

The Change of Building Information Modeling Maturity in the Last Five Years

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Abstract

Building Information Modeling (BIM) has been widely adopted and implemented since its inception. Some industrial studies and reports show that the BIM usage was more than half of the industry in the USA. However, the BIM Maturity (BIMM), which refers to the levels to which BIM is implemented, is different among projects, companies, and across years. This study is conducted to identify the change of the BIMM and its factors between 2013 and 2018 with descriptive statistical analysis. This study has both practical and theoretical implications. Practically, it sheds lights for the industry to know what areas of BIMM they shall focus on. Theoretically, this study identifies the key improvement of BIMM and the main areas of BIM that the industry has focused on across the years.

Keywords: Building Information Modeling, BIM Maturity, Change, Industry

1. Introduction

“Building information modeling (BIM) is a systematic approach to life-cycle delivery of a building (Smith and Tardif, 2009)” (Chen et al., 2016). A mature implementation of BIM relies on optimal and compatible growth of all aspects of a business, such as people, technology, information and process (Chen et al., 2014, Hua, 2013). BIM maturity (BIMM) is a system used to describe “the extent to which BIM is explicitly defined, managed, integrated and optimized (Succar, 2009)” (Chen et al., 2014). A BIMM model includes BIMM indicators and BIMM levels. BIMM indicators decide which aspect a project or an organization should focus more to improve the entire BIM process (Chen et al., 2016). And BIMM levels show an “evolutionary plateau toward achieving a mature” BIM process (Weber et al., 1994), specifically higher BIMM levels indicate better performance, predictability and control of process variation (Succar, 2009). Based on the review of previous studies, it is found that previous BIMM research either focused on specific geographical regions (Siebelink et al., 2018), or focused on providing a level of BIMM only at a particular time point (Dib et al., 2012, Chen et al., 2018). There is a shortage of research comparing the change of BIMM. Therefore, this study aims to represent the worldwide development of BIMM between 2013 and 2018.

2. Literature Review

BIM is considered useful in assisting different construction phases (Latiffi et al., 2013), since data of different phases can be transmitted in the BIM software, such as data of design review (Wu and Kaushik, 2015, Lin et al., 2018), data of construction process (Golparvar-Fard et al., 2015) and data of facility maintenance (Lucas et al., 2013). As BIM is widely utilized in different construction phases, the multidimensional BIMM model should be employed to assess mature level of BIM to better improve its implementation. Most of previous developed BIMM models, however, only focus on a limited number of dimensions. Particularly, (1) the capability maturity model (CMM) focuses on information dimension (NIBS, 2007), (2) the BIM deliverable matrix analyzes product data which belongs to information dimension (ACE, 2008), and (3) the BIM proficiency matrix also focuses on product data (IU, 2009). There are other developed BIMM models exploring more dimensions, such as (1) the BIM competencies framework which analyzes information and process dimensions (Giel and Issa, 2014), (2) the BIMM readiness of industry which aims at evaluating information, process and people dimensions (Gu and London, 2010), (3) BIM competency sets analyzing on technology and process dimensions (Succar, 2009), (4) BIM project execution planning guide focusing on technology, process and information dimensions (CIC, 2011), and (5) BIM framework evaluating technology and process dimensions (Jung and Joo, 2011).

These multidimensional BIMM models, however, can be utilized as a platform for guiding BIM implementation, not for evaluating BIMM (Chen et al., 2016). Therefore, Chen et al. have developed the measurement model of BIMM which connects all four BIMM dimensions (i.e., technology, process, information and people) and their model focuses more on BIMM evaluation (Chen et al., 2014, Dib et al., 2012). Even the evaluation model of BIMM are well designed, there still lacks a study which compares the development of BIMM in the Architecture, Engineering, and Construction (AEC) industry. An up-to-date understanding of the industry-wide change of BIMM is of great importance as it sheds light on how to further improve BIMM for employers and employees in the AEC industry. This research is conducted to overcome the above gaps. First, data of BIMM was collected in 2013 and 2018 respectively. Then a comparison study is conducted both horizontally and vertically to draw a picture of the development of BIMM in the AEC industry.

3. Research Methodology

The research methodology consists of three steps. First, 27 BIMM indicators of four BIMM dimensions are extracted from previous studies and those indicators are listed in Table 1 (Chen et al., 2013). Second, based on the identified indicators, an online survey was designed and distributed to the

identified professionals with BIM-related experience to obtain their evaluation of BIMM of most of their BIM-assisted projects. After the data collection, descriptive analysis is used to evaluate and discuss the change of BIMM between 2013 and 2018.

