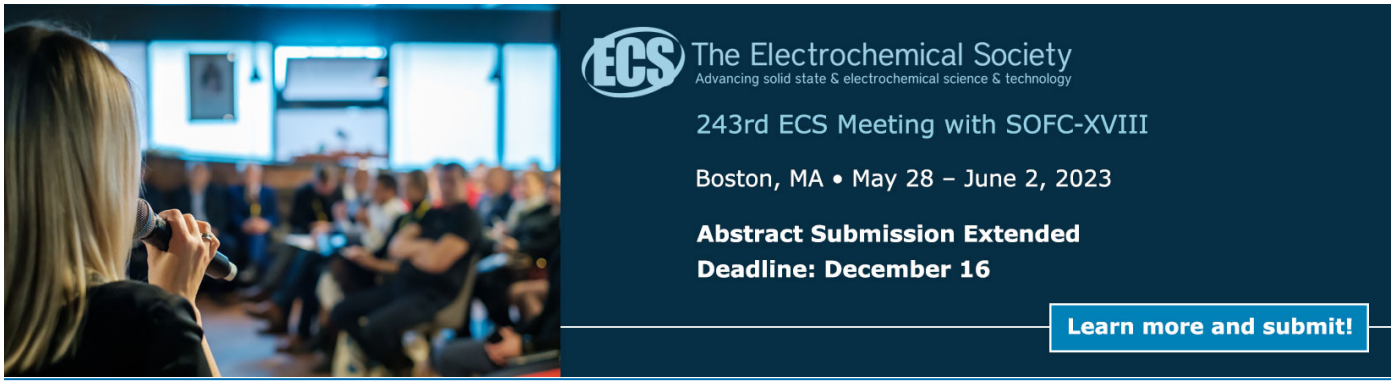
Assessment Strategies to Evaluate Building Information Modeling Capabilities of Organizations



Assessment Strategies to Evaluate Building Information Modeling Capabilities of Organizations

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Abstract. With the advances in technology, Building Information Modeling (BIM) has been implemented in construction projects to minimize its complexity by increasing project efficiency and effectiveness. While BIM has been widely implemented, construction projects are still unsuccessful due to inappropriate BIM capabilities among organizations that are involved in the project. Therefore, this study aims to determine the strategies for assessing an organization's BIM capabilities. The data collected through individual interviews with fifteen of BIM managers are analyzed using thematic analysis in order to achieve that objective. The findings suggest that the five parameters for evaluating an organization's BIM capabilities are: documentation process, project track record, staff competencies, availability of BIM experts, and software maturity. This study contributes by providing a set of strategies for measuring an organization's BIM capabilities in the construction industry. The lesson of this study would help researchers and industry practitioners prevent construction project failure from assessing project team members' BIM capabilities before starting a project.

1. Introduction

In addition to promoting social development by supplying essential infrastructure to nations, construction projects play a significant role in the development of a country's economy and status [1]. For example, the government and private sectors address the economic needs through the construction of commercial buildings and infrastructures [1]. However, construction projects often face challenges to achieve project success, including delays, polluted construction sites, dangerous and challenging site conditions, poor working standards, and injuries at construction sites [1]. These issues have negatively impacted the construction industry and indicate that there are shortcomings in the construction industry [2]. Also, improvement becomes a necessity as construction projects become more complex, thus requiring various skills and knowledge in different project areas and phases [3]. Therefore, the architecture, engineering, and construction (AEC) industries are always identifying ways to improve efficiency, effectiveness, productivity, and project quality while reducing project cost and delivery time [4].

Implementing Building Information Modeling (BIM) in construction projects is one of the approaches to address those common issues in the AEC industries [4]. BIM is developed as a tool for the effective management of construction projects [1]. In addition, BIM is an advanced 3D model-based

method for producing model data that is organized and computable that provide AEC practitioners the expertise and tools to plan, design, build, and operate construction buildings and facilities more efficiently. In other words, BIM is a revolutionary way of managing the preparation of construction projects [5]. Besides helping construction teams to plan and work more effectively, it also enables owners to data for operations and maintenance activities. Also, better project management and stakeholder engagement, effective workflows, 3D visualizations, and enhanced project performance are just some of the advantages of using BIM processes. These advantages of BIM provide architects, engineers, and contractors with an approach to address those common issues in construction projects through effective construction planning during the phase at pre-construction, construction, and post-construction [6].

