Section A-Research paper
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BIM Gauge: Design and Development of a Web-Based Building Information Modeling Implementation Maturity Assessment Tool for Construction Projects in The Philippines

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Abstract— The purpose of this research was to apply the established BIM Gauge Framework to the creation of a web-based BIM Maturity Assessment Tool for use in the Philippines' BIM sector. This instrument will assess the present state of BIM implementation inside a business and help determine the best way to enhance it to fit its needs. This study analyzed and compared the characteristics, benefits, frameworks, and methods of various existing BIM evaluation systems, as well as surveyed the relevant literature. The study concluded that the AEC sector has acknowledged a variety of BIM evaluation models which are crucial in implementing diverse BIM-based projects based on their features and purposes. These models were used to generate the BIM Gauge framework which consists of six main components that will measure the maturity of an organization in different areas. The study identified that the various parts of the BIM Gauge Framework are useful for assessing how BIM-based projects must and should be executed. As a result, respondents seemed to be satisfied with the use and result of BIM gauge as a tool for assessing the maturity of their BIM implementation.

Index Terms— ***BIM, BIM Gauge, BIM Maturity Assessment Tool, BIM Maturity Models.***

I. INTRODUCTION

Building Information Modeling (BIM) is an effective approach and powerful tool for building development and an emerging technique in the construction industry. The model is described as a digital representation of the functional and physical characteristics of a facility, containing all the building elements and the information associated with the elements [1]. It utilizes digital modelling software in the effective design, building, and management of projects. BIM allows the sharing and integration of multidisciplinary knowledge covering engineering and architecture, that benefits life cycle building optimization. It is characterized by intelligent and data-intensive features, a process which is computer-based for the visualization and simulation of a facility, having advantages of information extraction and analysis. The BIM technology provides visual-aid simulation and real-time data in order to facilitate exchange of knowledge and reduce construction rework and design alteration of a project [2]. Implementation of BIM has the life cycle benefits of planning optimization, dynamic onsite construction management, site selection, improvement in collaborative design efficiency, and innovative property management [3].

As the construction industry underwent a paradigm shift from a mere building design to the management of the building throughout its life cycle, a far more sophisticated information system which is digital based was developed, known as Building Information Modelling (BIM). A single visualization building model can be developed using the BIM, which is capable for use throughout the project life cycle. The model provides reliable foundation for decision making and a platform for automated analysis to assist design, planning, construction, mainten+ance, and operation activities. It has the capability of satisfying different criteria in the provision of comfortable and high-quality buildings while complying with building regulations, minimizing costs to clients, optimizing energy costs, confirming internationally accepted energy performance levels, and reducing environmental impacts [1].

Although extensive research has been carried out on the implementation of BIM in the construction industry, limited research has been conducted on the integration of BIM in project management in the construction industry in the development of assessment tool for measuring the effectiveness of BIM along with different success factors in the overall project performance. Current BIM studies focus on awareness of its adoption, policies, and implementation such as the studies of [4, 5, 6]. The present research study will fill this gap, providing a proposed assessment tool in the evaluation of success in managing projects in the construction industry, focusing on BIM complementary component. Thus, the present study will be focused on developing a BIM Maturity Assessment Tool, which will evaluate the organization's current condition in BIM implementation through a BIM maturity framework.

II. METHODS

The study will utilize a qualitative and quantitative approach to create a BIM Gauge Framework for the development of the Web-Based BIM Assessment tool. The developed web-based assessment tool can be used by industry experts, BIM Managers, BIM users, and stakeholders to assess their BIM Implementation. The development of the assessment tool will be divided into three phases.

A. Phase 1: Existing BIM Maturity Models

Phase 1 of the study covers the assessment of existing BIM maturity models: it is necessary to apply a selection principle to determine the tools to be evaluated. The selected tools should be:

- Well-recognized by the industry
- Developed by reputable research studies
- With detailed information and available literature

B. Phase 2: Development of BIM Gauge Framework

Phase 2 of the study will identify the BIM Gauge framework to be used on the proposed web-based BIM Assessment tool.

Through the study of different maturity models and their frameworks, the researcher will generate a main component of measures and each main component will consist of it's a sub-fundamental component of measures. Each component will have an objective that will help to measure the maturity of BIM Implementation across the organization. The generated components will form the BIM Gauge framework that will be used as the backbone for the development of the BIM assessment tool.

C. Phase 3: Development and Validation of BIM Maturity Assessment Tool

All the gathered data is used to develop a web-based BIM assessment tool. A Waterfall development methodology will be used to develop the tool inside a firebase database. The web-based assessment tool will evaluate the organization's BIM Capability and BIM Competency.

A validation will be then conducted to know the effectiveness of the developed web-based BIM assessment tools. The user's ratings, views, experiences, opinions, and suggestion will be recorded to help further improve the developed tool.

