THE RELATIONSHIP BETWEEN STUDENTS' READINESS, BIM USAGE, BIM ADOPTION AND BIM ADOPTION LEVEL AMONG MALAYSIAN POLYTECHNIC ARCHITECTURE STUDENTS

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by

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LIST OF SYMBOLS

α	Cronbach's Alpha
β	Beta
R^2	R square
SE	Standard Error
SD	Standard Deviation
r	coefficient

LIST OF ABBREVIATIONS

AEC	Architecture, Engineering, and Construction
AR	Augmented Reality
BIM	Building Information Modelling
CIDB	Construction Industry Development Board
CITP	Construction Industry Transformation Programme
JPPKK	Department of Polytechnic and Community College Education
DV	Dependent Variables
HEi	Higher Education Institution
iOT	Internet of Things
IR4.0	Fourth Industry Revolution
IV	Independent Variables
MoHE	Ministry of Higher Education
MR	Mixed Reality
PEU	Perceived Ease of Used
PMM	Politeknik Merlimau Melaka
POLISAS	Politeknik Sultan Haji Ahmad Shah
POLIMAS	Politeknik Sultan Haji Abdul Halim Mu'adzam Shah
PPD	Politeknik Port Dickson
PSIS	Politeknik Sultan Idris Shah
PU	Perceived Usefulness
PUO	Politeknik Ungku Omar
PWD	Public Works Department
SPSS	Statistical Package for Social Science
TAM	Technology Acceptance Model

TVET	Technical and Vocational Education and Training
VR	Virtual Reality

LIST OF APPENDICES

HUBUNGAN ANTARA KESEDIAAN PELAJAR, PENGGUNAAN BIM, PENERIMAGUNAAN BIM DAN TAHAP PENERIMAGUNAAN BIM DALAM KALANGAN PELAJAR SENI BINA POLITEKNIK MALAYSIA

ABSTRAK

Pemodelan Maklumat Bangunan, atau BIM, adalah sistem kolaboratif yang digunakan dalam industri pembinaan. Namun, pelaksanaan BIM dalam Industri Pembinaan Kejuruteraan Senibina Malaysia (AEC) masih rendah. Kaedah untuk menggalakkan industri AEC menggunakan BIM adalah untuk melengkapkan graduan dengan kepakaran dalam teknologi ini. Penyelidikan ini bertujuan untuk mengkaji status penerimagunaan BIM dalam kalangan pelajar seni bina di politeknik Malaysia. Persoalan yang diterokai dalam penyelidikan ini ialah, apakah tahap kesediaan pelajar, penggunaan BIM, dan tahap penerimagunaan BIM? Untuk menjawab persoalan ini, Model Penerimaan Teknologi (TAM) digunakan untuk penyelidikan ini. Model ini secara khususnya memperluaskan TAM dengan menambah kesediaan pelajar sebagai pembolehubah luaran. Penyelidikan kuantitatif dengan tinjauan soal selidik telah dijalankan untuk mengkaji hipotesis. Tinjauan diagihkan kepada pelajar seni bina semester kelima di Politeknik Malaysia menggunakan persampelan rawak mudah berstrata sebagai kaedah sampel. Respons dianalisis menggunakan analisis deskriptif, korelasi Pearson, dan regresi berganda dalam Pakej Statistik untuk Sains Sosial (SPSS) versi 26. Menurut dapatan kajian, kesediaan pelajar, penggunaan BIM, dan penerimagunaan BIM berada di tahap yang tinggi. Tahap penerimagunaan pelajar didapati berada pada tahap tinggi dan sederhana dengan majoriti pada tahap manipulasi. Hipotesis satu dan dua; kesediaan pelajar dan penggunaan BIM memberi kesan ketara terhadap penerimagunaan BIM, Hipotesis tiga; Penerimagunaan BIM

telah mempengaruhi tahap penenerimagunaan BIM dengan ketara. Semua hipotesis didapati positif. Keputusan ini menunjukkan penerimagunaan BIM dalam kalangan pelajar. Kesediaan pelajar didapati mempunyai kesan yang besar terhadap penerimagunaan BIM. Berdasarkan dapatan ini, pihak berkepentingan dalam bidang pendidikan perlu memberi tumpuan kepada peningkatan kesediaan pelajar untuk memperbaiki dan mempertingkatkan penerimagunaan BIM pada masa hadapan.