BIM is becoming an essential approach to the construction industry that improves collaboration among the project team, such as architects, contractors, engineers, owners, suppliers, and subcontractors [4, 3]. In Malaysia, while BIM has gained interest from construction players, gaining project success, there are also projects with mixed results [7]. One of the possible reasons for the mixed results includes inappropriate BIM capabilities among the project team. Specifically, this lack of BIM capabilities includes not having the resources or experience to operate the BIM software as well as not understanding the BIM concept. In consequence, these factors hinder construction projects from realizing the potential benefits of BIM, or even project failure in some cases. Therefore, identifying approaches to ensure each project team is equipped with the necessary BIM capabilities is crucial to ensure the success of BIM-based construction projects.

The objective of this research is to determine the strategies when assessing an organization's BIM capabilities. To achieve that objective, the research question of this study relevant to: What are the parameters that can be used in evaluating the BIM capabilities of organizations? The authors conducted individual interviews with fifteen practitioners in Malaysia, working on construction projects in order to answer the question. After that, thematic analysis is used to analyze the data collected from the open-ended interviews. The output is a set of evaluation methods to evaluate an organization's BIM capability. Hence, the results from this study may help the industry to prevent construction project failure by assessing an organization's BIM capability for a project.

2. Background

2.1. BIM in Malaysia

Construction projects in Malaysia are starting to use BIM to improve project effectiveness and productivity. The idea of implementing BIM in Malaysia is introduced by the Director of the Public Works Department (PWD) in 2007. BIM's progress in Malaysia has been managed mainly by the private sector since 2009. In 2010, the government announced its first initiative to use BIM methods. There are several BIM definitions, and it can be defined in many ways. It is hypothesized that BIM is a software platform that can be used by stakeholders in the construction project environment for project planning, design, tracking, and monitoring to ensure project success [8]. However, the vast majority of AEC organizations are not involved in BIM because of the challenges and difficulties they encounter in the process of adopting BIM practice. The introduction of BIM involves the creation of robust platforms for exchanging information between different software applications, thus allowing for effective and clear communication and tracking processes between project participants and team members. For project participants and team members, an acceptable level of interoperability and standardization of work methods needs to be developed [8]. Implementation of such a program is always complicated, and the recent introduction of BIM does not enable organizations to rely on established principles and practices with their practice [9]. Thus, the solutions to move towards a more streamlined and better-used BIM are recommended to establish an assisted model for the application of BIM by taking into account the different levels of maturity of each organization.

2.2. BIM Capabilities of Organizations

Besides that, many companies have put a lot of effort into trying to implement BIM technologies, in fact, bringing real-practice exposure to their challenges. Hence, a practical approach for consistently reviewing the application of BIM technologies at the corporate level where it comprises four main models which is BIM perception, BIM adoption, BIM performance, and BIM capability maturity and these models are developed and integrated within the AEC sector from numerous different BIM systems and strategies [10]. Furthermore, many organizations have been implementing BIM software tools and modifying their current delivery systems to address changing market needs. Although, it is important to identify the BIM skills to be learned, applied to the job, and tested for performance enhancement purposes in order to enable individuals within these organizations to develop their BIM skills. On that account, multiple taxonomies and analytical frameworks are developed to explain how to process, identify, and integrate individual competencies into an inventory of seed competences. Competency objects are then fed into a proprietary information engine to produce versatile training methods, learning guides, and workflows for procedures [11].

An understanding and development of an organization's BIM capabilities are one of the barriers that have been faced for adopting BIM as well as the failure to identify essential BIM features is also one of the key obstacles to inadequate development and poor acceptance of BIM [12]. So, to explore the complexities of different BIM capabilities and to consider how these capabilities can be interpreted as a collection of interrelated elements through the implementation of the Interpretive Structure Modeling (ISM) technique [12]. In addition, the evaluation of BIM strengths and repeatability helps an organization or initiative in determining its current status and how it can be continually enhanced, and this analysis can be carried out using BIM competence models. Despite that, the model can assess the BIM condition, but not precisely the use of BIM. Similarly, it is possible to assess capacity at a specified time for defined factors in inter-organizational project teams with a variety of factors from different companies, but repeatability cannot be measured unless the company continues to deal with the same project teams. Thus, BIM Use Assessment (BUA) tool has been introduced as there are no methods to define the extent of the use of BIM applications in construction project planning and design phases [13].