III. RESULTS

This section provides an introduction of the selected evaluation tools that have been used to assess the planning and design phases, performance, and the sustainability of BIM-based projects, which serves as a foundation for comprehensive comparisons.

3.1. BIM Evaluation Tools

Table 1. Comparison of Different BIM Maturity Assessment Models

Tool / Models	Purpose	Categories / Process Area	Maturity Level Attributes
BIM CAREM	Establish an appropriate BIM Capability assessment model for AEC/FM projects	Process, Technology, Organizations, human aspect, BIM Standard	Incomplete BIM Performed BIM Integrated BIM Optimized BIM
NBIMS BIM CMM	Provides tabular and dynamic BIM ratings for project outcomes and operational processes.	Data richness, life cycle view, roles or disciplines, change management, business process, timelines / response, delivery method, graphical information, spatial capability, and interoperability / IFC.	Not Certified Minimum BIM Certified Silver Gold Platinum
BIM Proficiency Matrix	Ranks companies' BIM Service quality for use in selecting subcontractors	Physical accuracy, integrated project delivery methodology, calculation mentality, location awareness, content creation, contribution data, as-built modelling, and FM data richness	Working towards BIM Certified BIM Silver Gold Ideal
BIM Maturity Matrix	Analyzes the BIM knowledge, skills, and abilities of team members, as well as the organization's capacity, maturity, and project results.	BIM capability stages, BIM maturity levels, BIM competency sets, organizational scale and granularity level.	Ad-hoc Defined Managed Integrated Optimized
BIM QuickScan	Details the company's BIM prowess and flaws	Organization and management, mentality and culture, information structure and information flow, tools and applications.	Ranging 0-5
VDC Scorecard	Compares the project's results to those of similar initiatives in the same field.	Planning (objective, standard, and preparation), Adoption (organization and process), Technology (maturity, coverage, and integration), and Performance (quantitative and qualitative)	Conventional Practice Typical Practice Advanced Practice Best Practice Innovative Process
Organizational BIM Assessment Profile	Identifies the level of development of the company's BIM planning elements.	BIM strategy, BIM uses, Process, Information, Infrastructure, and Personnel	Non-Existent Initial Managed Defined Quantitatively Managed

VICO BIM scorecard	Quantifies the efficacy of targeted BIM applications, including as coordination and cost prediction within the organizations.	Portfolio / Project management, cost planning, schedule planning, production control, coordination, and design team engagement	Optimizing No capability Low capability Satisfactory Capability High capability
Multifunctional BIM Maturity Matrix	Analyzes the level of BIM development present in individual projects, business with many ongoing projects, and the sector as a whole.	Technology, process, and protocol.	Stage 0 Stage 1 Stage 2 Stage 3

The table 1 above shows the variations of different BIM Capability and Maturity Assessment tools that have been used in AEC/FM on their BIM-based projects. For the purposes of comparison, nine models were identified and considered as the basis, leading to the output of the present study. These nine models were as follows: BIM CAREM, NBIMS BIM CMM, BIM Proficiency Matrix, BIM Maturity Matrix, BIM QuickScan, VDC Scorecard, Organizational BIM Assessment Profile, VICO BIM Scorecard, and Multifunctional BIM Maturity Matrix.

3.2. Development of BIM Gauge Framework

After a thorough review of each maturity framework and models, the researcher come up and generate six main fundamental components and fourteen sub-fundamental components. The sub-fundamental component is based on the criteria of the grouped assessment questions.

Table 2. Main Fundamental Component

Main Fundamental Component
BIM Usage and Information Flow
Infrastructure (Tools and Applications)
Organization and Management
Strategy (Collaboration and Working Strategy)
Personnel (Mentality and Culture)
Information Exchange and Data Structure

Table 3. Sub-fundamental Component

Sub-Fundamental Component	
BIM Usage and Information Flow	Coordination Information Flow
Infrastructure (Tools and Applications)	System IT Security
Organization and Management	Organizational Requirements Management Awareness and Motivation
Strategy (Collaboration and Working Strategy)	BIM Use Working Practice
Personnel (Mentality and Culture)	Roles and Responsibilities Qualification and Training Knowledge Management
Information Exchange and Data Structure	Information Exchange Data Structure

Table 3 to 7 below shows the description of the generated assessment questions on each main component of measures. There will be different sub-components measuring BIM maturity in different areas.

