An Assessment of BIM-CAREM Against the Selected BIM Capability Assessment Models

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Abstract

Although various BIM capability and maturity models have been developed to meet different BIM capability/maturity assessment purposes, there has not been a model which is broadly used and commonly accepeted in the literature. A Reference Model for BIM Capability Assessment (BIM-CAREM) was developed based on the meta-model of ISO/IEC 33000 to be used for assessing BIM capability levels of AEC/FM processes. This paper aims to compare the components of BIM-CAREM with the assessment questions of the identified models from the literature. Moreover, data collected from a previously performed case study was used to carry out self-assessments by using these models. Then, these assessment results were compared with the findings gathered from assessments performed with BIM-CAREM. The comparison indicated that, BIM-CAREM has more detailed and specified questions for assessing BIM capability of different AEC/FM processes and has comparable assessment results to that of identified capability models.

Keywords

Building information modeling • BIM capability assessment • BIM maturity

46.1 Introduction

Since use of BIM is mandatory in various countries such as North America, Finland and UK [1], adoption of BIM is increasing among AEC/FM organizations. In order to help organizations to adopt BIM seamlessly, several resources such as BIM guidelines have been published by governmental organizations of various countries. The two important and well-known example of these standards are, BS/PAS 1192 series of standards [2] which are published by The British Standards Institution and the National BIM Standard [3] which is published by buildingSMART. On the other hand, even after the BIM adoption, organizations need to measure their BIM performances to use BIM more efficiently. Thus, various BIM capability and maturity assessment models are developed for achieving different BIM assessment purposes. Among these, we have identified six BIM capability and maturity models by conducting a systematic literature review [4]. Later, we extended this review by including two recent models. Eight prominent BIM assessment models, which are NBIMS BIM Capability Maturity Model (NBIMS BIM CMM) [5], BIM Proficiency Matrix (BIM PM) [6], BIM Maturity Matrix (BIM MM) [7], BIM QuickScan [8, 9], Virtual Design and Construction Scorecard (VDC Scorecard) [10, 11], Organizational BIM Assessment Profile (Organizational BIM AP) [12], VICO BIM Scorecard [13], and Multifunctional BIM Maturity Matrix (Multifunctional BIM MM) [14], are analyzed based on several criteria [15]. It is identified that there is not a holistic model

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which enables BIM capability assessments of all AEC/FM processes [15]. Moreover, there is not a widely used and commonly accepted model which is developed based on established standards [15, 16]. In order to address this demand, a reference model for BIM capability assessments (BIM-CAREM) is created [15]. It is developed based on the meta-model of ISO/IEC 33000 [17, 18], and for assessing BIM capabilities of AEC/FM processes rather than capability or maturity of organizations and projects. The details about the structure of BIM-CAREM and its application areas can be found in the PhD dissertation of Yilmaz [15]. This paper aims to compare the structure and the components of BIM-CAREM with the structure of other two models which are BIM QuickScan and Organization BIM Assessment Profile. We investigated components and questions of each model in detail, and mapped the questions of each model to the elements of BIM-CAREM. Additionally, we performed self-assessments with these models by using the data collected from a previously performed case study. Later, we compared these assessment results with the findings gathered from assessments performed with BIM-CAREM. The methods used for the comparison and the self-assessment results are explained in Sects. 46.2 and 46.3, respectively.

46.2 BIM Capability and Maturity Assessment Models

46.2.1 Bim-Carem

BIM-CAREM was developed based on the meta-model of ISO/IEC 33000 [17, 18] and its applicability, generality, and coverage was tested by conducting case studies in four different AEC/FM firms [15]. It is composed of two major parts, namely BIM Measurement Framework (MF) and BIM Process Reference Model (PRM) as presented in Fig. 46.1.