Table 1: 27 BIMM indicators and classification

<i>Dimensions</i>	<i>Indicators</i>	<i>Dimensions</i>	<i>Indicators</i>
<i>Technology</i>	<i>Software applications</i>	<i>People</i>	<i>Role</i>
	<i>Interoperability</i>		<i>Strategic planning</i>
	<i>Hardware upgrade</i>		<i>Senior leadership</i>
	<i>Hardware equipment</i>		<i>Competency profile</i>
<i>Process</i>	<i>Specification</i>		<i>Training program</i>
	<i>Documentation and modeling standards</i>		<i>Training delivery method</i>
	<i>Standard operation procedure</i>		<i>Reward system</i>
	<i>Quality control</i>	<i>Information</i>	<i>Information delivery method</i>
	<i>Process & technology innovation</i>		<i>Data richness</i>
	<i>Change management</i>		<i>Real-time data</i>
	<i>Work flow</i>		<i>Information accuracy</i>
	<i>Risk management</i>		<i>Graphics</i>
	<i>Lifecycle process</i>		<i>Geospatial capability</i>
			<i>Strategic planning</i>

3.1 Questionnaire Design

The questionnaire was designed to solicit the BIM-related experts' perception regarding the BIMM of most of their BIM-assisted projects through a seven-point Likert scale. The questionnaire is consisted of four parts. The first part obtains information of the organizations including business type, year range of using BIM and coverage percent. The second part is designed to gather participants' personal experience with BIM-assisted projects and their positions. The third part mainly focuses on participants' evaluation of maturity level of each BIMM indicator and overall BIMM for most of their BIM-assisted projects. Finally, opportunities are provided to collect any comments from participants.

3.2 Data collection

The data collection was conducted twice, in 2013 and 2018 respectively. The participants of two investigations were professionals with the experience of BIM-assisted projects all over the world. For the data collected in 2013, the survey was sent out to a total of 3,813 professionals, including 2,050 participants who resided in the USA and 1,763 participants who resided outside the USA. The survey was sent to 8,000 professionals in 2018. To achieve a true reflection of BIMM in the AEC industry, the responses of those indicating no previous BIM-related experience were removed. Also, 3 responses in the 2013 investigation and 1 response in the 2018 investigation were removed as well due to their inaccurate responses to several questions. A total of 534 valid responses were received for

2013, which represented a response rate of 14.08%. A total of 228 valid responses were received for 2018, with a response rate of 2.86%. The breakdown of the business type of those respondents is shown in Table 2.

Table 2: Breakdown of survey respondents by their companies' business type

<i>Business type</i>	<i>2013</i>	<i>2018</i>
<i>Owner/Developer (O/D)</i>	27	16
<i>Architect/Engineer (A/E)</i>	206	58
<i>General Contractor</i>	67	60
<i>Construction Manager (CM)</i>	38	23
<i>Subcontractor</i>	25	18
<i>Consultant</i>	84	20
<i>Software Vendor</i>	42	9
<i>Other</i>	45	24
<i>Total</i>	534	228

3.3 Data Analysis

The data analysis consists of descriptive analysis. Descriptive analysis is employed first to summarize the respondents' qualification and experience, the demographic information of their companies and the profiles of the BIM-assisted projects. Then the means of the respondents' evaluations of BIMM of those BIM-assisted projects in which respondents had been involved are calculated and compared. Both vertical and horizontal comparisons are conducted. The vertical comparison helps understand the change of BIMM from 2013 to 2018, while the horizontal comparison is performed to understand the change in terms of business types, project types and projects delivery methods.

Figure 1 shows that the industry average BIMM level has increased from 4.68 to 4.88 out of a 7-point Likert scale from 2013 to 2018, indicating that the BIMM level is between 4 (neither mature nor immature) and 5 (somewhat mature). Specifically, the BIMM levels of construction management (CM) companies had remained almost the same, while the BIMM levels of owner/developer (O/D), architect/engineer (A/E), consultant, software vendor had experienced an increase from 2013 to 2018, which can be a result of wider application of BIM in the stage of design assessment (Azhar et al., 2015). In comparison, the BIMM levels of general contractors (GC) and subcontractors had slightly decreased probably because they tried to limit the hardware cost (Ryan and Derek Pierre, 2014).