Table 4. Assessment Criteria under BIM Usage and Information Flow

Sub-fundamental Components	BIM Uses
Visualization	Increasing the use of BIM in design communication in order to make it more efficient and cut down on any mistakes that may occur.
4D BIM	Enabling the use of BIM for construction sequencing in order to establish a phase-wise construction simulation for a project by synchronizing 3D geometry, building data, and the scheduling of materials
5D BIM	Performing material procurement may be done considerably more quickly, easily, and efficiently with the help of doing quantity take-offs based on BIM models; and this also saves time.
Sub-fundamental Components	Information flow
Information requirements	Defining the level of information that is required in each phase of a project in order to efficiently and clearly define and specify the content of Building Information Modeling (BIM).
Interoperability	Increasing the integration and efficiency of Open BIM across the industry will make it simpler for design and construction experts to share information with one another.
Collaborative process	Defining process maps for working on BIM models in order to gain an understanding of the overall BIM process, identifying the sharing of information that will be exchanged between two parties, and clearly articulating the various processes that need to be carried out for the identified BIM uses are all necessary steps.
Common Data Environment (CDE)	Doing an analysis of how the Common Data Environment can be used to improve the sharing of information that supports the building information modeling (BIM) delivery of the project.

Table 5. Assessment Criteria under Strategy (Collaboration and Working Strategy)

Sub-fundamental Components	Coordination
Virtual Design Review	Integrating building information modeling (BIM) technology into all construction and architectural projects as the primary means to drive change and help with execution.
3D Coordination and Drawings	Taking into consideration how the model will be used during the design and construction phases, as well as how it will immediately link to the generation of documentation like drawings.
Discipline Model Reviews	Determining whether or not the relevant checks and validations have been carried out in order to guarantee that the sharing of information is carried out in an appropriate

	manner.
Sub-fundamental Components	Working practice
Strategic	Ensuring the uninterrupted flow of information, requirements, and requirements as well as efficient discourse among external partners by figuring out the primary design workflow in order to improve productivity, accuracy, and coordination.
Quality Check	Performing quality checks on BIM models to ensure that they are consistent and conform to the BIM standards that are being utilized for the project.

Table 6. Assessment Criteria under Infrastructure (Tools and Applications)

Sub-fundamental Components	System
Software and hardware	Making sure that everything runs smoothly through the availability of hardware needed to run BIM software and through the use of computer programs to deliver BIM in an effective and efficient way.
Physical spaces	Creating a space within the business that is both physically and functionally equipped to facilitate the delivery of BIM services.
Sub-fundamental Components	IT Security
Data back-up and security	Taking into account data security with the goals of preventing data breaches, lowering the risk of data exposure, and making sure that regulations are met during the process of putting BIM into place in the Philippines.
Knowledge infrastructure	Managing of network systems for the gathering, storing, and dissemination of information both within and between organizations by means of shared platforms.

Table 7. Assessment Criteria under Organization and Management

Sub-fundamental Components	Organizational Requirements
BIM Execution Plan	Utilizing a BIM Execution Plan (BEP) to codify how information will be managed and provided in accordance with the requirements of the customer with reference to the implementation of the project.
BIM Contractual Obligations	Making it possible for the project team to reach an agreement and sign on to contractual duties, which will reduce the number of procedural and contractual issues.
Sub-fundamental Components	Management
BIM Vision	Creating and achieving the organization's vision, which describes what the organization wants to be in the long run, and using BIM technology to learn more about where the building and construction industry is going.
Management support	Increasing the level of support for BIM planning is essential to guarantee the successful implementation of BIM across the construction industry.
BIM Champion and Planning Committee	Putting together a BIM Planning Committee that will be responsible for developing the organization's BIM project strategy and putting together a BIM implementation plan.
Sub-fundamental Components	Awareness and Motivation
General Plans	Developing a strategy for the use of building information modeling (BIM) helps an organization make sure it is ready to use a new process or technology with the resources it has planned for.
BIM dissemination	Increasing motivation and maintaining constant awareness with regard to the adoption of BIM among the firm's key actors by promoting a leader, a motivator, or a follower inside the company.

Table 8. Assessment Criteria under Information Exchange and Data Structure

Sub-fundamental Components	Information exchange
Document/Model Referencing, Version Control, and Status	Assessing how effective the BIM model referencing, version control, and status features that have been implemented to manage code revisions are working.
Open Standards deliverables	Providing assistance to the project team in the form of organizing electronic submittals that have been approved during design and construction and providing a consolidated electronic operation manual with minimal effort by verifying deliverables according to open standard specifications such as IFC and Cobie.
Sub-fundamental Components	Data Structure
Model Element Classification	Organizing and defining the functional parts of a building using a categorization system to ensure a uniform structure that will allow people, software, and robots to communicate and use building information in an accurate and efficient way.
Level of Geometry (LoG) and Level of Information (LoI)	Providing data and information throughout the different stages of a BIM-based project by describing the level of geometric detail to which a model element is to be developed and the level of information (LoI) content that a model element is to have. This will help structural engineers, technicians, and other professionals understand their responsibilities in terms of data and information.