2.3. Positioning this study

In summary, since there are many barriers to implementing BIM, various studies have been proposed or developed models or tools in order to encounter the barriers. From the previous study, it can conclude that many researchers have been developed as an approach to overcome the barrier factors of BIM implementation. However, several organizations have been successful in implementing BIM, but still having problems during the process of the construction project due to inappropriate BIM capabilities among organizations involved in the project. Therefore, this study will address the gap by determining the strategies on how to evaluate the BIM capabilities of organizations.

3. Methodology

The collection of data includes collecting qualitative data from individual interviews with industry professionals that worked on construction projects. The collected data are analyzed by using qualitative approaches, which is the thematic analysis. The following subsections discuss the methods used in collecting and analyzing the data. Figure 1 outlines the methodology used by this study in determining the strategies for evaluating the BIM capabilities of an organization.

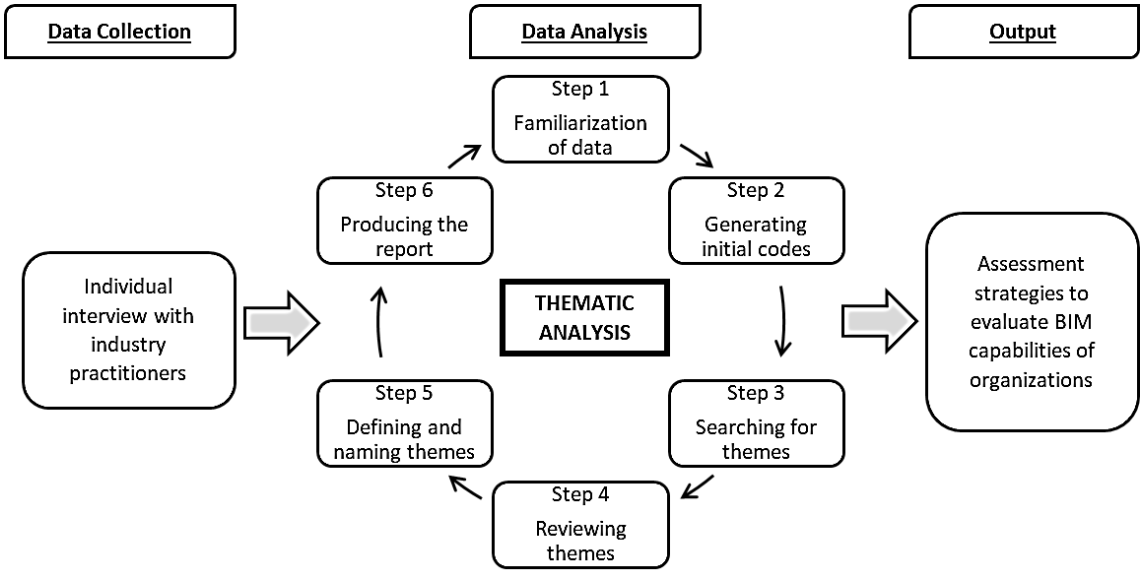

Figure 1. Summary of the methodology used in this study.

3.1. Data collection

This study gathers data through open-ended interviews with practitioners in the industry. Authors have chosen open-ended questions because it can encourage the interviewee to contribute as much detailed information as they wished [14]. Individual interviews are selected as the data collection approach because it helps the researcher to clarify, better understand, explore the respondents' opinions and experiences. Other studies also select open-ended interviews to identify parameters in construction projects, such as parameters to evaluate construction readiness of highway construction projects [15] and parameters to select change agents in adopting technologies in construction projects [16]. The individual from the industry practitioners is also consulted to discuss with the interviewee their unique perspectives, practical knowledge, and observations.

The target population of this study is professional organizations in construction companies holding a G7 license Construction Industry Development Board (CIDB). Thus, this research has purposefully selected G7-grade contractors, as these contractors are well-established organizations, and having a strong financial capacity is necessary for organizations to send employees to undergo BIM-related training, such as Revit Structural, Revit Architectural, and Navisworks [17].