THE RELATIONSHIP BETWEEN STUDENTS' READINESS, BIM USAGE, BIM ADOPTION AND BIM ADOPTION LEVEL AMONG MALAYSIAN POLYTECHNIC ARCHITECTURE STUDENTS

ABSTRACT

Building Information Modelling, or BIM, is a collaborative system used in the building industry. However, BIM implementation in Malaysia Architecture Engineering Construction (AEC) industry is still low. The method for encouraging the AEC industry to use BIM is to prepare graduates with this technology expertise. This research aims to examine the status of BIM adoption among Malaysian polytechnic architecture students. The questions that this research explores are: what is the level of students' readiness, BIM usage and BIM adoption level? In order to explore the questions, this research used the Technology Acceptance Model (TAM). The suggested model in particular, extends the TAM by adding students' readiness as an external variable. A quantitative research with questionnaire survey was conducted to examine the hypotheses. The survey was distributed to fifth semester Malaysian polytechnic architecture students using stratified simple random sampling method. Responses were analysed using descriptive analysis, Pearson correlation, and multiple regression in Statistical Package for Social Science (SPSS) version 26. The results showed that students' readiness, BIM usage, and BIM adoption level were high. Students' adoption levels were in the high and moderate levels, with the majority of them at the manipulation level. Hypotheses one and two; students' readiness and BIM usage significantly affected BIM adoption, hypothesis 3; BIM adoption has significantly affected BIM adoption level. All the hypotheses were found to be positively significant. These results suggest that students have adopted BIM. Students'

readiness was found to have a large significant affect on BIM adoption. On this basis, education stakeholders should focus on improving students' readiness to increase and level up BIM adoption in the future.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This research reports on the findings of a study on the adoption of building information modelling (BIM) among architecture students in Malaysian polytechnics. This chapter begins with a brief overview of the study, followed by a discussion of the research background and a declaration of the problem. BIM acceptance in the architectural, engineering, and construction (AEC) sector will be aided by its use in education. The demands for BIM graduates has led to the research aim, research objectives, research question, and research scope. The final section states the research limitations, significance of study, key term definition and structure of the thesis in detail.

1.2 Background of the Study

BIM is a software solution for the construction sector that is utilised by the AEC industries (Robinson, 2007). The technology was originally utilised 30 years ago in the aerospace and engineering industries. In the construction section, BIM was first used about 15 years ago to differentiate between the rise of 3D architectural modelling and traditional information-rich, primarily paper-based 2D drawings. In the pre-1980s, the production of drafting instruments for the construction sector began with pencil and paper. In the aftermath of 1980, computerised tools such as AutoCAD were introduced (Shahela et al., 2014). Professor Charles M. Eastman introduced the BIM concept in 1970, and the United States of America (USA) became the first country to implement the technology (Manoharan, 2018). BIM, which was invented in 2002 by

Phil Bernstein, an Autodesk building industry strategist, simplifies the actual term for building information modelling in a three-letter acronym.

BIM has been used in the construction sectors of most developed countries. Australia is at the vanguard of BIM adoption (18–75 percent), followed by the United States (31%), Europe (16%), the Middle East (11%), and India (9%). Construction companies in Malaysia have recently begun to incorporate BIM in their projects as a result of the growing knowledge of its benefits (Othman et al., 2021). According to CIDB, 17% percent of Malaysian construction companies are now using BIM (Ahmad Jamal et al., 2019). The latest Digital Construction Report 2021 indicates that 71% of construction professionals worldwide have adopted BIM (NBS, 2021).

Since 2009, the private sector has been the major driver of BIM's development in Malaysia. The suggestion to adopt BIM in Malaysia was offered by the Director of the Department of Public Works (PWD) in 2009 (Raja Soh, et al., 2017). The first government initiative to employ the BIM method was in 2010. The Multipurpose Hall of University Tun Hussein Onn Malaysia (UTHM) became Malaysia's first BIM project, while the Malaysian National Cancer Institute was the country's second (Wan Mohammad et al., 2018).

One strategy for encouraging Malaysian architecture firms to implement BIM is to train graduates in this field. An aspect of new technology adoption is to provide graduates with the necessary skills. Such a need indicates that to some extent, higher education institution (HEI) have a direct influence on the country's technical course. BIM can help students get a better sense of how much information they're getting, increased communication level, divisions of design, clash and visual information, and increased speed (Jin et al., 2018). Malaysian polytechnic students, in particular, have been taught about BIM skills, yet the number of skilled graduates in BIM in the country is still low. These obstacles need to be addressed in the HEIs by examining the students.

The amount of society's knowledge and readiness in any capital development is seen to be a determinant of human resources (Manen van Max, 1997). Students' readiness and adoption status must be examined to promote BIM adoption in the AEC industry. The Malaysian polytechnic architecture education system must create BIM-skilled graduates to meet the industry's demands. Such a need necessitates examining the students' readiness to embrace BIM.