Table 9. Assessment Criteria under Personnel (Mentality and Culture)

Sub-fundamental Components	Qualifications and Trainings
Training and Experiences	Implementing a fast-track BIM training programme for in-service professionals and management staff to understand BIM from a management perspective rather than a technical perspective. Providing sufficient training options featuring a variety of technical modules, such as BIM management and R&D at various levels. Sample courses could include a BIM CPD course, BIM certificate course, BIM diploma course, etc. by training institutes
Sub-fundamental Components	Knowledge Management
Collaboration and channels	Integrating infrastructure project management and infrastructure asset management to ensure that all the members of a project team are knowledgeable enough about BIM-based project and technology.

Feedback	Establishing a mechanism for staff to provide feedback on the information structure and BIM products
Platforms	Investing on the use of a Common Data Environment (CDE) platform and offering cross training and rotational schemes to encourage mutual understanding between different teams on the use of BIM.

Moreover, Figure 1 below shows the total number of assessment questions for each sub-fundamental component. BIM gauge has a total of forty-five assessment questions which are distributed on the six main components. BIM Usage and Information flow has a total of 9 assessment question which 3 of it is BIM Use and 6 questions is under Information flow. Strategy (Collaboration and Working Strategy) has a total of 8 assessment questions which equally divided to Coordination and Working Practice sub-component. Infrastructure (Tools and Applications) contains a total of 6 assessment question which both system and IT security have 3 questions. Organization and Management component has a total of 9 assessment questions which 2 of them is under organizational requirements, 4 questions are under management and 3 questions are under awareness and motivations. Information Exchange and Data structure component has 5 assessment questions which 2 of them is under Information exchange and 3 is under data structure. Lastly, Personnel (Mentality and Culture) component has a total of 8 assessment questions which 3 is under roles and responsibilities, 2 for qualification and training and 3 is under knowledge management.

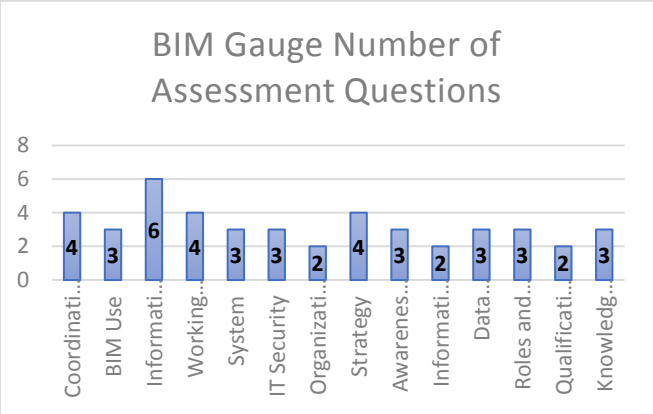

Figure 1. BIM Gauge Number of Assessment Question on main fundamental components

Figure 2 below shows the developed BIM Gauge Framework that consist of the six main components: BIM Usage & Information Flow, Infrastructure (Tools and Applications), Organization & Management, Strategy (Collaboration and Working Strategy), Information Exchange & Data Structure, Personnel (Mentality and Culture). Each main component has its own sub-fundamental components to measure the maturity on different aspects of implementation. BIM Usage & Information Flow component will assess the BIM Usage and Information Flow. Strategy (Collaboration and Working Strategy) will evaluate the organization's coordination and their working practices. Infrastructure (Tools and Applications) component will evaluate the technological system and IT security. Organization & Management will assess organization's requirements, management, and their awareness and motivations. Information Exchange & Data Structure will evaluate how the organization applies any BIM standards or protocol with regards to Information exchange and data structure. Finally, Personnel (Mentality and Culture) will assess how the management implements innovation with the implementation of BIM, the roles and responsibilities, qualification, and training of the people for BIM-based projects and how they do their knowledge management.

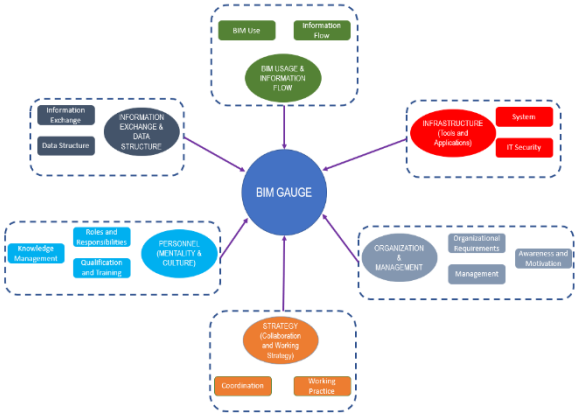

Figure 2. BIM Gauge Framework

3.3. Development of Web-based BIM Assessment Tool

After grouping all assessment questions into 6 main component and 14 sub-fundamental components, a web-based application is developed using a firebase database in an angular framework and waterfall development methodology. The development has 5 phases namely, Phase 1: Requirement gathering, Phase 2: Design, Phase 3: Development, Phase 4: Testing, and Phase 5: Deployment. The web-based application has a user interface wherein the user will first input some of his general information before proceeding with the assessment questions. After the self-assessment, a dashboard will show the result of their assessment and will also show an appropriate recommendation if some of its sub-fundamental component doesn't meet the required grade of 60% or above. Figure 3 below shows the landing page of the developed web-based BIM assessment tool.