BIM PRM comprises definitions of twenty-eight AEC/FM processes which are included in four different facility life cycle stages, namely conceptual planning, design (architectural, structural, and building services), construction, and facility management. Each AEC/FM process in BIM PRM is defined in terms of process purpose and BIM outcomes and the definitions of these processes are also included [15]. BIM MF is composed of BIM capability levels and their associated BIM attributes. As presented in Fig. 46.2, BIM MF has 4 levels of BIM capability. Level 1-Performed, Level 2-Integrated, and Level 3-Optimized have a total of 6 BIM attributes which are Performing BIM, BIM Skills, BIM Collaboration, Interoperability, Corporate-wide BIM Deployment, and Continuous BIM Improvement. Each BIM attribute has three components namely, BIM outcomes/BIM attribute outcomes (BO/BAO), generic BIM work products (G BIM WP) and generic resources (GR). BIM outcomes/BIM attribute outcomes are observable results of a BIM attribute achievement.

Users and assessors can use BIM-CAREM for conducting a formal appraisal to determine the BIM capability level of a selected AEC/FM process such as an architectural design process. In order to give ratings for each BIM attribute, assessors are required to investigate if the BIM outcomes/BIM attributes outcomes are achieved. Hence, generic BIM work products and generic resources are observed for understanding the achievement level of a BIM outcome/BIM attribute outcome.

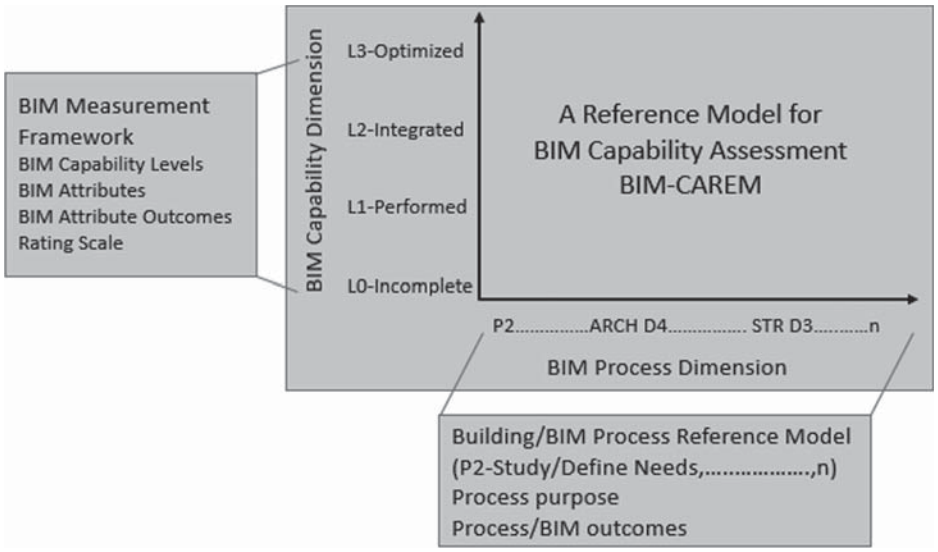

Fig. 46.1 Parts of BIM-CAREM [15]

Fig. 46.2 Components of BIM-CAREM

Grades of the associated BIM attributes are given according to these observations. Based on the assessment results, BIM improvement paths can be created for using BIM more effectively in the assessed processes. Thus, BIM-CAREM achieves to meet the different BIM assessment purposes of users by allowing process specific BIM capability assessments [15].

46.2.2 Assessment Models Used in the Comparison

We selected two of the eight models from literature, which are BIM QuickScan [9] and Organizational BIM AP [12], to include within the context of this comparison study. The extend of capability of the model and the availability of open source guidelines and tools were the criteria for including the models in this study. According to the first criteria, we selected the models which have more generic assessment purposes, hence we eliminated the BIM Proficiency Matrix [6] which is developed for assessing BIM performances of organizations for selecting designers or contractors in campus building projects. Moreover, models which are not very primitive, and have adequate number of metrics and two or more classification layers are included in the comparison. Only NBIM BIM CMM is eliminated based on the second criteria. The remaining models are presented in Table 46.1 with their number of classification layers and example metrics. Lastly, we looked at the availability of open source guidelines and tools for performing self-assessments. Except from BIM QuickScan and Organizational BIM AP, six models do not have open guidelines and tools, or the free versions of the tools contain limited contents. As a result, BIM QuickScan and Organizational BIM AP were included in this study.

