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Assessing Building Information Modelling (BIM) Maturity Level in Design and Build Public Projects: Case Studies of Public Projects in Malaysia

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Abstract: Design and Build (D&B) is one of the most common project delivery methods to incorporate with Building Information Modelling (BIM) and has brought to light many innovative benefits, including collaboration and integration of work processes. However, there is still confusion and a lack of empirical evidence in the construction industry regarding the interpretation of success in a BIM implementation, especially in D&B projects. Hence, this paper is aimed to assess the current maturity level of BIM in D&B BIM projects. A quantitative method by means of a survey via questionnaire has been used by adopting the "Migration Path Model of BIM for Construction Professionals" to 31 respondents in three (3) public D&B projects. The findings revealed that the implementation of BIM in those three (3) selected projects does not meet the requirement of BIM maturity in projects. Nevertheless, the BIM competencies of the projects gradually increase throughout the shift of project years. The low level of BIM maturity implies a need to have a standardised policy and guideline in determining the maturity and competencies of BIM implementation in projects at the national and market levels. Thus, it is expected that the results of this research will assist in ensuring the benefit of disruptive technology like BIM could be reaped by the construction industry.

Keywords: Building Information Modelling (BIM), performance, maturity model, Design and Build (D&B)

1. Introduction

Building Information Modelling (BIM) is said to be the evolving and disruptive technology that has transformed the current innovation in the Architecture, Engineering, Construction, and Operation (AECO) industry. This can be seen through the collaboration across organisational boundaries (Zaker & Coloma, 2018) of BIM technologies, processes, and policies for impacting the industry's deliverables, relationships, and roles (Miettinen & Paavola, 2014; Succar & Kassem, 2016). BIM should be seen as an object-based and multidisciplinary approach that aims to facilitate collaboration between construction professionals and integrate object-related information over the project life cycle of a building (Siebelink et al., 2018). A successful BIM implementation requires BIM knowledge and changing the construction professionals' mindsets, as BIM is not just a technology that changes 2-Dimensional (2D) documents into 3-Dimensional (3D) models.

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In addition, the current processes used in construction projects by construction professionals need to respond by adopting new technologies like BIM and perform amendments in collaborative work among different construction players.

BIM has been implemented in various types of projects, such as in Design and Build (D&B), Design-Bid-Build (DBB), and Construction Management at Risk (CMR) (Arshad et al., 2019). The common project delivery method used for BIM projects is D&B (Abd Jamil & Fathi, 2019), as it is accessible to control and reap the full benefit of BIM. D&B is defined as one entity signing one contract with a client to consolidate the design and construction services to provide an excellent opportunity to exploit BIM technology (Seng et al., 2020). Since BIM was introduced in Malaysia in 2007, the Government has embraced BIM through several initiatives and documents. Under the Eleventh Malaysian Plan (RMK11), the Government aims to adopt BIM on 10% of public projects above RM 50 million (Othman et al., 2021). In addition, at the beginning of 2019, BIM was mandated for any public project budgeted at RM100 million and above (MyBIM, 2017). Meanwhile, through the Public Works Department (PWD) Strategic Plan 2021-2025, the Ministry of Works had set the BIM mechanism's adoption to reach 50% in 2021 and 80% by 2025 (MyBIM, 2020). The initiatives are as summarised in Figure 1: (Abanda et al., 2018)