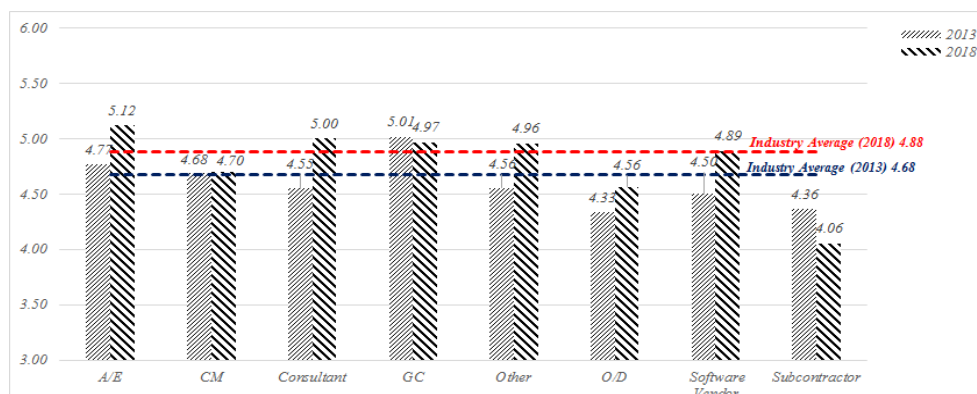


Figure 1: Change of global BIMM by business types in 2013 and 2018

Figure 2 shows the change of BIMM by different types of BIM-assisted projects. Some participants were involved in more than one project type. Therefore, their responses have different weight, compared with other participants who only focused on one project type. To address this, the BIMM levels were calculated by weighted average, as shown in the equation below, to evaluate their responses (Enshassi et al., 2016). It shows that the BIMM levels increased across all different project types. Especially, the BIMM level in transportation and healthcare projects were the highest and increased the most. It might be because healthcare and transportation projects are more complex and require a more systematic and collaborative approach (Merschbrock and Munkvold, 2014).

$$\text{BIMM level} = \frac{\sum_1^k \frac{x_i}{n_i}}{\sum_1^k \frac{1}{n_i}}$$

Where, k represents the number of participants who chose the project type, x_i represents the BIMM level based on the majority of BIM-assisted projects that each participant had been involved in, and n_i represents the number of project types a participant was involved.

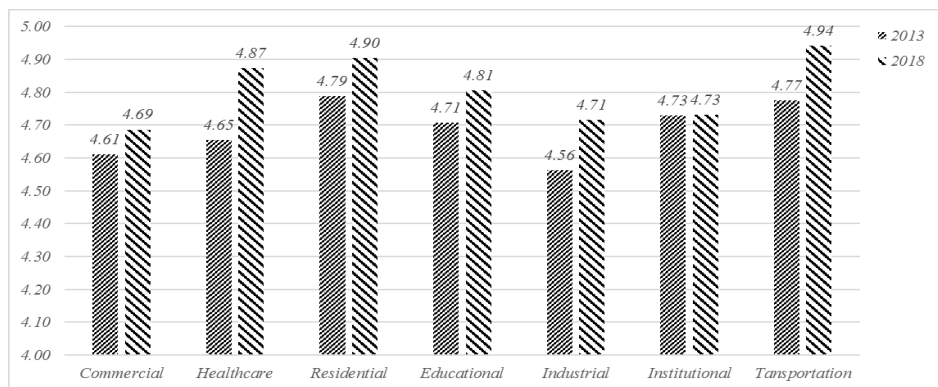


Figure 2: Change of overall BIMM by project types in 2013 and 2018

Figure 3 shows the change of BIMM level by project delivery methods including design bid build (DBB), construction management (CM), design build (DB) and integrated project delivery (IPD). Because a participant could be involved in more than one project delivery method, the same weight average method presented previously was used to analyze data. The BIMM level of projects with integrated project delivery had increased the most and was the highest in 2018. This finding is theoretically supported by that “the full potential benefits of both IPD and BIM are achieved only when they are used together” (Guide, 2007). The figure also shows that the more collaborative the delivery method is, the more mature the BIM becomes. This finding agrees with the conclusion of other independent studies that a collaborative process can maximize the benefits of BIM (Ashcraft, 2008, Succar, 2009).