BIM QuickScan provides insight about BIM strengths and weaknesses of the organizations [8]. It has a web-based online questionnaire which is composed of multiple choice questions. Free self-assessments can be performed by using this tool. It includes 44 questions in total. These questions are grouped under four categories which are Organization and Management, Mentality and Culture (People), Information Structure and Information Flow, and Technology and Applications. Total score

Table 46.1 Classification layers and example parameters of the models (which are found to be more elaborate)

Models	No. of classification layers	Example metrics
BIM MM	2 layers	Software, benchmarks/controls, activities/workflows
BIM QuickScan	2 layers	Vision and strategy of the company, BIM roles, linked BIM to geo-information
VDC scorecard	3 layers	Stakeholder formalization, VDC guidelines, data sharing, VDC training frequency
Organizational BIM AP	2 layers	Organizational mission and goals, facility data, software, education
VICO BIM scorecard	2 layers	Resource planning and cash flow analysis, 5D cost estimation, documented scheduling methodology, 3D coordination
Multifunctional BIM MM	2 layers	Software, BIM elements, spatial & coordination, clash analysis process

is the weighted sum of points for all categories. Resulting BIM level provides insight about BIM strengths and weaknesses of the construction organization [8, 9].

Organizational BIM AP can be used to evaluate the organization's BIM maturity focusing on six BIM planning elements which are Strategy, BIM Uses, Process, Information, Infrastructure and Personnel. These elements have 20 sub elements in total, and each sub element has six subsequent definitions which have been created based on the six maturity levels from 0 to 5. These six levels are; nonexistent, initial, managed, defined, quantitatively managed, and optimizing. For example, maturity level 0 for BIM project use is defined as no BIM uses for projects and maturity level 5 is defined as open sharing of BIM data across all project phases. Assessors can rate the elements by looking at these definitions and choosing the most appropriate ones. Organizational BIM AP has an excel-based tool which can be used for conducting self-assessments and also includes a user guideline [12].

46.2.3 Comparison of the Models

In order to perform the comparison, the assessment questions of the two models, i.e. QuickScan and Organizational BIM AP, were collected in separate excel sheets. Later, we compared the questions of these models with the questions of BIM-CAREM. For this, each question of BIM QuickScan was examined in detail and was mapped to corresponding (one or more) question/s of BIM-CAREM. If a question exists in BIM-CAREM and but not exist in BIM QuickScan, we marked that question of BIM QuickScan as not available. The same procedure was applied for the questions of Organizational BIM AP. The BIM-CAREM has 166 components whereas BIM QuickScan and Organizational BIM AP have 44 and 20 questions/elements in total, respectively. Table 46.2 presents the number of BIM-CAREM's measures within their respected categories and the number of these measures covered by BIM QuickScan and Organizational BIM AP. 0s presented as bold in Table 46.2 are metrics which exist in BIM-CAREM but do not in the two of the models.

Based on the same analysis, Fig. 46.3a shows the percentages of the BIM-CAREM's measures included in BIM QuickScan. For instance, 27% of Performing BIM measures and 40% of BIM Collaboration measures are included in BIM QuickScan. The metrics belonging to Interoperability are not defined in BIM QuickScan. Similarly, Fig. 46.3b shows the percentages of the BIM-CAREM's measures included in Organizational BIM AP. For example, only 6% of Performing BIM measures and 25% of Continuous BIM Improvement measures are covered by Organizational BIM AP. Furthermore, Organizational BIM AP does not have any measures related to Interoperability.