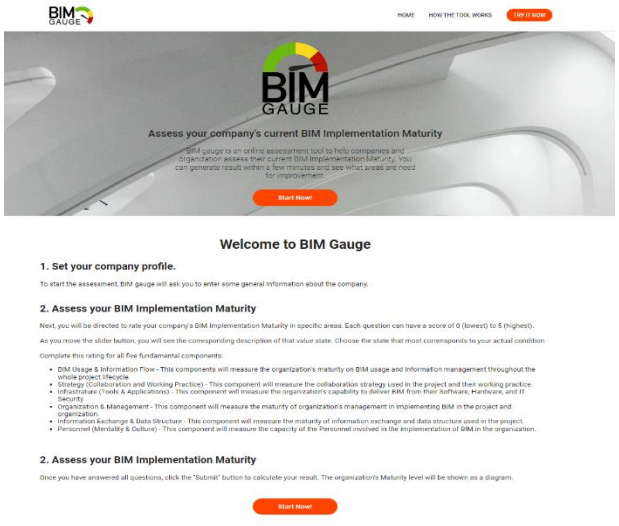

Figure 3. BIM Gauge web-based BIM Assessment tool landing page. http://www.bimgauge.com

3.4. Overall BIM Gauge Effectiveness

Table 10 showed the frequency and percentage distribution of the selected respondents in connection to the level of difficulty from the last time of using BIM gauge. The results showed that most of the respondents answered none with 18 respondents or equivalent to 62.1% while only one respondent or equivalent to 3.4% answered that it's hard to use the tool.

Table 10. Frequency and Percentage Distribution of the Respondents in Terms of Level of Difficulty from the Last Time of Using BIM Gauge

Category	Frequency	Percentage
It's hard to use the tool	1	3.4
User interface design is not friendly	3	10.3
Too many assessment questions	7	24.1
None	18	62.1
TOTAL	29	100.0%

On the other hand, with regards to the respondents' perception of agreeing with the result of BIM gauge, it can be seen that most of them answered Yes with 24 respondents or equivalent to 82.8% as compared to those who answered Somehow which garnered five respondents or equivalent to 17.2% of the total number of respondents included in the study (see table 5).

Table 11. Frequency and Percentage Distribution of the Respondents in Terms of their Perception of the Agreeing with the Result of BIM Gauge

Category	Frequency	Percentage
Somehow	5	17.2
Yes	24	82.8
TOTAL	29	100.0%

With regards to Table 12, in terms of the respondents' perception if the recommendation provided by the tool are considered to be relevant in helping the organization to improve their BIM implementation, it can be seen that majority of the respondents answered Yes with 25 respondents or equivalent to 86.2% while only about four respondents or 13.8% answered Somehow.

Table 12. Frequency and Percentage Distribution of the Respondents in Terms of their Perception if Recommendation Provided by the Tool are Relevant to Help the Organization to Improve their BIM Implementation

Category	Frequency	Percentage
Somehow	4	13.8
Yes	25	86.2
TOTAL	29	100.0%

Further, with regards to the distribution of the respondents in terms of their experience of the ease of using the BIM gauge, it can be noted that most of them answered Somewhat Easy with 17 respondents or 58.6% as compared to those who answered Extremely Easy with only four respondents or equivalent to 13.8% of the total number of respondents, as indicated in table 38.

Table 13. Frequency and Percentage Distribution of the Respondents in Terms of their Experience of Ease in Using the BIM Gauge

Category	Frequency	Percentage
Extremely Easy	4	13.8
Extremely Difficult	8	27.6
Somewhat Easy	17	58.6
TOTAL	29	100.0%

As for the respondents' perception in terms of finding out the result of the BIM gauge, it can be seen that most of them answered Very Reliable with the highest number of respondents of 18 respondents or about 62.1% as compared to those who answered Somewhat Unreliable with only one respondent or about 3.4% of the total number of respondents included in the present research.

Table 14. Frequency and Percentage Distribution of the Respondents in Terms of their Perception of Finding Out the Result of BIM Gauge

Category	Frequency	Percentage
Somewhat Reliable	10	34.5
Somewhat Unreliable	1	3.4
Very Reliable	18	62.1
TOTAL	29	100.0%

On the other hand, based from the findings presented in Table 15, in connection with the frequency and percentage distribution of the respondents in terms of their perception of using the BIM gauge again, majority of the respondents answered Yes with 27 respondents or about 93.1% as compared to those who answered Maybe with only two respondents or about 6.9%.