The data collection involves interviewing fifteen valid respondents as that number work very well when the participants are homogenous [18]. The interview question is: What are the parameters that can be used in evaluating the BIM capabilities of organizations? The following question is asked about their opinions, also based on their experiences regarding the success factor and the challenges when assessing an organization's BIM capabilities. Then, after each interview session had ended, a summary of the interview is made and sent to the participants for validation purposes.

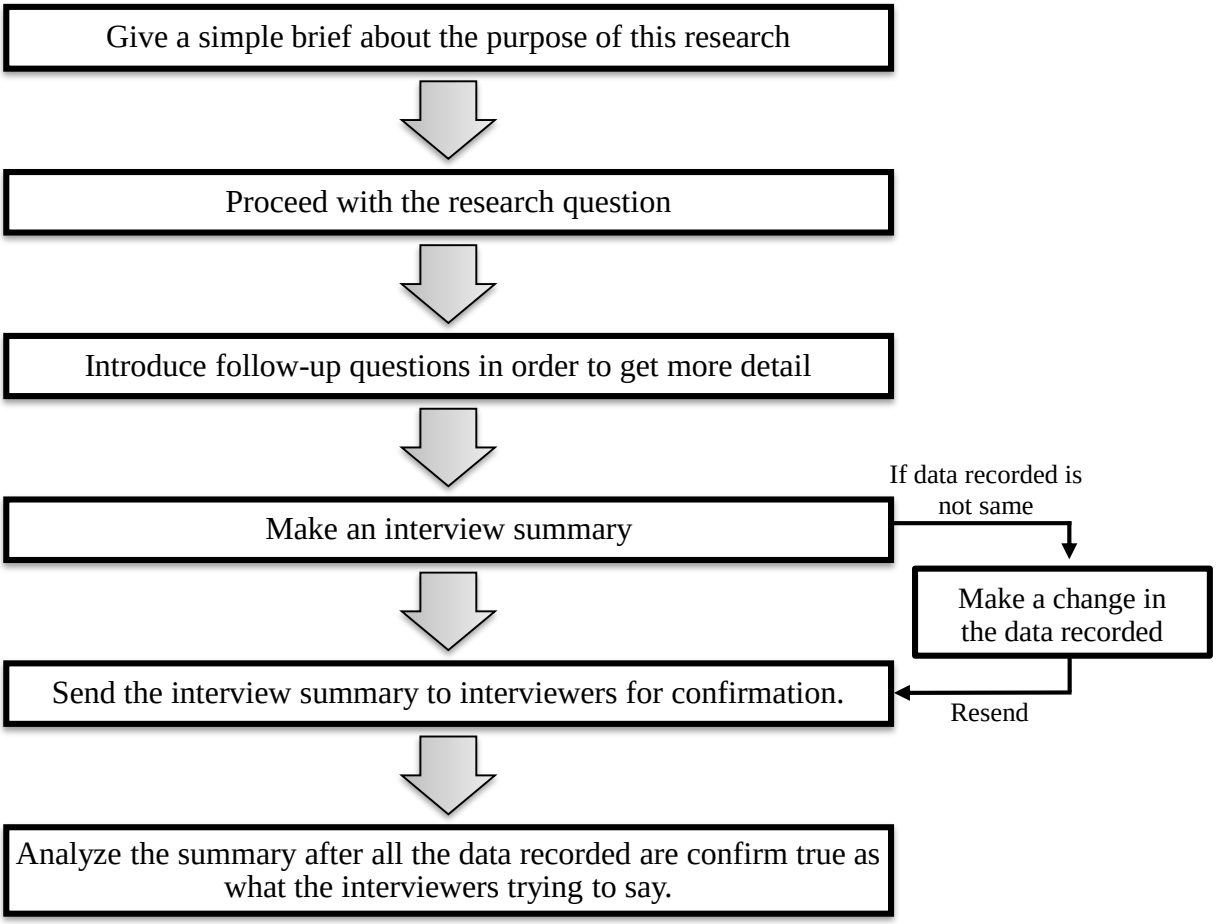

Figure 2. Flowchart for interview session.

