 (were there any changes in the main BIM services provided each year?), we analyzed variation in 2013 and variation in 2015. Variation in 2013 represents the subtracted frequency of BIM services provided in 2011 from that of BIM services provided in 2013, while variation in 2015 represents the subtracted frequency of BIM services in 2013 from that of BIM services in 2015. The calculated ratio of the two values was utilized to show the changes.

Table 2 Source of analysis for each year

Year of Analysis	Number of Samples	Source
2011	32	2010 Giants 300 report
2013	34	2012 Giants 300 report
2015	65	2014 Giants 300 report

To answer Q3 (what BIM services were provided for each project phase?), we classified the 20 BIM services according to the four project phases (planning, design, construction, or operation) defined by Penn State. The percentage of companies that provided BIM services for each project phase was measured.

To answer Q4 (what are the most popular BIM services provided by leading BIM companies?), the top 5 BIM services, which were those most frequently used in each year, were selected.

To answer Q5 (what BIM services were newly introduced in each year?), the top 5 BIM services that had the highest variation values in 2013 and 2015 were selected.

To answer Q6 (is there any correlation between BIM services?), we conducted Fisher's exact test. The test measured whether there was a significant relationship between BIM service pairs. For example, the first BIM service, existing condition modeling, was compared with the other 19 BIM services. This was done for each service.

To answer Q7 (what are the BIM-related characteristics of the contractors that stayed on the Giants 300 reports from 2011 to 2015), we conducted a t-test to compare the average amount of BIM services provided by companies that stayed on the Giants 300 reports from 2011 to 2015 and those that did not.

4 Results

Through the analysis described above, the collected data were analyzed. The frequency analyses conducted to answer Q1, Q2, and Q3 derived the following results. Regarding Q1, the average number of BIM services provided by companies increased from 5.16 in 2011 to 10.91 in 2015. The adoption rates of some BIM services increased evenly for five years, while some BIM services were adopted in the same year.

Regarding Q2, changes in the ranking of each BIM service are presented in Table 3.

Regarding Q3, in the four phases of the building life cycle, there were steady increases in the BIM services from 2011 to 2015.

- Plan: 40.6% in 2011 to 62.6% in 2015 (+22.0%)
- Design: 31.3% in 2011 to 59.4% in 2015 (+28.1%)
- Construct: 45.8% in 2011 to 59.3% in 2015 (+13.5%)
- Operate: 17.4% in 2011 to 50.6% in 2015 (+33.2%)

In total, the BIM services provided increased from 25.8% in 2011 to 54.5% in 2015.

Regarding Q4, the top 5 BIM services were phase planning, design reviews, site utilization, 3D coordination, and cost estimation, and they did not change over 5 years. The average adoption rate of the top 5 BIM services was approximately 70% in 2011. In 2015, this rate increased to 85%.

Regarding Q5, an analysis of the top BIM services with the highest variations was conducted to find the newly introduced BIM services in 2013 and 2015. In 2013, the adoption rates of services related to building system analysis, asset management, space management tracking, maintenance scheduling, and design authoring significantly increased. In 2015, many companies adopted services related to design authoring, code validation, programming, site analysis, and engineering analysis. Few companies used operation and management services in 2011; however, in 2013, more than half of the companies adopted these services. Similarly, less than 10% of companies used design-related BIM services in 2011; however, approximately 40% of the companies adopted these services in 2015. Therefore, there was a significant increase in the services adopted related to the operation phase in 2013 and those related to the design phase in 2015.

Regarding Q6, the relationships between each BIM service were analyzed using Fisher's exact test. The analyzed BIM services were grouped into five. The following list explains the five groups of related BIM services.

- Group 1 is comprised of services related to existing condition modeling and record model. It is expected that existing condition modeling, including laser scanning, affects record model.
- Group 2 is comprised of services related to cost estimation and phase planning. Group 2 consists of the BIM services considered to be fundamental for leading construction companies. More than 90% of the top companies have provided BIM services related to phase planning since 2011. BIM services related to cost estimation were also adopted by many companies in 2013 and 2015.