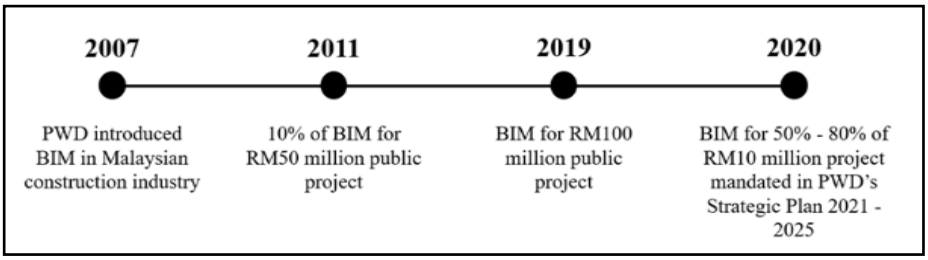

Fig. 1 - Government's BIM mandate in Malaysian construction industry timeline

Despite all the initiatives and benefits offered by BIM, there is still confusion and a lack of empirical evidence within the construction industry concerning the interpretation of BIM implementation (Attrill & Mickovski, 2020; Silverio et al., 2023). The confusion results from the inconsistency of BIM maturity levels across the collaboration of construction professionals in a project, limiting the degree of BIM goals and accompanying expectations (Siebelink et al., 2018). For that reason, several countries, including Malaysia, acknowledged a significant gap between implementing BIM and their current state of BIM implementation (Othman et al., 2021) as they did not know 'what', 'when', and 'how' to implement a proper BIM (Svalestuen et al., 2017). The proper implementation of BIM is impeded due to the lack of BIM competency or BIM expertise regarding BIM adoption (Doan et al., 2020), thus resulting in difficulties in identifying their current competency level in BIM (Siebelink et al., 2021). The statement is supported by Abanda et al. (2018) that many construction professionals in the industry claim themselves as an expert in BIM without knowing and understanding the notion of BIM.

For that reason, this paper is aimed to assess the current performance of construction professionals in public D&B BIM projects. The significance of this research is to measure the current performance of BIM implementation using the adopted BIM maturity model by previous researchers. From the findings, an improvement could be made in maximising the benefit of BIM, and thus, the construction professionals could improve the current processes and their competencies in construction projects.

2. Maturity Model Related to Building Information Modelling (BIM)

The maturity model is defined as a stage model, stage theories, stages-of-growth concepts (Serenko et al., 2014; Ho et al., 2016), and classification schemes (Andersen & Henriksen, 2006) are used to show the performance of an individual or organisation in a related matter. This concept is best used to describe the effectiveness of an organisation in performing tasks. The most common maturity model is the Capability Maturity Model (CMM) (Succar, 2009; Meng et al., 2011; Chen et al., 2014; Azzouz et al., 2016). CMM was introduced as a model representing a set of recommended practices in several key process areas to enhance software development and maintenance capability (Paulk, 1993; Chen et al., 2014; Azzouz et al., 2016). The maturity model concept has been investigated and proposed widely in different areas, including BIM. To enrich the understanding of the current BIM maturity model, a comparative study of eighteen (18) existing BIM maturity models were conducted to identify the purpose of the model, the various levels of maturity, the different types of users, and the available assessment methods. Table 1 summarises the characteristics of existing BIM maturity models from 2007 to 2021.

From the comparative study, fifteen (15) models adopted the maturity concept to show the performance levels in BIM-related matters and as a reference for the individual or organisation to evaluate and classify their performance. This concept aligns with previous researchers, where maturity is a method used to show the BIM development stage and assist in measuring BIM capability (Dakhil et al., 2019; Sun et al., 2021). On the other hand, only three (3) models (BIMMI, BIM Maturity Model for Design Team, and Migration Path Model of BIM for Construction Professionals) use the same concept to identify the current performance level and also provide the key actions that need to be taken by the individual or organisation to move from the current level to a better one. Not only that, all models except for The Bew Richard BIM

Maturity Model, BIM Maturity for Design Team, and BIM and Lean Construction Maturity Model (IDEAL) consist of an assessment method for identifying the current maturity level of the user.

Table 1 - Characteristics of Existing BIM Maturity Model (Team, 2002; Suermann & Issa, 2010; Dib et al., 2012; Van Berlo et al., 2012; Jayasena & Weddikkara, 2013; Du et al., 2014; Giel & Issa, 2016; Liang et al., 2016; Succar & Kassem, 2016; Kam et al., 2017; Mohd et al., 2017; Wu et al., 2017; Brahim, 2018; Mollasalehi et al., 2018)