3.2. Data analysis

This study is using thematic analysis to identify the assessment strategies to evaluate the BIM capabilities of an organization because thematic analysis has unique features that include its flexibility and its status as a technique that can be used in a wide range of qualitative research approaches [19]. This approach is also used to analyze other individual interviews, including data on success factors for design-build projects [20] and factors affecting highway construction projects [21]. The thematic analysis represents an iterative method of how to go from chaotic data to a diagram of the data's most important themes.

The thematic analysis is carried out based on six phases in their paper [22]. The first phase is the familiarization data. Analysis of the data is facilitated by in-depth knowledge and engagement of the data set. The authors read and re-read texts, listen to audio files, make notes of any original theoretical findings, thereby allowing the authors to push the study beyond the most apparent senses of emphasis. The second phase is generating initial codes. It is a systematic process for identifying and labeling data relevant to the research issue. Coding is the first step in the data pattern identification process because it combines similar data segments. Thus, in this process, the authors coded the data as many possible themes and trends, then checked and debated any coding improvements or adjustments, and approved. The third phase is searching for themes based on the initial codes. The themes are not in the data waiting for an intrepid researcher to discover them. Instead, the researcher clusters codes together to establish a logical representation of the main patterns in the results. Thus, the authors regularly checked codes from the second phase and initial first phase data during the thematic creation process.

Next, the fourth phase is reviewing the themes. The researcher pauses the theme development process to test whether respondent themes represent a strong 'match' with the coded data and the whole data set, each with a simple, distinct 'essence'-or core organizing principle. Reviewing can result in no or few adjustments or discard the respondent themes and restart the preceding process. Hence, the authors checked continuously, identified and optimized the subthemes to ensure consistency of the data, testing whether themes function regarding the coded excerpts and the whole data set, and updating data to look for another topic. The fifth phase is defining and naming the themes. Creating theme outlines that simply provide a brief summary of each theme and choosing a name for the theme guarantees logical clarity of each theme, which offers a road map for the final write-up. The authors walked back and forth regularly between the topics, codes, and transcriptions of the interview to ensure the themes remained accurate to the individually coded responses. The sixth phase, or the last phase, is producing the report. The researcher tied their conceptual framework and vibrant, convincing fragments of data together. Themes provide the analytical organizing framework, but analytical conclusions are drawn across the themes. In this final phase, the authors write the report of the output analysis.

4. Results and discussion

Figure 2 illustrates the parameter used in evaluating the BIM capabilities of organizations in Malaysia that are identified by analyzing the data from individual interviews with fifteen industry practitioners. In summary, the data can be classified into five categories, from a total of 50 parameters that have been identified in this study. These five categories are documentation process, project track record, staff competencies, availability of BIM experts, and software maturity. All of these categories can be grouped into three themes, which is the process, people, and technology. Details of each parameter will be discussed in the subsections that follow.

4.1. Process

4.1.1. Documentation Process

Based on the interview results, one of the parameters used to determine the strategies when assessing an organization's BIM capabilities is making sure that the documentation of the organization is enough information to demonstrate its professionalism. This is because the documentation process can reveal a company's story, which is its roots, purpose, and the path it requires to achieve its objectives. Other than that, having a proper documentation process is also important to keep a record of any issues and decisions in construction projects, especially BIM-based construction projects. Clients evaluate organizations by looking at the policy of the organization, which means by observing the organization reference document for BIM projects such as BIM guidelines and standards, work process manual and contractual, and what approach they used for the construction projects. This is because clients want to make sure either this organization can fit with the job that they want to distribute it, which resonates with prior findings that having proper BIM processes is crucial for successful BIM-based construction projects [23]. Thus, an excellent documentation process also becomes one of the best practices for the organization to show to the client that the organization is dedicated and committed to delivering the best tools to help them do their job efficiently. Therefore, documentation can become one of the parameters that can be used to evaluate the BIM capabilities of an organization.

4.1.2. Project Track Record

Looking at the previous project record also can assess the capabilities of an organization. From the past projects, clients can know how many numbers of projects are using BIM, and either the projects are successful or not. This is because clients want to know how well they are in operate and manage their projects. Clients also want to see the type of projects that are delivered by that organization. The type of project delivered will also influence the execution of the project, and from there, clients will know whether or not the organization has experience in managing the client's type of project. In addition, clients can also tell whether the organization is appropriate or not based on the project requirements that these customers want to execute. Thus, evaluating the BIM capabilities of an organization involves looking at the history of the existing and past projects.