The definition of ready, according to Aziz & Salleh, (2011), cannot be described because it is dependent on the situations, conditions, and people involved. For example, the Harvard University Center for International Development (2001) defines readiness as "the degree to which a group is prepared to participate in the Networked World." (N. Othman et al., 2012) in their research on students' readiness for entrepreneurship education defined readiness as "the willingness and ability to do something." The Cambridge Advanced Learner's Dictionary (2008) defines readiness as "willingness or ready for something," as stated in Subramaniam et al., (2013) in article "E-Content Creation in Engineering Courses: Students Needs and Readiness." Because readiness measures both willingness and competence (ability) in both senses, the study used these two criteria to determine the students' BIM readiness. In this study, BIM readiness is defined as a student's willingness to learn about BIM and their capacity to perform in a BIM-enabled setting.

1.3 Problem Statement

Human resources are crucial in attaining economic development in a country. To effectively leverage a country's output potential, physical resources must be properly utilised by its labour force and other sorts of labour (OECD, 2012). Human resources will be evaluated only on the basis of their educational and training quality (Jajri & Ismail, 2006). For the creation and manufacture of new technologies, general education, and technical education, in particular, are critical. The ability to introduce and use new ICT technologies is largely dependent on society's ability to teach, adapt, and handle large amounts of data. The only way to achieve this is to overhaul the educational system from the ground up, from primary to higher education (Zaed et al., 2021). Higher education institutions play a critical role in delivering the skills needed by businesses and ensuring that their graduates are equipped with the necessary skills and knowledge (OECD, 2012). Polytechnics, as one of the higher education institutions, play a critical role in the development of human resources with cutting-edge ICT capabilities, ensuring the future usage and implementation of cutting-edge technology. The success of the integration hinged on the perceptions of potential new technology adopters (Ngampornchai, 2016).

BIM is gaining popularity in the AEC industry, particularly in the United Kingdom and the United States. Nonetheless, the adoption of BIM in the local industry is still limited (I. Othman et al., 2021). The adoption of BIM in the construction industry is still in its early stages, with the majority of participants reporting low BIM usage (Ahmad Jamal et al., 2019). According to a CIDB, (2019) report, only 17% of construction players in Malaysia use BIM. Before BIM can be implemented, all affected personnel must be trained and prepared (McGraw Hill Construction, 2012)(Arayici et al., 2011). Higher education institutions in Malaysia have been encouraged to include BIM courses in their curricula so that students can learn how to use BIM software and prepare for successful careers, which could influence BIM adoption (Zaed et al., 2021). Malaysian polytechnics' architecture programmes already include BIM in the curriculum for their students. A more methodical strategy based on proper knowledge and readiness evaluation is required for successful and long-term BIM adoption (Abbasnejad, 2018). Even if students are already studying BIM, their readiness to use the technology in the future may have an impact on its adoption in the industry. Yet, little information is available about students' BIM readiness, which is required by industry and employers to fill skill gaps. To prepare students for future BIM adoption, further study is needed to ensure that graduates gain BIM expertise while at the university.

The Malaysian government recognises the value of BIM as an evolving technology that is innovating the entire construction industry. It is in this context that government entities such as the Construction Industry Development Board (CIDB), Public Works Department (PWD), and other professional organisations have been encouraged to develop a Construction Industry Master Plan (CIMP) that promotes the use of modern technology (Sinoh et al., 2020). The implementation of BIM in construction projects is non-negotiable for governments and business organisations, based on its integration in the building industry. The construction business, therefore, requires trained BIM graduates for the country's growth. As noted in CIDB's BIM roadmap (2014–2020), approximately 300 to 600 qualifying BIM graduates from engineering and environmental colleges in Malaysia will be produced each year (Construction Industry Development Board Malaysia, 2014). Many Malaysian building education institutions can use BIM to meet their role expectations (Zaed et al., 2021). However, due to the lack of trained professionals from BIM, the challenges have been significant (Yusoff et al., 2021).

Malaysia's workforce is lacking in skills and experience in BIM-related projects (Ahmad Jamal et al., 2019). To prepare students for careers in the industry, it is critical that BIM be incorporated into the educational pedagogy (Jellah & Zaed, 2022). Companies frequently hire fresh graduates for BIM-related positions. According to Wu et al. (2014), both practitioners and academics recognise the importance of university education in accelerating apprenticeship and recruiting BIM experts in the industry, as well as the large gap between business expectations and graduates. Therefore, BIM should be made more relevant in educating architects and other professions in the construction sector, alerting that refusal to accept this trend in educational institutions can be a major setback. According to Kugbeadjor W et al. (2015), students are not prepared to work in a BIM-enabled environment because their courses did not adequately prepare them. While polytechnics already include BIM in their syllabus, skilled BIM graduates are still lacking. Further research is required to determine the students' readiness and BIM usage toward BIM adoption for improving the courses.