Table 15. Frequency and Percentage Distribution of the Respondents in Terms of their Perception of Using the BIM Gauge Again

Category	Frequency	Percentage
Maybe	2	6.9
Yes	27	93.1
TOTAL	29	100.0%

As for the findings presented in Table 16, in connection with the respondents' perception of how the BIM maturity assessment tool will be considered to be helpful in the construction industry to assess and improve their BIM implementation, it can be seen that most of the selected respondents of the study answered Yes with 28 respondents or equivalent to 96.6% as compared to those who answered Maybe with only one respondent or equivalent to 3.4% of the total number of respondents.

Table 16. Frequency and Percentage Distribution of the Respondents in Terms of their Perception of how the BIM Maturity Assessment Tool will be Helpful in the Construction Industry to Assess and Improve their BIM Implementation

Category	Frequency	Percentage
Maybe	1	3.4
Yes	28	96.6
TOTAL	29	100.0%

3.5. BIM Gauge as a Tool

The following tables presented the weighted of the responses provided by the selected respondents with regards to assessing BIM gauge as a tool.

Table 17. Weighted Mean of the Rate of Satisfaction on BIM Gauge Usage

Indicator	Mean	Verbal Interpretation
Easily Accessible	4.31	Very Satisfied
Ease of Use	4.14	Somewhat Satisfied
Browser Compatibility	4.28	Somewhat Satisfied
Security	4.14	Somewhat Satisfied
Look and feel	4.14	Somewhat Satisfied
Overall Reliability	4.24	Somewhat Satisfied
Overall Tool Performance	4.24	Somewhat Satisfied
Composite Mean	4.21	Somewhat Satisfied

In terms of the weighted mean of the rate of satisfaction generated on BIM gauge usage, it can be seen that the indicator "Easily Accessible" had obtained the highest mean of 4.31 and was verbally interpreted as Very Satisfied. On the other hand, the indicators "Ease of Use"; "Security" and "Look and feel" gained the lowest mean of 4.14 respectively and was verbally interpreted as Somewhat Satisfied. The overall weighted mean for the rate of satisfaction generated on BIM gauge usage was 4.21 and was interpreted as Somewhat Satisfied.

IV. Summary of Findings

This chapter discusses a brief narrative regarding the study. It includes important information that was found in the study. It presents generalization and answers to the problems and objectives stated at the beginning of the study. Furthermore, it includes suggestions or proposed solutions for the problems encountered during the study.

4.1. BIM Assessment models and its questions, frameworks, and mechanisms

1. Number and Quantifications of Questions / Measurements

a. VDC Scorecard - has 96 questions, indicating the challenging and resource-intensive to use the technology and to which highlight the importance of BIM maturity in the context of the organization and its processes

b. Owner's BIM CAT – has 66 questions, demonstrating the challenging and resource-intensive to use these technology

c. Characterization Framework – has 56 questions, showing how difficult and time-consuming it is to implement the technology. In the context of the organization and the procedures it uses, this model emphasizing the significance of BIM maturity.

d. NBIMS CMM - has 20 questions, demonstrating its simplicity

e. BIMCS - has 20 questions, also signifying its simplicity which emphasized technical features of BIM.

f. IU BIM Proficiency Index - has 32 questions, medium difficulty

g. BIM MM (Level 2) - has 36 questions, medium difficulty which features a more uniform question distribution

h. BIM Quick Scan - has 44 questions, medium difficulty

i. BIM Assessment Profile - has 30 questions, medium difficulty

2. BIM Capability and Maturity Assessment Models

a. BIM-CAREM - It creates a suitable BIM capacity assessment model for AEC/FM projects focusing on the process, technology, organization, human elements, and standards across four maturity level attributes.

b. NBIMS BIM CMM - It prioritizes tabular and dynamic BIM ratings for project results and operational procedures. It has six features and three levels of maturity: data richness, life cycle view, roles or disciplines, change management, business process, timeliness/response, delivery method, graphical information, spatial capability, interoperability/IFC, and six identified attributes in its maturity level.

c. BIM Proficiency Matrix - It is useful when choosing contractors. Based on the five maturity level attributes, it was also able to integrate to reach physical correctness, integrated project delivery methodology, calculating mindset, location awareness, content creation, contribution data, as-built modeling, and FM data richness.

d. BIM Maturity Matrix - It evaluates the entire organization's BIM expertise, maturity, and project outcomes.

e. BIM QuickScan - It reveals the ins and outs of the firm's BIM capabilities and weaknesses. This is more focused on the organization and management, mentality and culture, information flow, tools, and applications in a BIM-based projects.

f. VDC Scorecard - It compares a project's progress to that of others in its field. Due to its three classification levels of metrics in four areas—planning, adoption, technology, and performance—it provides comprehensive coverage of BIM.

g. Organizational BIM Assessment Profile - It provides understanding on how far along in their BIM planning stages an organization. This framework is perfect for improving the BIM strategy, BIM applications, processes, data, and resources of your business.

h. VICO BIM Scorecard - It is used for measuring the ROI of specific BIM usages, such as project management and budget forecasting which focused on the portfolio and project management, budgeting, allocating time and resources, monitoring and coordinating production, and getting the design team involved.

i. Multifunctional BIM Maturity Matrix - It evaluates the degree to which BIM has progressed in specific projects, companies with multiple active projects, and the industry as a whole which offers moderate adaptability.