Figure 46.4 depicts the percentage of BIM QuickScan questions which are covered by metrics of BIM-CAREM. All of the questions of the Technology and Applications are included in BIM-CAREM. BIM-CAREM has 64, 50, and 75% of BIM QuickScan's questions defined under the categories of Organization and Management, Mentality and Culture (People), and Information Structure and Information Flow, respectively. Although BIM-CAREM does not include 13 questions of BIM QuickScan in total, derivatives of these questions are defined in the context of BIM-CAREM. For example, although short and long term objectives of BIM across the organization are not included in our model, BIM-CAREM has questions related to BIM goals as part of the development of BIM Execution Plan (BEP). Quality checks of the model and data, which is a question of Organization and Management, is not included in BIM-CAREM. Instead of the model and data quality, there are questions asking how organizations are performing quality assurance of a facility during the construction. BIM-CAREM does not examine the benefits of using BIM, since we thought that measured BIM capability levels can indicate whether BIM produces sufficient results or not. BIM-CAREM does not include questions related to the role of companies in terms of BIM uses. Instead, we conducted a literature review to identify different BIM uses, and included them as part of the process definitions.

In terms of Mentality and Culture, although BIM-CAREM has measures to assess the availability of BIM skilled employees within the company and if these employees are assigned to BIM related processes, it does not include questions related to existence of BIM champions. Questions related to the disadvantages and advantages of BIM are not included in BIM-CAREM. Although object libraries and facility data benchmarks are defined within the context of the BIM-CAREM, usage of object catalogue is not asked as a question which is defined under the categories of Information Structure and Information Flow of BIM QuickScan. We assess if the organizations use the model for several tasks such as costing, planning and design, but BIM-CAREM do not focus on re-usability of the model for performing these tasks.

Figure 46.5 depicts the percentage of Organizational BIM AP questions which are covered by the metrics of BIM-CAREM. All of the questions of the three categories, namely BIM Uses, Process, and Personnel, are covered with the questions of BIM-CAREM. BIM-CAREM has 40, 67, and 67% of the questions of Strategy, Information, and Infrastructure

Table 46.2 Components of BIM-CAREM included in BIM QuickScan and Org BIM AP

Components of BIM-CAREM	No. of components	No. of components covered	
		By BIM QuickScan	By Org BIM AP
BIM attribute performing BIM (Total)	*108*	*29*	*6*
BIM outcomes of conceptual planning	6	2	**0**
BIM outcomes of architectural design	19	5	2
BIM outcomes of structural design	9	1	**0**
BIM outcomes of building services design	10	**0**	**0**
BIM outcomes of construction	17	7	**0**
BIM outcomes of facility management	14	2	**0**
Generic BIM work products	9	**0**	**0**
Generic resources	24	12	4
BIM attribute BIM skills (Total)	*12*	*3*	*3*
BIM attribute outcomes	3	3	2
Generic BIM work products	5	**0**	1
Generic resources	4	**0**	**0**
BIM attribute BIM collaboration (Total)	*15*	*6*	*3*
BIM attribute outcomes	4	4	1
Generic BIM work products	6	1	1
Generic resources	5	2	1
BIM attribute interoperability (Total)	*6*	*1*	*0*
BIM attribute outcomes	1	1	**0**
Generic BIM work products	2	**0**	**0**
Generic resources	3	**0**	**0**
BIM attribute corporate-wide BIM deployment (Total)	*17*	*7*	*2*
BIM attribute outcomes	4	4	**0**
Generic BIM work products	6	1	1
Generic resources	7	2	1
BIM attribute continuous BIM improvement (Total)	*8*	*2*	*2*
BIM attribute outcomes	3	1	1
Generic BIM work products	2	**0**	**0**
Generic resources	3	1	1

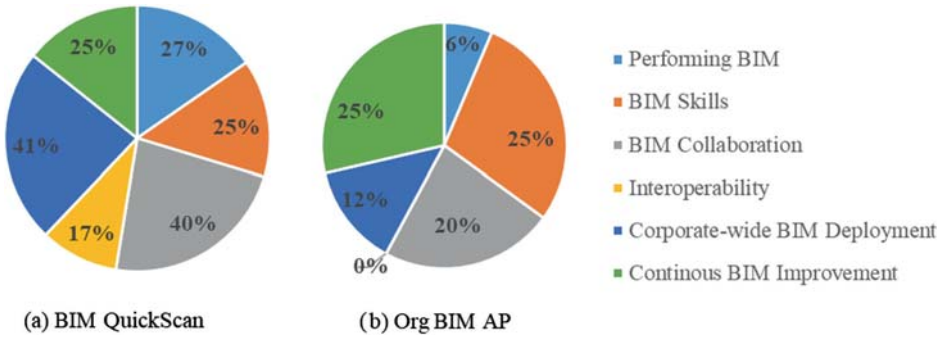

Fig. 46.3 Percentage of BIM attributes included in **a** BIM QuickScan and **b** Org. BIM AP