No	Maturity Model (name of the model)	Purpose of Model	Maturity Level (no of level)	User	Assessment Method
1	The NBIMS-CMM (2007)	To evaluate business practices along with a continuum or spectrum of desired technical-level functionality.	10	Individuals or organisations	Questionnaire
2	The Bew-Richards BIM Maturity Model (iBIM) (2008)	To examine the BIM maturity in an industry or an organisation.	4	Individuals or organisations	-
3	BIM Maturity Index (BIMMI) (2009)	To assess the quality of teams and organisations rather than evaluating information management on a BIM-assisted project.	5	Individuals specific to designers, contractors, and clients	Multi-method
4	VDC/BIM Scorecard (2009)	To conduct a methodological, adaptive, quantifiable, holistic, and practical assessment.	4	Individuals and organisation	Questionnaire
5	TNO'S BIM Quickscan (2010)	To assess the BIM performance of firms executing technology and processes.	Percentage of 100	Individuals specific to designers and contractors	Online Questionnaire
6	BIM QuickScan (2011)	To evaluate the BIM performance level of organisations providing BIM services.	0	Individuals or organisation	External certified evaluator or online assessment
7	IU's BIM Proficiency Matrix/Index (2012)	To evaluate the BIM experience of potential designers and contractors.	5	Individuals specific to designers and contractors	Questionnaire
8	The Organisational BIM Assessment Profile (2012)	To develop a standard approach for a facility owner to plan the integration of BIM throughout the organisation and the lifecycle of a facility more effectively and to assess BIM planning elements.	5	Individuals specific to facility owners	Interviews, Document Analysis, Process observation, Workflow analysis
9	CIC Research Program's Owner Matrix (2012)	To support project teams by directing through a planning process for BIM implementation.	6	Individuals specific to clients/facility owners	Questionnaire
10	Vico's BIM Score (2013)	To evaluate their current 234 solutions for clash detection, scheduling, and estimating in terms of three aspects: functionality/capability, best	5	Individuals specific to designers, contractors, and clients	Multi-Method

No	Maturity Model (name of the model)	Purpose of Model	Maturity Level (no of level)	User	Assessment Method
		practices, and enterprise integration.			
11	Building Information Modelling Maturity Measure (BIM-MM) (2014)	To assess and compare the maturity of BIM implementation within a project.	5	Organisations	Questionnaire
12	Owner's BIMCAT (2015)	A tool that regards owners as significant users.	6	Individuals specific to Clients	Questionnaire
13	BIM Maturity Model for Design Team (2015)	To assist the design team in BIM implementation, specifically at the design stage.	5	Organisation specific to design teams	-
14	Multifunctional BIM Maturity Model (2016)	To identify components needed in terms of technology, process change, organisation readiness, and protocols.	3	Individuals, organisations, and public policymakers	Rubrics assessment
15	Migration Path of BIM for Construction Professionals	To review and improve the current performance level of BIM among construction players in projects.	5	Individuals	Rubrics assessment
16	BIM and Lean Construction Maturity Model (IDEAL) (2018)	To assess and analyse the performances of the projects implementing BIM and Lean together.	5	Individuals	-
17	BIM Cloud Score (BIMCS) (2018)	To assess the maturity levels of BIM modelling techniques.	6	BIM Modeller	Multiple mathematical tests
18	Building Information Modelling Application Maturity Model (BIM-AMM) (2021)	To predict the real level of BIM application in different actual projects, carry out a comprehensive pre-evaluation of the project BIM conditions.	4	Organisations	Questionnaire

It was found from the comparative study also that the BIMMI, BIM Maturity Model for the Design Team, and the Migration Path Model of BIM for Construction Professionals were the most related to be used to assess the current performance of BIM among different construction professionals and the use of BIM tools in projects such as the process of developing the digital model. Nevertheless, the BIMMI has been used extensively in developed countries like Australia, where the BIM implementation and maturity are more advanced and different compared to developing countries like Malaysia (Succar, 2009; Succar & Kassem, 2016). Meanwhile, the BIM Maturity Model for design teams is limited to only measuring the maturity level of construction professionals involved at the design stage. Therefore, the Migration Path Model of BIM for Construction Professionals **(Appendix A)** has been selected as an indicator to assess the current performance of construction professionals in D&B BIM projects as it is not limited to specific project phases and can be applied throughout the entire BIM project. The Migration Path Model of BIM for Construction Professionals, which has been developed for the Malaysian construction industry, consists of five (5) maturity levels (Level 1: BIM Awareness, Level 2: Develop BIM Strategies, Level 3: Implement BIM, Level 4: Monitor BIM Implementation and

Level 5: Expand BIM Implementation). Each level represents three (3) BIM enablers: BIM work contract, process, and technology.