The lack of BIM knowledge is a serious barrier to the construction industry's adoption of technology (Almutiri, 2016). Application system specifications, a lack of expertise, and a willingness to adapt are among the other challenges impeding BIM uptake in Malaysia (N. A. Haron, Harun, et al., 2017). The primary challenges to BIM adoption in Malaysia, according to Keung et al., 2022, are a lack of expertise, a reluctance to adopt new technologies, and a lack of chances to persuade stakeholders to deploy or use BIM for project implementations. Increased BIM knowledge and awareness through TVET and HEI, particularly in their construction-related curricula, could accelerate BIM deployment (Ibrahim et al., 2019). HEI students' knowledge of BIM will give an impact on our country's BIM implementation status. The TVET students are already taught with BIM knowledge and skill, but the industry still lacks expertise. Such would suggest a possible obstacle in the education requiring further research. Program evaluation is required to address the problem of lack of knowledge. Program evaluation is an evaluation process that considers all components of education. This procedure can be carried out by assessing the students' level of knowledge and readiness (Yüksel & Yüksel, 2012). More research is needed to ensure that knowledge and readiness give an impact towards BIM adoption.

1.4 Research Aim

The aims of this study is to examine the BIM adoption among Malaysian polytechnic architecture students in their project and future working environment.

1.5 Research Objectives

The objective of this research is to define the status of BIM adoption in Malaysian polytechnic architecture education. This study seeks to fulfil the following objectives:

I. To evaluate the level of (i) students' readiness factor (knowledge, skill, attitude), (ii) BIM usage (perceived ease of use (PEU), perceived usefulness (PU)), (iii) BIM adoption, and (iv) BIM adoption level (Illustration, Manipulation, Application, Collaboration) among architecture students in Malaysian polytechnics

II. To examine the relationship between students' readiness and BIM adoption among the architecture students in Malaysian polytechnic

III. To examine the relationship between BIM usage and BIM adoption among the architecture students in Malaysian polytechnics

IV. To examine the relationship between BIM adoption and BIM adoption level perceived by Malaysian polytechnic architecture students

1.6 Research Question

Fulfilling the research objectives necessitates answering the following research questions:

I. What is the level of (i) students' readiness factor (knowledge, skill, attitude), (ii) BIM usage (perceived ease of use (PEU), perceived usefulness (PU)), (iii) BIM adoption, and (iv) BIM adoption level (Illustration, Manipulation, Application, Collaboration) among architecture students in Malaysian polytechnics?

II. Is there any significant relationship between students' readiness and BIM adoption among architecture students in Malaysian polytechnics?

III. Is there any significant relationship between BIM usage and BIM adoption among architecture students in Malaysian polytechnics?

IV. Is there any significant relationship between BIM adoption and BIM adoption level perceived by Malaysian polytechnic architecture students?

1.7 Research Scope

This study explores the readiness of Malaysian polytechnic architecture students for BIM adoption, using the technology acceptance model (TAM). The study was conducted in the institutions to identify gaps or obstacles that have delayed BIM adoption in Malaysia from an educational perspective. Students' readiness factors were explored in terms of knowledge, skill, and attitude towards BIM and BIM usage. Research was conducted in six Malaysian polytechnics under Department of Polytechnics and Community Colleges Education (JPPKK) that offer a diploma in architecture programme. The population of the study consists of fifth-semester architecture students who have already undertaken the BIM subject and are in their final semester before joining the industry. This research was undertaken with limited time and financial constrain. Furthermore, the current Coronavirus pandemic impeded carrying out fieldwork and therefore, the data were collected via an online survey in the June 2021/2022 session.

1.8 Limitations of The Study

The participants in this study were architecture students from six Malaysian polytechnics that offer diploma programmes in architecture. Despite meeting its objectives, the study was met with several constraints. The survey was based on data collected from previous studies. As a result, the findings may stand in contrast to current thinking, particularly regarding BIM as a tool. Each respondent could have defined *BIM tool* differently than other academics; it could simply mean BIM as a system and technology.

The data were derived only from an online survey, and the responses were rated on a five-point Likert scale. Therefore, the data lacks the depthless for establishing a framework for BIM adoption. The findings will be more accurate since the researcher will be able to explain the meaning of each question. Also noted is that the data gathering was performed online due to time constraints and the pandemic condition. More respondents, such as employers, experts, and academicians, may be included in future investigations.

Some limitations were inherent in the research design and small sample size. The sample size was not considered large enough for a regression analysis. Also, the study focused primarily on fifth-semester students in session 1 of 2021/2022. Including a larger number of graduates from various levels of education and institutions may result in more comprehensive findings.

1.9 Significance of the Study

Many previous studies on BIM adoption have concentrated on industry. There has yet to be any research done on Malaysian polytechnic architecture students. The majority of previous studies have looked at the industry's readiness to adopt BIM. This study will concentrate on the factors that influence BIM adoption among architecture diploma students, such as students' readiness, BIM use, and BIM adoption level. As a result of this research, important factors that contribute to the adoption of BIM can be identified and improved.