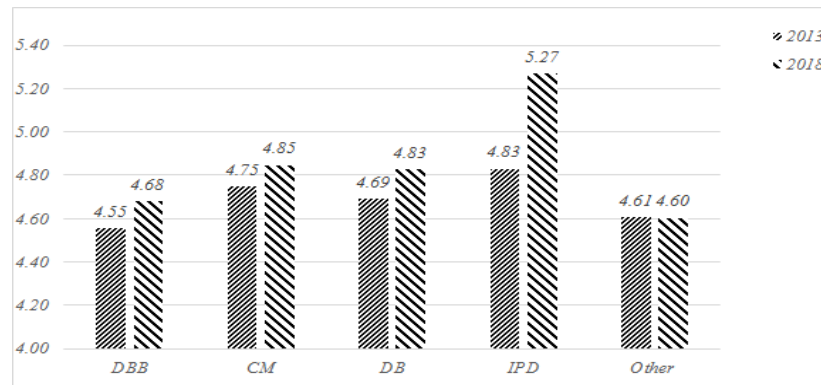


Figure 3: Change of overall BIMM by project delivery methods in 2013 and 2018

The BIMM model consists of four dimensions, which are technology, information, process, and people. The analysis of BIMM in different dimensions can provide researchers with an accurate view of BIMM level in each dimension. Figure 4 shows the change of the BIMM level of the technology dimension. Technology dimension includes four indicators. The maturity levels of software applications and hardware equipment had increased dramatically in past five years because of the development of smarter software design and more advanced hardware. However, the maturity levels of interoperability and hardware upgrade had decreased from 2013 to 2018. This finding is interesting. Probably because compared with the dramatic development of software application and hardware equipment, there is comparatively limited progress of interoperability and hardware upgrades. This is consistent with other research findings that exchange data with different platforms (Kieran et al., 2014) and hardware upgrade cost (Ryan and Derek Pierre, 2014) are main barriers for BIM implementation.

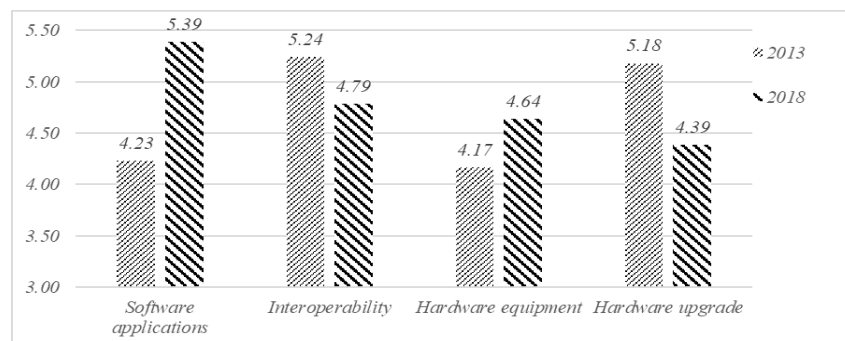


Figure 4: Change of BIMM indicators of technology dimension in 2013 and 2018

Figure 5 indicates the BIMM level of the information dimension consisting of information delivery method, information assurance, data richness, real-time data, information accuracy, graphics and geospatial capability. The maturity level of graphics had increased the most from 3.37 to 5.18, as virtual models has been widely used to present design information (Liu et al., 2017). However, information delivery method, information assurance, and information accuracy had decreased slightly probably because of the difficulty in transforming building data into BIM objects has not been fully solved (Volk et al., 2014).

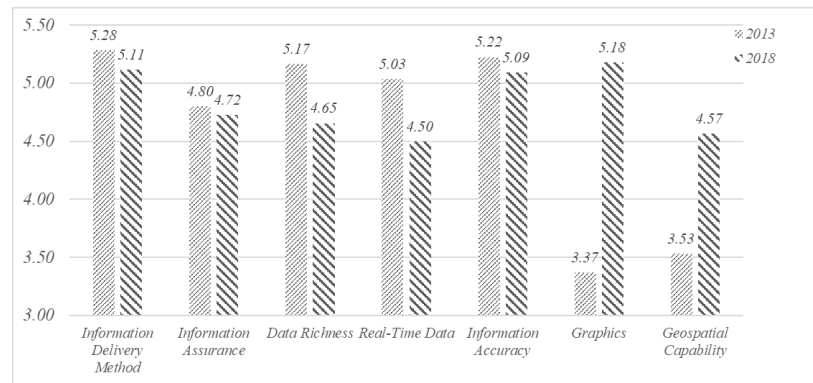


Figure 5: Change of BIMM indicators of information dimension in 2013 and 2018

Figure 6 shows the BIMM level of the people dimension, which is composed of strategic planning, role, senior leadership, competency profile, training program, training delivery method and reward system. It can be seen that all BIMM indicators of the people dimension had experienced a drop, except for the reward system. One potential reason is that implementing BIM alone is not effectively enough to achieve cross-company collaboration (Dossick et al., 2009).