4.2. People

4.2.1. Staff Competencies

One of the factors that lead to the successful performance of organizations is having staff with adequate competencies. Generally, the word "competencies" is characterized as a combination of attributes, behaviors, and skills that are directly related to successful job results. Therefore, clients want to evaluate the capability of team members involved in BIM projects. The competency of team members is assessed by looking at their technical knowledge or skills in terms of how they operate the BIM software. Besides that, clients are also observing job-relevant behaviors among the organization's staff, such as past performance in collaborating and communicating with the project team. This aligns with prior findings that while BIM involves adopting new technologies and processes, having non-technical skills, such as problem-solving, teamwork, and communication, among project team is also necessary for successful BIM-based construction projects. In fact, evidence of executing programs is still disseminated and dispersed [24, 25]. Other than that, clients can get insights from BIM communities that have been involved in their projects before. Hence, the competencies of staff in the organization become one of the parameters used in assessing the BIM capabilities of the organization.

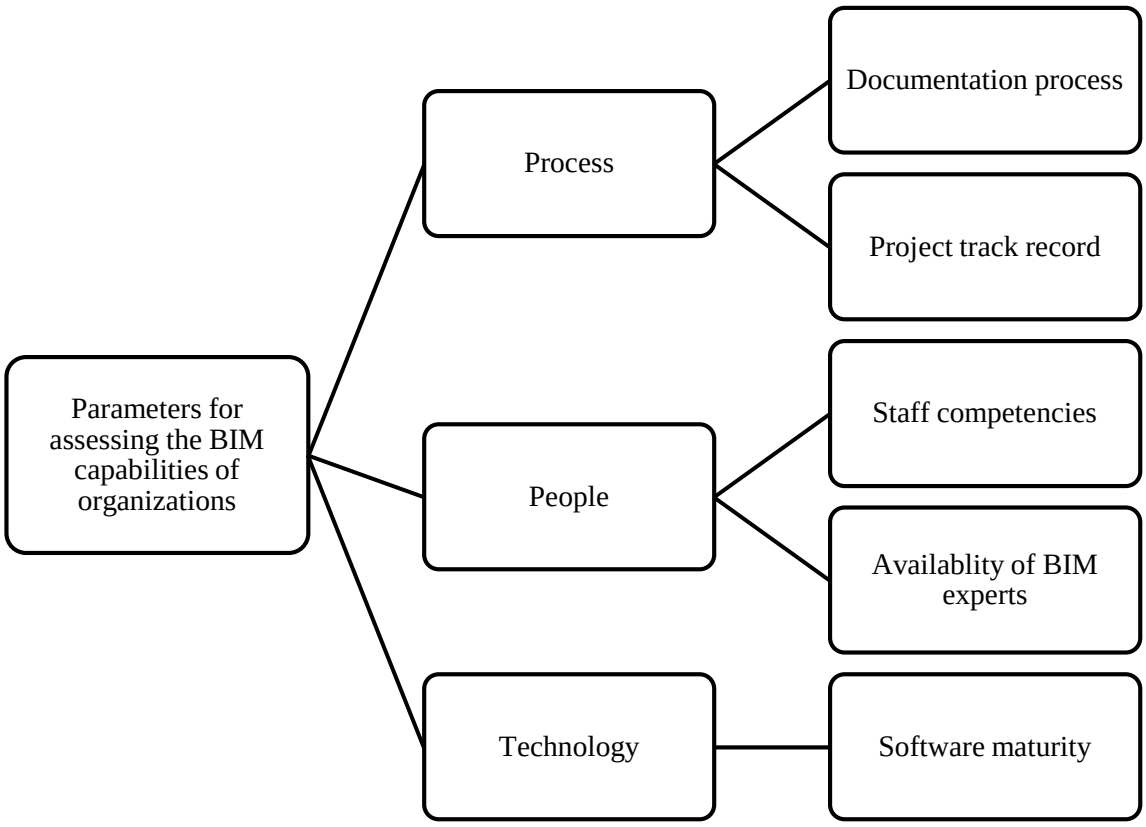

Figure 3. Summary of parameters for assessing the BIM capabilities of organizations.

Table 1. The total number of hits for parameters for assessing the BIM capabilities of organizations.