In order to provide a trained workforce for the industry, this study focuses on raising the degree of BIM adoption among architecture diploma students. The Department of Polytechnic and Community College Education (JPPKK) can use the study's findings to identify issues and concerns related to them and incorporate them into the education of architecture. Additionally, JPPKK can enhance current practices and curricula to boost students' adoption of BIM.

Polytechnics require this study to assess the extent to which polytechnics have progressed toward achieving a predetermined vision of being an excellent TVET institution that meets industrial needs. With this research, the polytechnic will be able to determine the best way to increase the number of students who meet the requirements of the BIM-focused industry.

Through this study, students can self-assess their abilities in BIM and can increase their self-confidence to adopt BIM which can indirectly increase the use of BIM in the industry in the future. This study may aid students in preparing for a career in architecture hence the undertaking in Industrial Revolution.

Polytechnics require this study to assess the extent to which polytechnics have progressed toward achieving a predetermined vision of being an excellent TVET institution that meets industrial needs. With this research, the polytechnic will be able to determine the best way to increase the number of students who meet the requirements of the BIM-focused industry.

This finding is expected to support the construction industry's aspirations to develop efficient workers capable of meeting the industry's demands, particularly those focused on BIM. To improve the quality of graduates for national development, the quality and delivery of TVET programme must be improved.

1.10 Key Term Definition

1.10.1 Building Information Modelling (BIM)

Building information technology (BIM) is a modelling technology and related set of methods for creating, communicating, and analysing digital information models for the construction life cycle. (CIDB, 2016b)

1.10.2 Malaysian Polytechnic

Malaysia polytechnics are the country’s largest TVET institution, providing students with a diploma, advanced diploma, and bachelor’s degree to further their studies.

1.10.3 Architecture Education

The educational programme for skilled architects and technicians in architecture. In addition, architectural education included mathematics, history, philosophy, and not only the knowledge of building materials, the construction trade and construction elements.

1.11 Structure of the Thesis

This research is organised into six chapters, each of which includes the following information. The organisation of the thesis is shown in Figure 1.1.

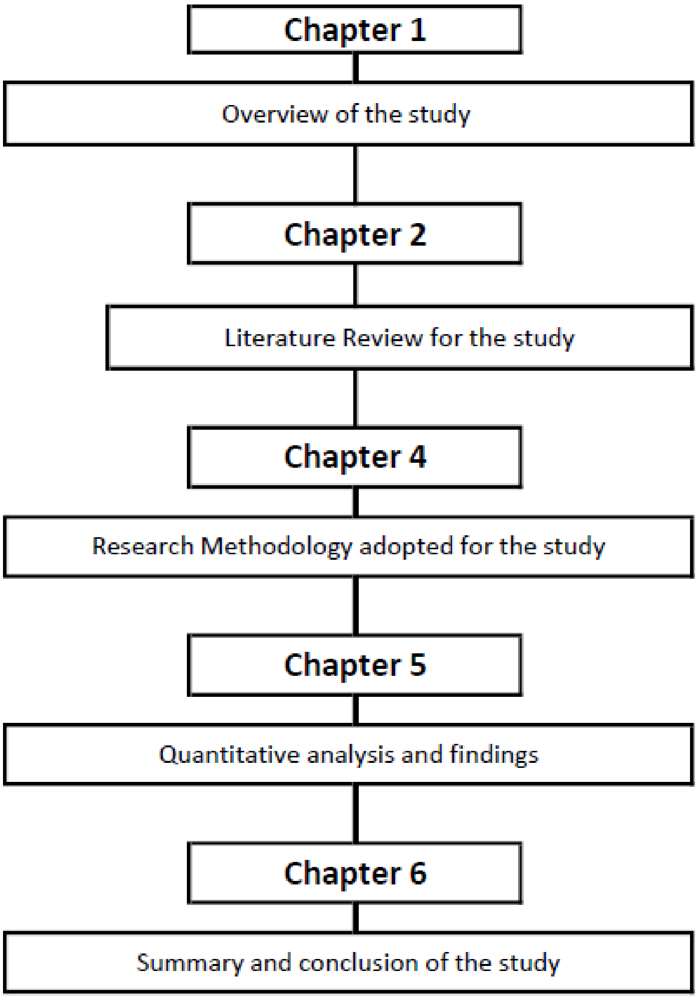

Figure 1.1 Summarises the organization of the thesis

Chapter one provides an overview of the full study. It gives an overview of the research, starting with the study's background, a description of the issue, the goals, the research question, the scope of the study, and the significance of the research. The research structure is presented in the concluding section of this chapter.