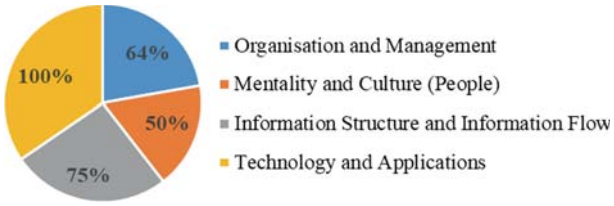

Fig. 46.4 Percentage of BIM QuickScan questions included in BIM-CAREM

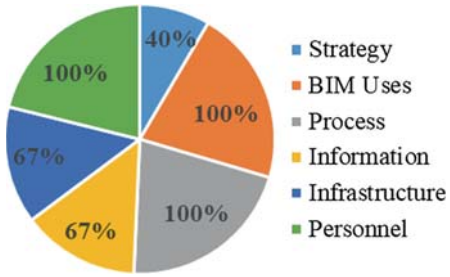

Fig. 46.5 Percentage of Organizational BIM AP questions included in BIM-CAREM

categories, respectively. BIM-CAREM does not include five questions of Organizational BIM AP, in total. Although BIM-CAREM includes questions related to BIM mission and BIM vision as part of required sections of BEP, defining organization-wide BIM missions and BIM visions are not included in the set of questions of BIM-CAREM. As mentioned previously, a question directly related to the existence of a BIM champion within the organization is not included in BIM-CAREM, which is a question of Organizational BIM AP too.

During the assessment of Corporate-wide BIM Deployment, which is a BIM attribute of BIM Capability Level 3-Optimized, we asked if model view definitions are used and if different views of the models are available. But, model element breakdown, which is defined as the identifiers assigned to each physical or functional element, is not included as a component of BIM-CAREM. Although, hardware adequacy of organizations for storing and sharing models are evaluated in our model, questions related to the existence of physical spaces are not included, which is defined in Organizational BIM AP as functional areas within a facility that are used to properly implement BIM.

There is not one to one relationship between the metrics of BIM-CAREM and the questions of evaluated models. For example, one question of BIM QuickScan has to be matched to several metrics of BIM-CAREM and vice versa. Furthermore, some categories cannot be mapped to each other. For example, BIM outcomes of Performing BIM in BIM-CAREM are mapped to the questions of Organization and Management, Information Structure and Information Flow, and Technology and Applications of BIM QuickScan. In other words, questions of BIM QuickScan are defined more generically than the metrics of BIM-CAREM. This was an expected result since BIM-CAREM has 166 questions while BIM QuickScan has 44. Organizational BIM AP is as comprehensive as BIM-CAREM too. For example, interoperability in BIM-CAREM, which is used to measure if interoperable formats are preferred for storing and sharing facility data, is not included by Organizational BIM AP as depicted in Fig. 46.3b. Additionally, metrics of BIM Collaboration are mapped to the elements in four areas of Organizational BIM AP, namely Strategy, BIM Uses, Processes, and Information. As presented in Table 46.2, 108 different metrics are defined for facility life cycle phases under Performing BIM which means that BIM-CAREM allows process specific assessments. Stakeholders from different organizations such as designers and general contractors can use BIM-CAREM for assessing their specific BIM tasks.