	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5	Respondent 6	Respondent 7	Respondent 8	Respondent 9	Respondent 10	Respondent 11	Respondent 12	Respondent 13	Respondent 14	Respondent 15	Total no of hits
Process																
Documentation process	√	√	√	√				√	√							6
Project Track Record		√		√	√			√	√	√	√	√	√	√	√	11
People																
Staff competencies	√	√	√	√	√					√	√	√	√			9
Availability of BIM experts												√	√			2
Technology																
Software Maturity	√	√	√		√	√	√		√	√				√	√	10

4.2.2. Availability of BIM Experts

In addition to assessing the employees' competencies, clients will also look if the organization has experts in BIM modeling. Based on the individual interview data, clients will request the organization to submit a mock-up model from previous projects. The mock-up model is a sample model depend on the requirement needed from the client. For example, in design and build, clients will ask to submit an as-built BIM model, which is not the whole building but only have a specific area that needs to submit. Nevertheless, the important is that information on the model is sufficient enough to represent the model as the as-built BIM model. However, it depends on the requirement of the client. Sometimes the organization needs to submit only the contract document model or only the as-built BIM model. Thus, clients can evaluate an organization's BIM capabilities based on the quality of the model. Therefore, expertise in modeling also one of the parameters that have been identified in data analysis that can be used for evaluating the BIM capabilities of the organization.

4.3. Technology

4.3.1. Software Maturity

BIM is one of the advanced software that is created to help industry professionals to work more effectively and efficiently. Moreover, some of the organizations already adopt BIM in their organization because of its benefit toward the construction industry. In order to evaluate the BIM capabilities of organizations, clients also look into the organization's history in adopting BIM and the success rate in implementing BIM. Besides that, clients also want to see the level of development (LOD) that the organization experienced in the previous projects and which level of BIM maturity that organization owned either level 1 or level 2.

Furthermore, clients will assess the BIM software, whether it latest revision or not, and also the hardware such as workstations, data centers, and other tools to support the BIM implementation in that organization. However, some of the clients want to see if the organization can make MEP design and collaborate in real-time to support the project delivery process and digitize their construction site and also connect the project information from design through construction and handover. Besides, the BIM range is pervasive, which is it comes in 2D, 3D, 4D, 5D, 6D, and 7D. Therefore, any of the organizations

that adapt and successfully perform one of these BIM dimensions can be classified as having BIM capability. Consequently, the capability of software development in an organization becomes one of the critical parameters in assessing the organization's BIM capabilities.

5. Conclusion

This study identifies the parameters used to evaluate the BIM capabilities of the organizations by analyzing individual interview data using thematic analysis with fifteen industry practitioners that have experience in managing projects that implement BIM. In conclusion, the significant results are:

- The five parameters for assessing an organization's BIM capabilities are: documentation process, project track record, staff competencies, availability of BIM experts, and software maturity.
- These parameters can be groups into three categories, which are process, people, and technology.

Not fulfilling these parameters might indicate that an organization might not have the BIM capabilities to be successful. In other words, the organization might not have a robust capability for implementing BIM in the projects because of skills issues among the people involved in the project that have been affecting the organizational capabilities and become one of the factors that lead to construction project failure. These findings highlight the need for industry practitioners to evaluate the BIM capabilities of organizations before the construction start. Therefore, the lesson of this study would help the industry to prevent construction project failure by assessing an organization's BIM capability before starting the project and also minimize the complexity of construction projects. This study contributes to the researchers and industry practitioners by providing a set of strategies for measuring an organization's BIM capabilities in the construction industry.

6. References

[1] Sundaraj G 2006 The Way Forward: Construction Industry Master Plan 2006-2015 *Master Builder 1st quarter 2007 Article* p 48–51

[2] Latiffi A A, Mohd S, Kasim N and Fathi M S 2013 Building information modeling (BIM) application in Malaysian construction industry *International Journal of Construction Engineering and Management* **2**(4A) p 1–6

[3] Dossick C S and Neff G 2010 Organizational Divisions in BIM-Enabled Commercial Construction *Journal of Construction Engineering and Management* **136**(4) p 459–67.