Table 3 Rankings of BIM services each year

BIM Services	2011		2013		2015	
	Change	Ranking	Change	Ranking	Change	Ranking
Existing Conditions Modeling	.	10	▼4	14	▼5	19
Cost Estimation	.	4	.	4	▼1	5
Phase Planning	.	1	.	1	.	1
Programming	.	16	.	16	▲2	14
Site Analysis	.	16	.	16	▲2	14
Design Reviews	.	3	▲1	2	▲1	1
Design Authoring	.	16	▲2	14	▲7	7
Engineering Analysis	.	16	.	16	▲2	14
LEED Evaluation	.	9	▼4	13	▲4	9
Code Validation	.	16	▼4	20	▲6	14
3D Coordination	.	2	.	2	▼1	3
Site Utilization Planning	.	5	.	5	▲1	4
Construction System Design	.	6	.	6	.	6
Digital Fabrication	.	8	▼4	12	▼2	14
3D Control and Planning	.	11	▼8	19	▼1	20
Record Model	.	7	▼4	11	▲3	8
Maintenance Scheduling	.	11	▲3	8	▼5	13
Building System Analysis	.	11	▲4	7	▼3	10
Asset Management	.	11	▲3	8	▼3	11
Space Management/Tracking	.	11	▲3	8	▼3	11

Table 4 Answers to the research questions

Question	Answer	
Q1	The average number of BIM services provided by leading companies was 5.16 in 2011, 8.35 in 2013, and 10.91 in 2015.	
Q2	Some BIM services increased evenly, while some were adopted at the same time.	
Q3	Plan	: 40.6% → 62.6%
	Design	: 31.3% → 59.4%
	Construct	: 45.8% → 59.3%
	Operate	: 17.4% → 50.6%
Q4	Phase planning, design reviews, site utilization, 3D coordination, cost estimation	
Q5	2013:	Building system analysis, asset management, space management tracking, maintenance scheduling, design authoring
	2015:	Design authoring, code validation, programming, site analysis, engineering analysis
Q6	Group 1:	Existing condition modeling, record model
	Group 2:	Cost estimation, phase planning
	Group 3:	3D Coordination, design reviews, site analysis, construction system design
	Group 4:	Programming, design authoring, engineering analysis, code validation, site analysis
	Group 5:	Maintenance scheduling, building system analysis, asset management, space management/tracking
Q7	No significant differences exist between companies that stayed on the Giants 300 reports from 2011 to 2015 and those that did not.	

- Group 3 is comprised of services related to 3D coordination, design reviews, site analysis, and construction system design. In 2011, only 3D coordination and design reviews services were provided. In 2013, site utilization planning and construction system design were also added, but they were not related to 3D coordination or design reviews. In 2015, there was a correlation between all four BIM services included in Group 3.
- Group 4 is comprised of services related to programming, design authoring, engineering analysis, code validation, site analysis, and LEED evaluation. In 2011 and 2013, few companies utilized these services. However, by 2015, more than one third of the leading companies adopted and provided these services.
- Group 5 is comprised of services related to maintenance scheduling, building system analysis, asset management, and space management/tracking. It is expected that the development of facility management and building operation led to the use of these four services.

Regarding Q7, the t-test, which was conducted to compare the average amount of BIM services that were provided by the companies that stayed on the list from 2011 to 2015 and those that did not, showed no significant statistical difference between these two groups.

5 Conclusion

The major findings of this study are listed in Table 4, and their implications for contractors are as follows.

In 2015, more than 40% of the companies adopted all the primary BIM services defined by Penn State except for 3D control and planning. In addition, the adoption rate of newly introduced BIM services increased. In 2015, most companies (94%) provided BIM services related to phase planning and design reviews.

In 2011, construction-related functions (site utilization, phase planning, etc.) tended to be utilized more than other BIM services by contractors. In 2013, Engineering analysis, code validation, and those for building operation are increased. BIM uses for communication (design authoring, programming, etc.) between stakeholders are also rapidly increased in 2015.

In this study, a cross-tabulation analysis showed that BIM services with similar functions were adopted together. BIM services could be grouped into five. Group 1 was related to existing condition or record model. Group 2 was related to cost and schedule management, and Group 3 was related to the design reviews. Group 4 was related to design and engineering, and Group 5 was related to facility management and operation.

The top 5 BIM services provided include phase planning, design reviews, site utilization, 3D coordination, and cost estimation. The adoption rate of design authoring, site utilization, building system analysis, asset management, space management/tracking, and maintenance scheduling increased more than 40% from 2011 to 2015. These services became common among construction companies. In addition, design authoring, asset management, building system analysis, maintenance scheduling, and space management/tracking were newly introduced in 2013 and design authoring, site analysis, engineering analysis, code validation, and programming were newly introduced in 2015. BIM, which is defined as "process of generating and managing building information in an interoperable and reusable way [19]", is a tool that emphasis co-work between project participants. This study contributes to offering longitudinal BIM trend derived from websites, brochures, and/or reports generated by top BIM contractors. The trend will notice what BIM functions companies have to complement to become a real BIM partner in AEC industry.