Chapter two provides an overview of BIM technology and BIM education. The chapter covered relevant BIM literature in terms of development and idea, methodology, tools, benefits, and problems. The chapter also discusses theories and their relevance to BIM adoption. It discusses students' readiness, BIM usage, BIM adoption, and BIM adoption level. This chapter ends by presenting the framework and research hypotheses.

Chapter three discusses the research methods. It covers the concept, design, research approach, sampling, population, data collection, and analysis, among other aspects of the study.

Chapter four presents the results and outcomes of the quantitative analyses of the research. The survey data were analysed using Statistical Package for Social Science (SPSS) version 26. The quantitative data were analysed using descriptive and inferential statistics, correlation, and regression.

Chapter five presents the conclusion of the study. The chapter summarises the major findings, knowledge contributions, study limitations, and research areas that could be investigated further.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses BIM-related subjects and key topics. It begins with an overview of BIM, BIM usage in the AEC industry, and BIM in academia. The chapter then explores factors that affect BIM adoption in architecture education. It then continues to clarify the main subjects for this study, namely the adoption of BIM in the Malaysian polytechnic architectural education system. The later sections then discuss students' readiness, BIM usage, BIM adoption, BIM adoption level related reviews, theoretical frameworks, and research hypotheses. Conclusion is presented in the last section of this chapter.

2.2 Overviews of Building Information Modelling

In the Malaysian AEC sector, BIM has become a significant trend. The introduction of BIM began in developed countries much earlier. The BIM adoption rate in the United States reached 72% in 2012, followed by Korea 54%, as recorded in the Smart Market (McGraw-Hill Construction, 2012). Masterspec, (2013) reported that New Zealand become the third-highest country that has implemented BIM (34%) while Australia recorded only 19% in 2012. In the United Kingdom, the Royal Institute of British Architects (RIBA) reported a BIM adoption rate of 31% in 2012, while the United Arab Emirates (UAE) levels were at nearly 25%. Figure 2.1 shows the percentage of BIM adoption in developed countries.

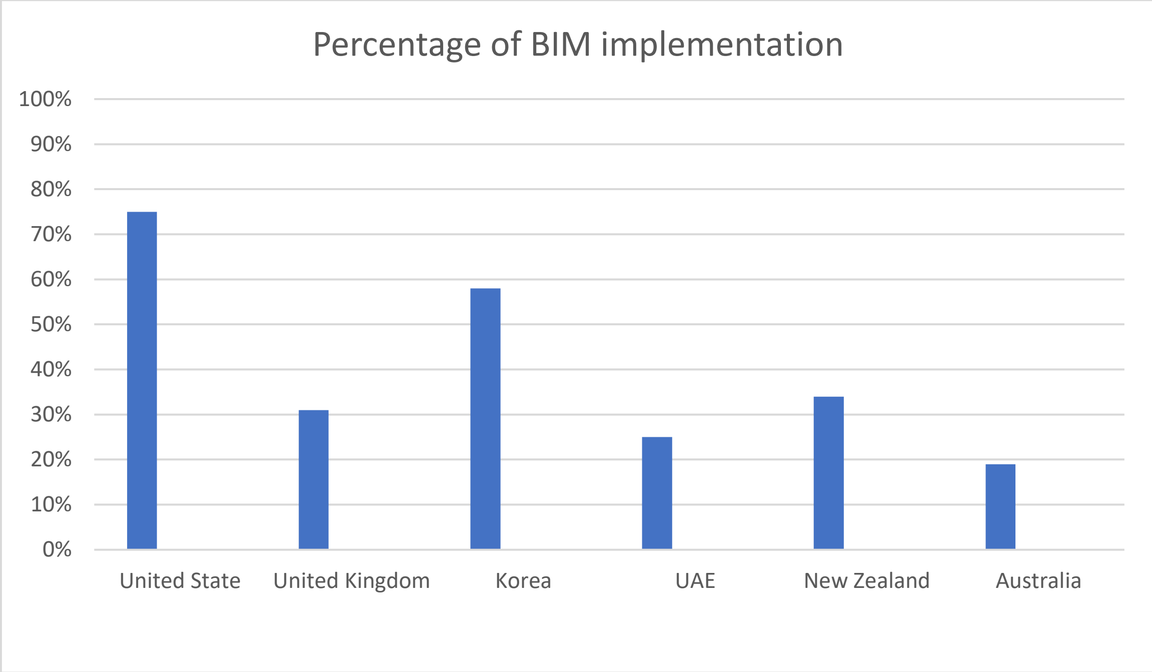

Figure 2.1 Percentage of BIM adoption in the developed country.