[4] Azhar S 2011 Leadership and Management in Engineering Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry **11**(3) p 241–52

[5] Khoshnava S M, Ahankoob A, Preece C and Rostami R 2012 Potential Application of BIM in Construction Disputes and Conflict *Management in Construction Research Association (MiCRA) conference*

[6] National Center for Construction Education and Research (NCCER) 2008 *Project Management* Gainesville: Pearson Education Inc. chapter 6.1-6.20

[7] Nasly Ali M, Ahmad Haron T, Marshall-Ponting A, Zuhairi and Hamid A 2013. *Exploring the Barriers and Driving Factors in Implementing Building Information Modelling (BIM) in the Malaysian Construction Industry: A Preliminary Study*

[8] Haron N A, Soh R, Ana R P Z, and Harun A N 2017. Implementation of Building Information Modelling (BIM) in Malaysia: A Review *Pertanika Journal of Science & Technology* **25**(3).

[9] Morlhon R, Pellerin R and Bourgault M 2014 Building Information Modeling Implementation through Maturity Evaluation and Critical Success Factors Management *Procedia Technology* **16** p 1126–34

[10] Mom M and Hsieh S H 2012. Towards Performance Assessment of BIM Technology Implementation *Proc. of the 14th Int. Conf. on Computing in Civil and Building Engineering* (Moscow: Academia Edu.)

[11] Succar B, Sher W and Williams A 2013 An integrated approach to BIM competency assessment, acquisition and application *Automation in Construction* **35** p 174–89

[12] Ahuja R, Sawhney A and Arif M 2017 Prioritizing BIM Capabilities of an Organization: An

Interpretive Structural Modeling Analysis *Procedia Engineering* **196** p 2–10
[13] Rojas M J, Herrera R F, Mourgues C, Ponz-Tienda J L, Alarcón L F and Pellicer E 2019 BIM Use Assessment (BUA) Tool for Characterizing the Application Levels of BIM Uses for the Planning and Design of Construction Projects *Advances in Civil Engineering* p 19
[14] Turner III D W 2010. Qualitative interview design: A practical guide for novice investigators the qualitative report **15**(3) p 754–60
[15] Radzi A R, Rahman R A, Doh S I and Esa M. 2020. Construction readiness parameters for highway projects. In *IOP Conference Series: Materials Science and Engineering* (**Vol. 712**, No. 1, p. 012029). IOP Publishing.
[16] Radzi A R, Bokhari H R, Rahman R A and Ayer SK 2019. Key Attributes of Change Agents for Successful Technology Adoptions in Construction Companies: A Thematic Analysis. In *Computing in Civil Engineering 2019: Data, Sensing, and Analytics* (pp. 430-437). Reston, VA: American Society of Civil Engineers.
[17] Jabatan Kerja Raya (JKR) 2011 Laporan Tahunan JKR 2011 p 28-9
[18] Braun V and Clarke V 2013 *Successful qualitative research* Sage Publications Ltd.
[19] Smith J A 2015 Qualitative Psychology: *A Practical Guide to Research Methods* Sage Publications Ltd.
[20] Lee Z P, Rahman R A and Doh S I, 2020. Success Factors of Design-Build Public Sector Projects in Malaysia. In *IOP Conference Series: Materials Science and Engineering* (**Vol. 712**, No. 1, p. 012045). IOP Publishing.
[21] Rahman R A, Radzi A R, Saad M S H and Doh S I 2020. Factors affecting the success of highway construction projects: the case of Malaysia. In *IOP Conference Series: Materials Science and Engineering* (**Vol. 712**, No. 1, p. 012030). IOP Publishing.
[22] Braun V and Clarke V 2006 Using thematic analysis in psychology. *Qualitative Research in Psychology* **3**(2) p 77–101
[23] Ibrahim F S, Shariff N D, Esa M and Rahman R A 2019. The Barriers Factors and Driving Forces for BIM Implementation in Malaysian AEC Companies. *Journal of Advanced Research in Dynamical and Control System*. **11**, Special issue 08/2019, 275 – 284.
[24] Rahman R A, Alsafouri S, Tang P and Ayer S K 2016. Comparing building information modeling skills of project managers and BIM managers based on social media analysis. *Procedia Engineering*, **145**, pp.812-819.
[25] Rahman R A and Ayer S K 2019. Enhancing the non-technological skills required for effective building information modeling through problem-based learning. *Journal of Information Technology in Construction*, **24(9)**, pp.154-166.

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