Level 1 indicates an individual's lowest maturity level in BIM implementation. Therefore, this level focuses on how construction professionals can fully understand BIM concepts and how the concepts can be utilised in improving current practices in construction projects. Construction professionals at this level will answer the question of how BIM could be implemented in a construction project to achieve the benefits BIM offers. Level 2 describes the needs of construction professionals to identify and develop BIM strategies. The strategy is essential as it could be used as a guideline for construction professionals on how to accelerate the process and practice of BIM implementation. Next, Level 3 describes how construction professionals implement BIM in real projects by referring to developed strategies. In Level 4, the focus is on monitoring the progress and performance of construction professionals involved during the implementation of BIM. The monitoring process will be undertaken by the project leader for that implementation. And for Level 5, the construction professionals have already reached the optimum level of maturity as the implementation of BIM at this level is expected to involve a proper process with collaboration by all professionals.

The model allows user to rate their performance based on their current involvement and experience in implementing BIM in projects. Based on the rate, the score will represent BIM projects' current performance and maturity. The score of the model is tabulated in Table 2:

Table 2 - Maturity Level Range Score and Action Needed by Brahim (2018)

	ACTION				
LEVEL	**LOW**	**MEDIUM**	**MODERATE**	**HIGH**	**EXTREME**
RANGE SCORE (%)	0-20	21-40	41-60	61-80	81-100
DESCRIPTION	Need to fulfil all activities at the current level.	Need to fulfill several activities at the current level.	Considered to fulfil several activities in the current level of maturity.	Move to the next level.	The highest maturity level was achieved.

For a range score of between 0% to 60%, construction professionals are considered as not achieving the maturity level and incompetent. Therefore, they need to fulfill the minimum requirement of each current level. Meanwhile, construction professionals with a range score of 61% to 100% are said to have achieved the required level of maturity. Therefore, they could proceed to the next level of maturity.

3. Research Method

This section will discuss the research strategy, research instrument, and data analysis:

3.1 Research Strategy and Sampling

The research started with a thorough comparative study through a literature review related to the BIM maturity model. The goal of the comparative study is to explore the extent to which levels of the BIM maturity model has achieved in the construction industry. This exploration was performed using two primary sources: academic studies and industrial cases, where conventional reviews in BIM were mainly focused on academic publications only. Previous researchers have used this review extensively to observe the topic in a broad view before narrowing it into the research prospect (Shou et al., 2015; Pinti et al., 2022).

Next, multiple case studies by means of questionnaire surveys with construction professionals involved in projects using D&B BIM projects have been conducted to achieve the aim of this paper. Multiple case studies using questionnaire survey were deemed appropriate to identify the phenomena of BIM implementation in D&B projects, as the same method have been used by (Rufat et al., 2015) and (Ajibade et al., 2013). Hence, two (2) public buildings and one (1) academic institutional building that adopted D&B BIM projects have been selected as the case studies. The project has adopted BIM and has been completed in its implementation. The details of the project are as follows:

Table 3 - Details of the Case Studies

Case Studies	Project Completion	Type of Project
Public Building (A)	2013	Hospital
Academic Institution (B)	2015	University
Public Building (C)	2021	Hospital

The "Building Information Modelling (BIM) Migration Path Model for Construction Professionals," which was developed by Brahim (2018), has been used to identify the current levels of BIM performance among construction professionals involved in BIM projects. According to Korb (2012), adopting a replicated survey instrument is nearly verbatim as the instrument has been significantly based on the suitability of research objectives.

Since the number of public D&B projects with BIM implementation in the Malaysian construction industry is limited, the non-probability sampling method, specifically purposive sampling, is chosen and considered suitable for this research. According to Wurtz (2016), non-probability is a sampling technique in which each unit in a population does not have a specifiable probability of being selected. Meanwhile, purposive sampling, called judgement sampling, was used as it is the deliberate choice of a participant due to the qualities the participant possesses (Etikan, 2016). Not only that, the use of purposive sampling focused on similar cases to establish typical cases and helps improve confidence in findings (Çetin et al., 2022). Therefore, the construction professionals involved in the selected case studies in respective disciplines were approached to retrieve information regarding BIM performance. For that, a total of 31 sample respondents were identified for this research from the three (3) case studies.