Malaysia began looking forward to adopting BIM after the technology was officially introduced in 2009 at the opening Conference of Infrastructure & Construction Asia's BIM and Sustainable Architecture (Harris et al., 2014). BIM usage since then has continued to grow around the world. In a 2014 survey, 80% of architecture companies in Malaysia were found to be aware of BIM and its benefit. Yet, only 17 percent of construction players in Malaysia have used BIM, and the adoption of the technology is still lagging behind the developing world (Ahmad Jamal et al., 2019). All sectors of the Malaysian AEC industry should play a role in growing the usage of BIM. Education is a key player in training human resources to promote BIM adoption in the AEC industry.

2.2.1 Definitions of BIM

BIM has been defined in different ways due to the various areas of expertise or the need to serve the function of the definer. In the Malaysian context, BIM is defined as a modelling technology or an associated set of processes to produce, communicate, and analyse digital information models for the construction life cycle (CIDB, 2016b). This model contains three major parts: modelled technology, digital information model, and construction project life-cycle. Modelling technology refers to the modelling tools used to develop a BIM model. Digital information model refers to the intelligent 3D model that consists of comprehensive construction information. Project life-cycle is the construction process that begins with design and proceeds to construction and management of the building or infrastructure throughout the project lifecycle. Figure 2.2 presents the simplest diagram of the BIM in the Malaysian context (CIDB, 2016a).

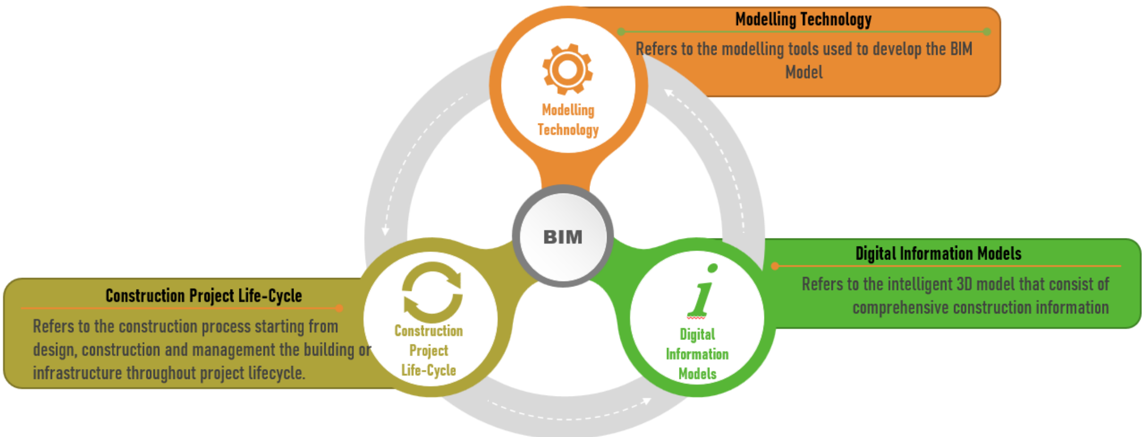

Figure 2.2 Diagram of the BIM in Malaysian context

Source: CIDB, 2016

According to Latiffi (2013), BIM is a set of digital tools that can manage construction projects' effectiveness. NIBS, (2007) describes BIM as a digital representation that often serves as a shared knowledge resource for information of physical and functional features of a facility. It requires collaboration by different parties at different phases in the construction project, either to insert, extract, update or modify information in the BIM process.

American General Contractors (AGC) defines BIM as the development and use of a computer software model to simulate the construction and operation of a facility (Mamter & Mamat, 2014). BIM is described as a design and construction approach via modelling technology, or an associated set of processes and people for producing, communicating and analysing information models (A. T. Haron et al., 2014). Harsritanto et al. (2019) referred to BIM as a system that integrates the multi-dimensional aspects of a construction project at every phase. Ismail et al. (2019) refers to BIM as an emerging technological process that highly promotes a better collaborative working environment in the AEC industry. Table 2.1 summarises the various definitions of BIM.

Table 2.1 Summarises the various definitions

No.	Statement	Author
1.	Building Information Modelling (BIM) is modelling technology and associated set of processes to produce, communicate, and analyse digital information models for construction life cycle.	(CIDB, 2016b)
2.	BIM is a set of digital tools that can manage construction projects effectiveness.	(Latiffi et al., 2013)
3.	BIM has been described as a digital representation that serves as a shared knowledge resource for information of physical and functional characteristics of a facility.	(NIBS, 2007)
4.	American General Contractors (AGC) defines BIM as the development and use of a	(AGC, 2010)

	computer software model to simulate the construction and operation of a facility.	
5.	BIM is defined as an approach to building design and construction through modelling technology, an associated set of processes and people to produce, communicate and analyse building information models.	(Haron et al., 2014)
6.	BIM is a system that integrates multi-dimensional aspects of construction project at every phase.	(Harsritanto et al., 2019)
7.	BIM is an emerging technological process which highly promotes a better collaborative working environment in the Architecture, Engineering and Construction (AEC) industry.	(Ismail et al., 2019)

Based on the various meanings of BIM, this can be concluded that BIM is a combination of technology and process that promotes a better partnership in the architecture, engineering, and construction (AEC) industries for project success.