46.3 Evaluation Using Case Study Data

In order to test the generality and coverage of BIM-CAREM, we performed multiple case studies with four different AEC/FM companies [15]. Within this study, we used the case study data collected from one of those companies for performing self-assessments with the two selected BIM assessment models, namely BIM QuickScan and Organizational BIM AP. The selected company works on structural design and detailing of various facility types such as buildings, airports, sports facilities, and industrial plants. It is located in Ankara, Turkey and has less than 50 employees including civil

Table 46.3 Assessment results by using BIM-CAREM

Categories	BIM capability	
	Structural design of steel frames	Structural design of RC frames
Performing BIM	4/4	4/4
BIM skills	4/4	4/4
BIM collaboration	3/4	3/4
Interoperability	4/4	4/4
Corporate-wide BIM deployment	3/4	2/4
Continuous BIM improvement	2/4	2/4

engineers and technicians. During the case study, primary data has been collected through semi-structured interviews by asking the predefined interview questions. The secondary data has been gathered by observations of BIM artifacts (such as models) and BIM resources (such as BIM tools). Primary data was recorded in an excel sheet and secondary data was collected in a checklist. Based on these two data resources, a case study report has been written [15].

Ratings of the BIM attributes are given based on this case study report. We used the four-point ordinal scale which are Not Achieved (N–1 point), Partially Achieved (P–2 point), Largely Achieved (L–3 points), Fully Achieved (F–4 points) and Not Available (N/A). In order to achieve a BIM capability level, all of the BIM attributes should be rated as F or L. Ratings given for each of the BIM attributes are presented in Table 46.3. As the company is using BIM for performing their design processes and they have employees who have BIM skills, Performing BIM and BIM Skills attributes are rated as 4. They also use BIM for collaborating especially within the company. If their contractors want them to use BIM for collaboration, they also use BIM for external collaboration. They use IFC file formats for exchanging models. Based on these findings they received scores of 3 and 4 for BIM Collaboration and Interoperability, respectively. They facilitate digital fabrication from models for steel frames but not for reinforced concrete structures. Thus, while Corporate-wide BIM Deployment for steel frames was rated as 3, it was rated as 2 for concrete frames. They handle BIM problems with ad-hoc solutions. In other words, they do not have any strategies for identifying BIM related problems and for improving BIM usage. Thus, Continuous BIM Improvement was rated as 2. The structural design process for both steel and concrete frames were found at "BIM Capability Level 2-Integrated BIM", since they received "P-2 points" for Continuous BIM Improvement.

The case study report of the company provided basis for performing self-assessments by using BIM QuickScan and Organizational BIM AP. We answered the multiple choice questions of the BIM QuickScan through the online questionnaire. Similarly, the excel-based assessment tool of Organizational BIM AP was used to assess the BIM capability of the selected company. Even though direct answers of 13 questions of BIM QuickScan do not exist in the assessment report of BIM-CAREM, we were able to answer these questions by looking at the details of the case study report and the secondary data. Likewise, although 5 questions such as organizational missions and goals have not been asked directly, the relevant information from the secondary data was used. BIM performance levels of the company with respect to each area of BIM QuickScan and Organizational BIM AP are given in Tables 46.4 and 46.5, respectively.

Table 46.4 Results by using BIM quickscan and the case study data

Category	BIM performance	
Organization and management	2.71/4	67.85%
Mentality and culture (people)	2.4/4	59.96%
Information structure and information flow	3.05/5	60.9%
Technology and applications	1.87/4	46.67%

Table 46.5 Results by using Organizational BIM AP and the case study data

Category	BIM maturity levels	
Strategy	8/25	32%
BIM uses	4/10	40%
Process	3/10	30%
Information	4/15	27%
Infrastructure	8/15	53%
Personnel	10/25	40%

BIM QuickScan produces performance levels with respect to each area at the end of the self-assessment. As presented in Table 46.4, the company received ratings of 2.71, 2.4, 3.05, and 1.87 out of 4 points for Organization and Management, Mentality and Culture, Information Structure and Information Flow, and Technology and Applications, respectively.