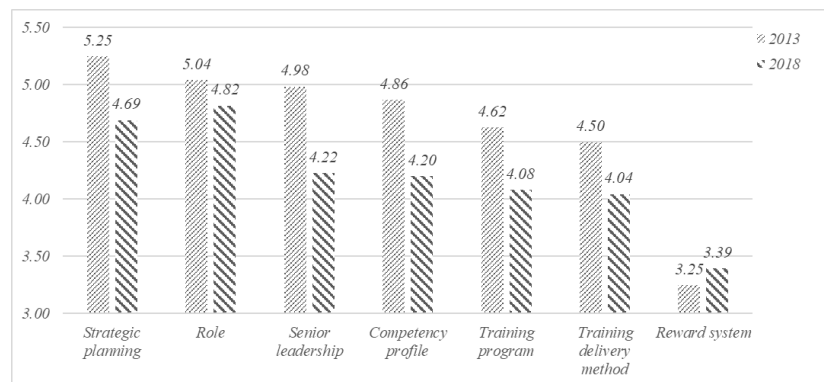


Figure 6: Change of BIMM indicators of people dimension in 2013 and 2018

The BIMM level of indicators of the process dimension is listed in Figure 7. The process dimension includes nine indicators. The BIMM levels of specification, standard operation procedure, change management, risk management and lifecycle process had decreased from 2013 to 2018, which can be likely explained by that interoperability in BIM is low and it cannot support lifecycle design (Arayici et al., 2018). The BIMM levels of other indicators (i.e., document model standards, quality control, process and technology innovation, work flow) had remained a similar maturity level.

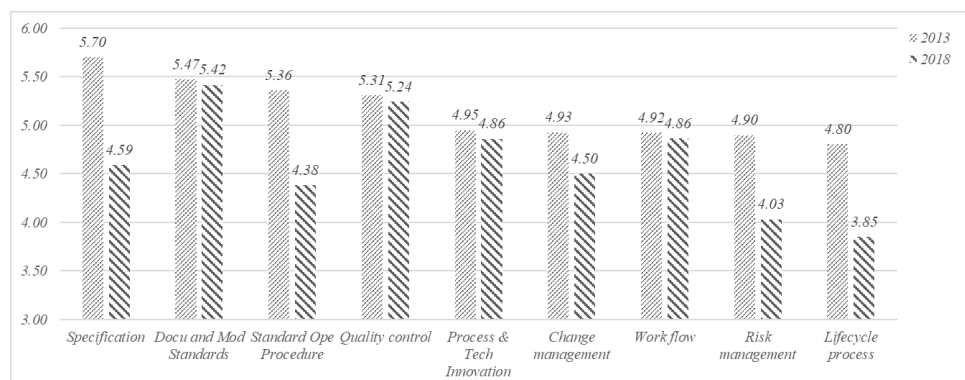


Figure 7: Change of BIMM indicators of process dimension in 2013 and 2018

Figure 8 shows the overall change of BIMM of all the four dimensions. The order of the dimensions based on their maturity levels has changed from process (5.15), technology (4.70), people (4.64), and information (4.63) in 2013, to information (4.83), technology (4.80), process (4.64), and people (4.21). Especially, the information dimension has dramatically changed from the least mature dimension in 2013 to the most mature one in 2018. Looks like the focus of BIM implementation in the industry has shifted to information, which is in consistency with other research findings (Husin and Rafi, 2013; Smith and Tardif, 2009). Moreover, the BIMM levels of technology and information dimensions both increased, while the BIMM levels in both people and process dimensions decreased. One potential explanation is that more emphasis may be placed on technology and information, since BIM is perceived more as a technology than a process (Ashcraft, 2008). In addition, the current business process and structure are in collision with the requirement for BIM implementation (Ashcraft, 2008; Kiviniemi, 2011; Rekola et al., 2010). Specifically, extensive communication and collaboration are required (Ashcraft, 2008), with information being the center of BIM (Chen et al., 2016; Smith and Tardif, 2009). However, there has been an old adversarial relationship among project stakeholders in the AEC industry, with the inherent conflict of interest based on the dictation of distinct roles and responsibilities (Ashcraft, 2008; Larson, 1997).