Though this study aimed to be objective, this study has a limitation in that an ambiguous representation of BIM functions in the text may be interpreted differently by different researchers.

An analysis using 2017 data is still too early to be conducted. The study will be continued to continuously track the changes in the BIM service provisions.

References

[1] Building design + Construction. Giants 300 Report. Online: https://www.bdcnetwork.com/giants-300, Accessed: 02/20/2017.

[2] Yalcinkaya M. and Singh V. Patterns and trends in Building Information Modeling (BIM) research: A Latent Semantic Analysis. *Automation in Construction*, 59(2015):68-80, 2015.

[3] Azhar S. and Cochran S. Current status of Building Information Modeling (BIM) adoptability in the U.S. electrical construction industry. *Proceedings of the 5th International Conference on Construction in the 21st Century (CITC-V)*, Istanbul, Turkey, 2009

[4] Kiziltas S. and Akinci B. Lessons learned from utilizing building information modeling for construction management tasks. *Proceedings of the Construction Research Congress 2010: Innovation for Reshaping Construction Practice*, 318-327, Banff, Canada, 2010

[5] Becerik-Gerber B., Jazizadeh F., Li N. and Calis G. Application areas and data requirements for BIM-enabled facilities management. *Journal of construction engineering and management*,

138(3):431-442, 2011.

[6] Alin P., Maunula A. O., Taylor J. E. and Smeds R. Aligning Misaligned Systemic Innovations: Probing Inter - Firm Effects Development in Project Networks. *Project Management Journal*, 44(1):77-93, 2013.

[7] Won J., Lee G., Dossick C. and Messner J. Where to focus for successful adoption of building information modeling within organization. *Journal of Construction Engineering and Management*, 139(11):04013014, 2013.

[8] Samuelson O. and Björk B.-C. A longitudinal study of the adoption of IT technology in the Swedish building sector. *Automation in Construction*, 37(2014):182-190, 2014.

[9] Lee G. and Jung W. Slim BIM Charts for Rapidly Visualizing and Quantifying Levels of BIM Adoption and Implementation. *Journal of Computing in Civil Engineering*, 30(4):Online publication, 2016.

[10] McGraw Hill Construction Research & Analytics. Smart Market Report. Online: http://analyticsstore.construction.com/smartmarket-reports.html, Accessed: 02/16/2017.

[11] National Building Specification. NBS National BIM Report Knowledge Articles | NBS. Online: https://www.thenbs.com/knowledge/nbs-national-bim-report, Accessed: 02/02/2017.

[12] Ketokivi M. A. and Schroeder R. G. Perceptual measures of performance: fact or fiction? *Journal of Operations Management*, 22(3):247-264, 2004.

[13] Messner J., Anumba C., Dubler C., Goodman S., Kasprzak C., Kreider R., Leicht R., Saluja C. and Zikic N. *BIM Project Execution Planning Guide*, The Computer Integrated Construction Research Program, Pennsylvania State University, United States, 2010

[14] Kreider R., Messner J. and Dubler C. Determining the frequency and impact of applying BIM for different purposes on projects. *Proceedings of the 6th International Conference on Innovation in Architecture, Engineering and Construction (AEC)*, PennState, United States, 2010

[15] Kreider R. G. and Messner J. I., *The Uses of BIM: Classifying and Selecting BIM Uses Version 0.9*, Penn State University, United States, 2013

[16] Building design + Construction. 2010 Giants 300 BIM Report. Online: https://www.bdcnetwork.com/sites/default/files/Top Firms by BIM Project Revenue.pdf, Accessed: 02/20/2017.

[17] Building design + Construction. 2012 Giants 300 Report. Online: https://www.bdcnetwork.com/bim-finally-starting-pay-aec-firms, Accessed: 02/03/2017.

[18] Building design + Construction. 2014 Giants 300 Report. Online: https://www.bdcnetwork.com/bim-giants-firms-enhance-bimvdc-advanced-collaboration-tools-2014-giants-300-report, Accessed: 02/02/2017.

[19] Lee G., Sacks R. and Eastman C. M. Specifying parametric building object behavior (BOB) for a building information modeling system. *Automation in Construction*, 15(2006):758-776, 2006.