3.2 Survey Participants

As shown in Table 4 below, a total of thirty-one (31) questionnaires were sent out to the multi-disciplined respondents involved in the selected D&B projects with BIM implementation case studies. Out of 31 respondents, 21 questionnaires were completed and returned within seven weeks, representing 67.74 %. The response rate of 67.74 % is considered appropriate in construction management research since the norm response rate in the construction industry postal questionnaire survey is around 20% to 30% (Mohd Nordin, 2015; Sunindijo & Kamardeen, 2017). Thus, the response rate of 67.74 % makes the comparisons of responses statistically valid.

Table 4 - Response data

Case Studies	Sent	Return
Public Building (A)	13	10
Academic Institution (B)	6	4
Public Building (C)	12	7
Total	**31**	**21**

3.3 Data Analysis

This research used descriptive data analysis using a combination of manual calculation of maturity level score and Statistical Package for the Social Sciences (SPSS) software to analyse the data collected from the questionnaire survey. According to Hanafi & Fadilah (2017), SPSS is a statistical package designed by the IBM Corporation which facilitates to undertake both comparison and correlational statistical tests in the context of univariate, bivariate, and multivariate analysis for both the parametric and nonparametric statistical techniques.

4. Findings and Discussion

4.1 Respondents' Designation and Experience in BIM Projects

Table 5 presents the respondents' designation in their respective organisations. From the result, the group of multi-disciplinary respondents involved in Public Building (A) contributed the highest response in which a total of ten (10), followed by the group of Public Building (C) with a total of seven (7) respondents and the remaining four (4) for Academic Institution (B) project.

Table 5 - Respondents' Designations

	Designations						
Case Studies	**Architect**	**Engineer**	**Quantity Surveyor**	**BIM Specialist**	**Project Manager**	**Others**	**TOTAL**
Public Building (A)	3	3	2	0	0	2	10
Academic Institution (B)	1	2	1	2	1	0	7

Public Building (C)	1	2	0	1	0	0	4
TOTAL	5	7	3	3	1	2	21

Meanwhile, Figure 2 presents the respondents' experience in BIM projects. From the result, ten (10) respondents (47.6%) have 6 – 10 years of experience in BIM projects. Meanwhile, respondents with 16 – 20 years of experience contributed equal numbers of seven (7) respondents (3%) and the remaining respondents with less than fifteen (15) years of experience. The minimum number of years of experience relevant to provide information about BIM is 6 – 10 years. Thus, it is practical to conclude that most respondents have sound knowledge of the industry and are familiar with the conventional construction process (Noghabaei et al., 2020). This is also supported by the previous researcher, where a person with more than five (5) years of experience in the construction industry is expected to have good knowledge and is capable of handling essential issues (Zaira & Hadikusumo, 2017). For that reason, the respondents could be assumed to be capable of providing relevant information because the duration of their involvement in the construction industry has made them familiar with current construction industry practices and issues.

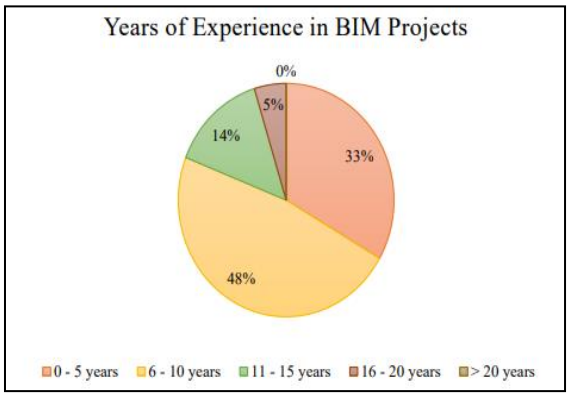

Fig. 2 - Respondents' Years of BIM Experience

4.2 BIM Competencies in Public D&B Projects

This section discusses respondents' performance in public D&B BIM projects. A self-rating Likert scale assessment was conducted to identify the level of BIM competencies of respondents in respective project involvement. The results from the total score are summarised and tabulated in Table 6:

Table 6 - Results of Respondents' Range Score of BIM Competencies Public Building (A)