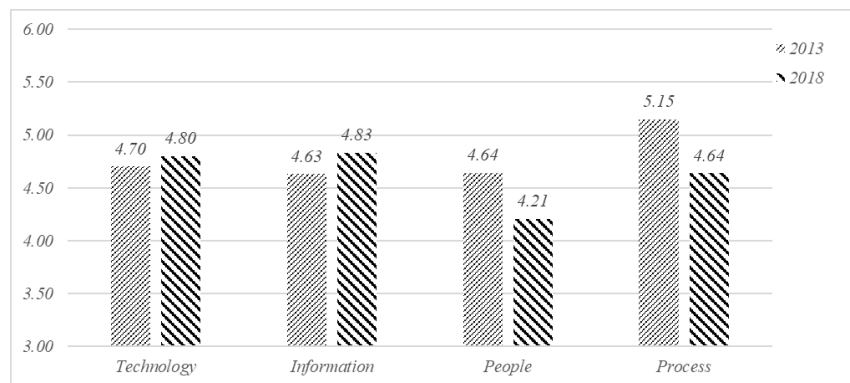


Figure 8: Change of four BIMM dimensions in 2013 and 2018

4. Discussion

The overall BIMM level had increased from 4.68 in 2013 to 4.88 in 2018. Therefore the BIMM is considered somewhat mature for the past five years. Among all the 27 BIMM indicators, the BIMM of five indicators had increased during the past five years, which are graphics, software applications, geospatial capability hardware equipment and reward system. The BIMM of graphics had significantly increased from 3.37 to 5.18 because BIM was used as virtual model to present design information. The BIMM of five indicators had remained almost the same, which are documentation and model standards, work flow, quality control, information assurance, process and technology innovation. The BIMM of the remaining 17 indicators had experienced a drop in the past five years. Specifically, the BIMM of standard operation procedure and lifecycle process had decreased dramatically due to the limitation of interoperability and the data loss caused by that limitation. The BIMM of the information dimension was the least mature dimension in 2013 and then reached the most mature dimension in 2018. The BIMM of the technology dimension remained the second. And the BIMM of both the people dimension and the process dimension had dropped in past five years.

From this study, it can be found that the cost of BIM implementation is still a major concern for contractors and the incompatibility of BIM has limited its wider adoption. Therefore, more focus should be placed on how to further reduce the cost of BIM implementation and increase the interoperability of BIM to make the data transition process smoothly. Additionally, in contrast with the increased maturity of the technology and information dimensions, both the people and process dimensions decreased. The improvement of current business process and structure may be the main

challenges to maximize the benefit of BIM.

Although this research was well organized, some limitations are inevitable. First, the overall sample size and the sample size of each subgroup are different between 2013 and 2018, therefore future work will increase the number of participants. Second, the majority of the participants were based in the USA, which may cause a bias for the research findings. Future studies will include more non-USA practitioners to explore the chronicle change of BIMM in the non-USA countries.

5. Conclusions

BIM has been widely adopted in the AEC industry since its inception in 1970s. Evaluation of BIMM is of great importance because it can shed light for BIM development in the future. However, few studies have focused on the change of BIMM across years. This research is then conducted to address this gap by designing a questionnaire, collecting data in 2013 and 2018, and analyzing data to evaluate the industry-wide BIMM change. The analysis shows that the average BIMM had increased in the past five years, indicating BIM-assisted projects are more mature now than 2013. Then, to get a more specific view of how BIMM level changed horizontally, the data was analyzed through different categories. It shows that the implementation of BIM is higher in complex projects such as healthcare, transportation, industrial projects in the past five year. The change of the maturity level of each BIMM indicator is also analyzed, and it is found that five of them increased; five of them remained almost the same; six of them decreased slightly; and 11 of them decreased significantly. For the four BIMM dimensions, process, technology, people, information ranked from the highest maturity level to the lowest in 2013, while the information dimension became the highest in 2018, then was followed by the technology, the process and the people dimensions. The potential explanations are that more emphases may have be placed on the technologies and information dimensions, while the current business process and structure are in collision with the requirement for BIM implementation. These findings shed lights for researchers to study how to further improve BIMM in the future.

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