4.2. Development of BIM Gauge Framework

1. BIM Gauge Framework components

a. BIM Usage and Information Flow – measure the organization's maturity on BIM usage and information management throughout the whole project lifecycle.

b. Strategy (Collaboration and Working Strategy) - measure the collaboration strategy used in the project and their working practice.

c. Infrastructure (Tools and Applications) - measure the organization's capability to deliver BIM from their Software, Hardware, and IT Security

d. Organization & Management - measure the maturity of organization's management in implementing BIM in the project and organization.

e. Information Exchange & Data Structure - measure the maturity of information exchange and data structure used in the project.

f. Personnel - assess how the management implements innovation with the implementation of BIM, the roles and responsibilities, qualification, and training of the people for BIM-based projects and how they do their knowledge management.

4.3. Development of Web-Based BIM Assessment Tool

It is developed using a firebase database in an angular framework and waterfall development methodology.

The development has 5 phases namely:

- Phase 1: Requirement gathering
- Phase 2: Design
- Phase 3: Development
- Phase 4: Testing, and
- Phase 5: Deployment

4.4. BIM Gauge Experience

1. In terms of their time spent in BIM gauge website, majority of them had been spending between 5-8 minutes in the BIM gauge website with 10 respondents or about 34.5%.

2. In connection to the level of difficulty from the last time of using BIM gauge and showed that most of the respondents answered none with 18 respondents or equivalent to 62.1%.

3. In terms of the important main fundamental components measured by the tool, the most important main fundamental component is the process with 24 respondents or equivalent to 82.8%.

4. In terms of their perception of the need to consider the assessment questions under the Process component (BIM Usage & Information Flow) to measure BIM maturity satisfactory, most of the respondents answered Somewhat Satisfied with 13 respondents or equivalent to 46.4%.

5. In terms of the respondents' perception of the need to consider the assessment questions under Technology component (Tools & Applications) to measure BIM maturity satisfactory, most of the respondents answered Very Satisfied with 13 respondents or about 44.8%.

6. In terms of the respondents' perception of the need to consider the assessment questions under Organization component (Organizations & Management) to measure BIM maturity satisfactory, most of the respondents answered Very Satisfied with 13 respondents or equivalent to 44.8%.

7. In terms of the respondents' perception of the need to consider the assessment questions under Standard component (Information Exchange & Data Structure) to measure BIM maturity satisfactory, most of the respondents answered Somewhat Satisfied with 13 respondents or about 44.8%.

8. In terms of the respondents' perception of the need to consider the assessment questions under People component (Mentality & Culture) to measure BIM maturity satisfactory, most of the respondents answered Very Satisfied with 14 respondents or equivalent to 48.3%.

9. In terms of the distribution of the respondents in terms of their perception of the important sub-fundamental components measures under Process (BIM Usage & Information Flow), it can be seen that most of the selected respondents answered Information Flow with 20 respondents or about 69%.

10. With regards to the important sub-fundamental components measures under Technology (Tools & Applications), the respondents answered that the sub-component of System is the more significant for them with 28 respondents or about 96.6%.

11. In terms of the respondents' perceptions of the important sub-fundamental components measured under Organization (Organizations & Management), it can be noted that most of the respondents answered Strategy with 22 respondents or equivalent to 75.9%.

12. The respondents' perception of the important sub-fundamental component of Standard (Information Exchange & Data Structure), it can be seen that Data Structure was considered by the respondents as the most important sub-fundamental component of Standard component with 24 respondents or equivalent to 82.8%.

13. The respondents' perception of the important sub-fundamental component of People (Mentality & Culture), it can be seen that People and Responsibilities was considered by the respondents as the most important sub-fundamental component of People component with 22 respondents or equivalent to 75.9%.

14. With regards to the respondents' perception of agreeing with the result of BIM gauge, it can be seen that most of them answered Yes with 24 respondents or equivalent to 82.8%.

15. In terms of the respondents' perception if the recommendation provided by the tool are considered to be relevant in helping the organization to improve their BIM implementation, it can be seen that majority of the respondents answered Yes with 25 respondents or equivalent to 86.2%.