Case Study	Respondent	Level 1 (%)	Level 2 (%)	Level 3 (%)	Level 4 (%)	Level 5 (%)
Public Building (A)	R1	25	37	50	46	53
	R2	33	27	40	34	33
	R3	35	33	40	31	33
	R4	33	30	30	29	23
	R5	30	30	27	34	33
	R6	35	50	50	60	53
	R7	23	40	60	54	43
	R8	93	93	80	86	40
	R9	43	37	57	60	27
	R10	60	50	60	56	53

By referring to the range score as developed and tabulated by Brahim (2018), it is proven that the maturity of each level is still low. In Level 1: BIM Awareness, the majority of the respondents scored range 21% - 40%, which is Medium. It is highlighted by Brahim (2018) that respondents need to fulfil several activities at the current level for them to move to the next level. There are many reasons for this low level of maturity, such as the lack of understanding of the process

of BIM implementation in preparation of plans in BIM and the ability to utilise it with stakeholders effectively, resistance to changing current ways of working, lack of collaboration and coordination among various disciplines, and limited availability of usage guidelines (Al-Ashmori et al., 2020; Othman et al., 2021).

Nevertheless, one (1) respondent scored 60%, which is moderate and is considered to fulfil several activities in the current level of maturity. In summary, most respondents still have not fulfilled the first level of BIM maturity. Only one (1) respondent reached Level 4: Monitor BIM Implementation, which is R8. This level focuses on monitoring the progress and performance of construction professionals involved during the implementation of BIM. The monitoring process will be based on the documented BIM process, progress reports, and activities by referring to the developed strategies and KPIs. This process might occur during the implementation and not necessarily after the completion of the projects. This is because the monitoring process during the implementation could assist in continuous improvement in delivering targeted output during BIM implementation.

Meanwhile, Table 7 presents the survey results on the respondents' range score of BIM performance in the Academic Institutional Building (B) project. Out of four (4) respondents, one (1) respondent (R14) managed to achieve Level 3 of BIM competencies, which is Implement BIM.

Table 7 - Results of Respondents' Range Score of BIM Competencies for Academic Institutional Building (B)

Case Study	Respondent	Level 1 (%)	Level 2 (%)	Level 3 (%)	Level 4 (%)	Level 5 (%)
Academic Institutional Building (B)	R11	53	53	60	60	47
	R12	60	50	53	56	53
	R13	65	53	60	63	40
	R14	90	87	87	46	40

Four (4) respondents rated their competencies as Level 1, which indicates an individual's lowest level of maturity. Construction professionals at this level will answer the question of how BIM could be implemented in a construction project to achieve the benefits of BIM. However, the lack of understanding of BIM among construction professionals regarding the process with the inclusion of the technology involved caused the maturity of BIM competencies of R11, R12, and R13 were not achieved. Somehow R14 has attained the maturity of Level 1, proving that the respondents are well aware of and understand the BIM concept to be implemented in the project. This level focuses on how construction professionals can fully understand BIM concepts and how they can improve current practices in construction projects. R14 has also consecutively achieved up to Level 3: Implement BIM, indicating the highest level of BIM maturity among respondents involved in the project. At this level, construction professionals will execute the developed strategies for implementation in real projects. From the result, the fragmentation in Public Building (A) has been improvised in Academic Institution (B) as the project was constructed in 2012, where guidelines have been developed to standardise the work and ensure the workflow is efficient throughout the project lifecycle. This can be seen through the several initiatives made by the Malaysian Government (Al-Ashmori et al., 2020; Othman et al., 2021).

Temporarily, Table 8 presents the survey results on the respondents' range score of BIM performance in the Public Building (C) project. From the results, the majority of the respondents reach Level 4 of BIM competencies, Monitor BIM implementation, and only one (1) respondent has achieved Level 5: Expand BIM Implementation.

Table 8 - Results of Respondents' Range Score of BIM Competencies for Public Building (C)

Case Study	Respondent	Level 1 (%)	Level 2 (%)	Level 3 (%)	Level 4 (%)	Level 5 (%)
Public Building (C)	R15	75	80	83	83	87
	R16	80	77	87	80	53
	R17	70	80	80	77	43
	R18	85	83	73	83	40
	R19	75	77	80	80	40
	R20	68	63	77	71	60
	R21	80	77	73	80	43

The results from Table 6 indicate that the respondents understand their tendency to succeed in projects with BIM by getting its benefits, considering their strengths, weaknesses, opportunities, and threats (SWOT) analysis to determine their capability to deliver BIM in projects. The score for Levels 2, 3, and 4 also indicated that the respondents had developed strategies for implementing and improving work activities in BIM projects and the action taken in delivering BIM in a construction project. On the other hand, one (1) respondent (R15) has achieved all five levels of maturity, which indicates the knowledge of BIM is expanding to different project phases and other BIM uses, which could also be a way to expand BIM implementation in construction projects throughout the project lifecycle.