Some of the questions of BIM QuickScan are not clear; hence, it was difficult for us to understand and answer these questions. For example, there is a question asking if the company works based on a specific structure. However, what is meant by the structure is not explained; hence, it was not possible for us to answer this question. Moreover, some of the questions are not in the scope of designers' tasks but it is not allowed to mark a question as not applicable. This creates conflicts since some of the questions are not clear and some of them are not applicable to all AEC/FM companies. For instance, there is a question to evaluate if the company linked BIM to geographical information systems. Although we know that the company has not done this in our case, this question is not applicable to a structural design company. Hence, it should have been possible to leave this question out of the BIM performance calculation. Available answer options for some of the questions of BIM QuickScan neither match the question nor self-explanatory. For example, one of the questions about measuring the employee motivation of companies has two answers as (A) No and (B) Yes, on average, always. Choice B is contradictory since it contains both of the words "on average" and "always". Some of the questions were hard to answer due to the nature of the Turkish AEC/FM industry. For example, BIM QuickScan includes a question asking whether companies have specific kind of contracts with their partners. This structural design company cannot prefer a specific kind of contract, since as a designer company they have to fulfill the request of general contractors.

Organizational BIM AP produces one final BIM maturity score for the company as well as scores for each area in terms of points and percentages. The BIM maturity score of the company is 37 points out of 100 which is equal to the sum of the scores of all BIM planning areas. As presented in Table 46.5, the company received 8, 4, 3, 4, 8, and 10 points for Strategy, BIM Uses, Process, Information, Infrastructure, and Personnel, respectively.

Although some of the measures of Organizational BIM AP are only applicable to specific type of organizations, it is not allowed to leave these elements as null. Even though, we did not have the primary data to give a rating for some of the measures, we chose the answers that fit best with the secondary data available. For example, Operational Uses are not in the scope of a structural designer's tasks. However, we selected the best level of the element that fits the company which is defined as record (as-built) models received by operations. Some of the obtained results may contain conflicts, since elements of Organizational BIM AP are not customized with respect to the organization type. For some of the measures, terms used within the answers to define the levels of maturity are not self-explanatory. For example, high level, integrated, and defined are the consecutive definitions of maturity levels for BIM processes.

During the comparison of the models, it is identified that one category of BIM-CAREM contains questions/elements from multiple categories of the BIM QuickScan or Organizational BIM AP. Thus, in order to compare the resulting BIM performances, we needed to recalculate the results based on the mapping of these elements. We were only able to compare the score of the BIM Skills of BIM-CAREM and the score of the Personnel of the Organizational BIM AP directly (without doing any recalculation), since these two categories have one to one relationship. The scores of the BIM Skills and the Personnel are 4/4 (see Table 46.3) and 10/25 (see Table 46.5), respectively. The resultant rating of BIM Skills is higher than the rating found for Personnel of the Organizational BIM AP, since elements of the Personnel are more detailed than the BIM attribute outcomes of the BIM Skills. For example, BIM Skills does not contain questions which asks how frequently companies give trainings to their employees and how many employees are given trainings. Organizational BIM AP also contains separate elements for training and education in the Personnel category. Besides, it was hard to compare the score found via BIM-CAREM and score calculated through BIM QuickScan/Organizational BIM AP, since most of the categories and their sub elements do not have one to one relationship.

46.4 Conclusions

In this study, we compared the metrics of BIM-CAREM with the questions/elements of the selected models from the literature, namely BIM QuickScan and Organizational BIM AP. One of the major problems of both of these models is that some of the questions/elements are not in the scope of designers tasks, which was our case study organization. Additionally, it is not allowed to select those measures as not applicable in the context of self-assessments, although answering unrelated measures can create errors in the final assessment results. In other words, both of these models do not allow customized assessment based on the organization type. On the other hand, since BIM-CAREM includes definitions of AEC/FM processes in BIM PRM, it allows users to perform assessments specific to organization types based on the processes they are involved in. BIM-CAREM has more detailed and specified questions for assessing BIM capability of different AEC/FM

processes and has comparable assessment results to these capability models. Both of the evaluated models have self-assessment tools. BIM QuickScan has an online questionnaire and it is very easy to conduct a self-assessment. Organizational BIM AP has an excel-based tool and it is also easy to use. However, BIM-CAREM does not have a self-assessment tool. In order to eliminate this limitation, a web based assessment tool can be developed which may also allow collecting benchmark datasets with BIM-CAREM.

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