16. With regards to the distribution of the respondents in terms of their experience of the ease of using the BIM gauge, it can be noted that most of them answered Somewhat Easy with 17 respondents or 58.6%.

17. As for the respondents' perception in terms of finding out the result of the BIM gauge, it can be seen that most of them answered Very Reliable with the highest number of respondents of 18 respondents or about 62.1%.

18. In connection with the frequency and percentage distribution of the respondents in terms of their perception of using the BIM gauge again, majority of the respondents answered Yes with 27 respondents or about 93.1%.

19. In connection with the respondents' perception of

how the BIM maturity assessment tool will be considered to be helpful in the construction industry to assess and improve their BIM implementation, it can be seen that most of the selected respondents of the study answered Yes with 28 respondents or equivalent to 96.6%.

20. Some respondents shared those certain improvements that should be concentrated more on providing further or more elaborate explanation or description under each item; changing the way that answers are selected for convenience; being more specific on questions or adding more assessment questions; and should be able to generate statistical and graphical results for better understanding. It was also added that it should be modified to be used as a mobile device app for convenience and improved access; more streamlining and appropriate alignment of questions with regards to BIM implementation and gauging; as well as the need to improve choices; and finally, its overall interface for improved and better use and performance.

4.5. BIM Gauge as a Tool

In terms of the weighted mean of the rate of satisfaction generated on BIM gauge usage, it can be seen that the indicator "Easily Accessible" had obtained the highest mean of 4.31 and was verbally interpreted as Very Satisfied.

V. CONCLUSIONS

Based on the findings of the study, the following conclusions were drawn:

1. The AEC/FM sector has acknowledged a variety of BIM evaluation tools. Among these assessment methods are the BIM-GBI Assessment Method model, which produced and maintained standardized information on buildings' green rating system certification; the BIM Use Assessment (BUA) Tool, which was designed for the application levels of BIM use in the planning and design phases; and the BIM Performance Assessment Tools, which were more focused on competency and capability/maturity assessment. It was concluded that different BIM evaluation tools are crucial in implementing diverse BIM-based projects based on their features and purposes, as evidenced by the findings.

2. The findings revealed a wide range of questions and quantifications of measurements across a wide range of identified models, including the VDC Scorecard, Owner's BIM CAT, Characterization Framework, NBIMS CMM, BIMCS, IU BIM Proficiency Index, BIM MM (Level 2), BIM Quick Scan, and BIM Assessment Profile. Measuring features on six frameworks (BIM Usage and Information flow, Infrastructure, Organization and management, Strategy, Personnel, and Data Structure and Information Exchange) were used to provide a critical evaluation of these models. BIM-CAREM, NBIMS BIM CMM, BIM Proficiency Matrix, BIM Maturity Matrix, BIM QuickScan, VDC Scorecard, Organizational BIM Assessment Profile, VICO BIM Scorecard, and Multifunctional BIM Maturity Matrix were included for comparison analysis in the current study. These outcomes demonstrate that these models have been leveraged by the AEC/FM industry and organizations to successfully implement their BIM-based projects. So, the study's results show that these BIM models can be used over and over again to do BIM-based projects the way they were meant to be done.

3. BIM Gauge framework development has uncovered a variety of assessment questions in each tool. Thus, there were 9 types of questions and measures for organization and management, 5 types of questions and measures for the standard which focused on information exchange and data structure, and 8 types of questions and measures for people, specifically on mentality and culture. Importantly, the BIM Gauge Framework has highlighted areas where distinct metrics have been placed, including Strategy, Infrastructure, Organization & Management, Information Exchange & Data Structure, and Personnel. It follows that the various parts of the BIM Gauge Framework are useful for assessing how BIM-based projects must and should be executed and evaluating their efficacy based on the areas/aspects as indicated.

4. It can be concluded that the development of the Web-Based BIM Assessment Tool took into account five (5) factors, which are as follows: Phase 1 is for gathering requirements, Phase 2 is for design, Phase 3 is for development, Phase 4 is for testing, and Phase 5 is for deployment. As a result, if the five phases are carried out correctly, the BIM Gauge tool may be effectively implemented as a web-based BIM assessment tool to monitor the overall effectiveness of BIM-based project execution utilizing this designed tool.

5. It can be concluded that based from the findings of the study, the demographic profile of the respondents can be considered to be strong or sufficient enough in order to make their use or application of BIM as part of their company or industry's construction process well-integrated and also can help to enhance their skills with its improved usage.

6. As such, it can also be concluded that the majority of the respondents had a good and productive experience of using BIM gauge although there are still some improvements in its features that the respondents wanted to emphasize but are also acceptable since they consider such factors as a hindrance in their effective use of the BIM gauge tool.

7. Overall, the respondents seemed to be satisfied with the use and experience of BIM gauge as a tool for assessing the maturity of their BIM implementation.

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