Due to the timeline of BIM implementation and initiatives developed by the Government, the lesson has been learned from the previous two (2) projects. Thus, BIM usage needs a proper continuous improvement approach for construction professionals to improve their performance and maximise the benefits gained from BIM over time. Hence, there is a need to determine the level of change required within construction professionals and propose the best they can achieve in implementing BIM.

5. Conclusions and Further Work

The research objective is purposely to assess the extent of the level of BIM competencies by construction professionals, especially in D&B projects, in terms of the proper BIM activities from the three (3) enablers during the implementation. Based on the results of self-assessed BIM competencies by respondents in selected public D&B projects as case studies, there are different BIM maturity levels for the three (3) projects. The results show that the implementation of BIM in these three (3) projects was not meeting the maturity for all five levels as the implementation does not meet the requirement of BIM in projects. Previous researchers believed that the driving enablers relating to people, processes, policy, and technology should be addressed for future improvement in BIM (Jamal et al., 2019; Kamari & Kirkegaard, 2019; Munianday et al., 2022). From the identification of the current maturity level, there is a need to investigate the activities that could assist construction professionals in improving their current maturity level and help them earn BIM benefits. This could be achieved by investigating the actions that could be used as a strategy to enhance performance in BIM, specifically in a country that is new to BIM implementation, like Malaysia.

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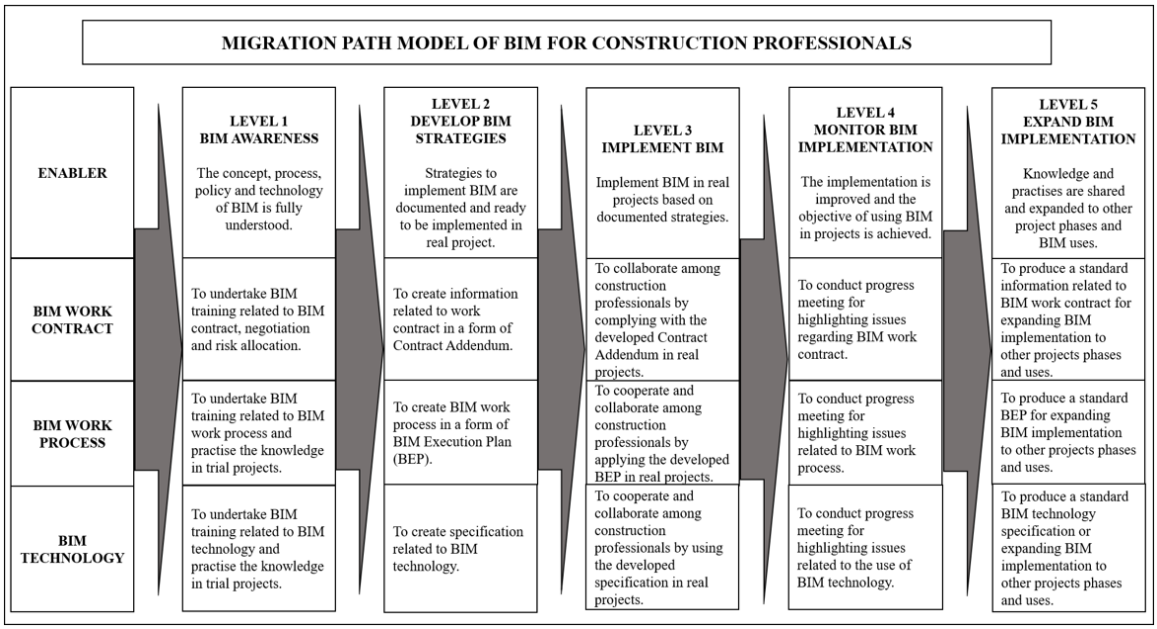
APPENDIX A



Migration Path Model for Construction Professionals developed by Brahim (2018)