2.2.2 Evolution of BIM

The BIM idea is thought to derive from the projects of Professor Charles Eastman at the Georgia Tech Architecture Department. In the early 1970s, the BIM abbreviation stood, which for building information modelling (or model), was introduced, and in the 1980s with computer-aided design (CAD) (Dobelis, 2013). The development of ArchiCAD software in Hungary in 1982 marked the beginning of BIM adoption, and Revit technology was considered a major turning point in the introduction of BIM in 2000 (Sardroud et al., 2018). Yet, two decades later, the application of BIM in the construction sector has been relatively slow compared to those other fields, such as production and engineering (Herr & Fischer, 2019). Nevertheless, over the past few years, there has been a great deal of advancement in the production and implementation of BIM. It was said that the implementation of the BIM model was a paradigm shift for the AEC industry as the measure has helped to improve productivity and quality in construction projects (BIM_Uk.Standards, 2019). It was a collection of digital tools that enabled the AEC sector to manage building projects by improving building scheduling, layout, construction, and operation. By assisting building participants in adding, removing, updating or modifying facility data, BIM was also recognised as a new approach to creation and documentation. The technological revolution is said to be due to the use of 3D CAD software programmes. As of now, BIM is seen as a set of design management resources that offers advantages during the construction project phases. (Aryani et al., 2014). A brief history of BIM is given in Figure 2.3 (Sardroud et al., 2018).

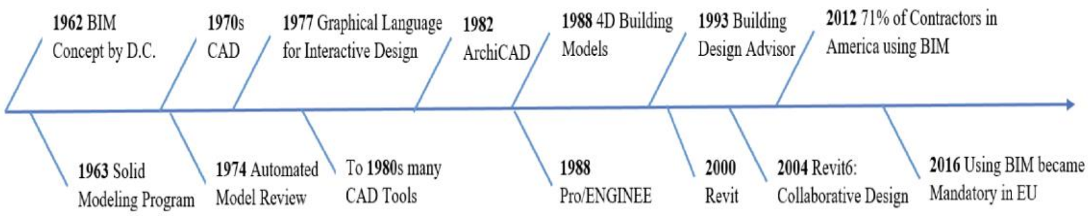

Figure 2.3 Timeline of BIM history

Source: Sardroud et al., 2018

Since early 2000, the implementation of BIM in Malaysia has been driven primarily by the private sector. BIM only became a turning point when the technology was implemented by Jabatan Kerja Raya (Public Works Department, PWD) in construction project preparation for public works in 2007 through its BIM Framework Manual and Guideline (Zainon et al., 2016). The Construction Industry Development Board (CIDB) then established the BIM Steering Committee, BIM Roadmap, and a

BIM portal to promote the BIM environment in the Malaysian construction industry (CIDB, 2016b). To support and encourage the potential and advantages of BIM, PWD, CIDB and Multimedia Super Corridor Malaysia also have provided programmes, such as roadshows, conferences, workshops, and accessible learning programmes. Malaysia's National Cancer Institute in Sepang was the first initiative to incorporate BIM in Malaysia, followed by other BIM pilot projects such as the Type 5 Pahang Healthcare Centre and Suruhanjaya Pencegah Rasuah Shah Alam Administration Complex (Aryani et al., 2014). BIM is more likely to be used in complex and high-risk projects in Malaysia recently (Mat Ya'Acob et al., 2018).

2.2.3 Building Information Modelling Process

BIM is not only a piece of tools or software; it is also a process in a construction project. The process offers reliable information throughout a project, and changes can be readily accommodated (Mamter & Mamat, 2014). BIM also supports a project's entire lifecycle and provides the ability to coordinate costing activities across all stages of the project.

The BIM process consists of a few phases, each identified by the level of information collaboration. The process of collaborating information determines the maturity of the BIM process (CIDB, 2016a). There are four phases in a BIM process: conventional, modelling, collaboration, and integration. The conventional phase is a zero level that contains 2D manual and CAD-based drawings (2D or 3D). In this phase, manual and computer-based documents for designing are used, such as CAD drawings and spreadsheets. Much of project information is not managed manually, and design information is not communicated effectively. The second phase is modelling, which involves a single disciplinary usage within a single field of object-based 3D modelling software. Digital information is used to coordinate design without major overlap. Collaboration is in the third phase and the second level. This phase involves the sharing of object-based models and data between two or more disciplines. In this phase, all disciplines collaborate and communicate digital information using a specific and common platform to produce a multidisciplinary model collaboration process. The final phase is integration, in which a model server or other network-based technology is used to integrate several multidisciplinary models. A 3D model and digital information are integrated through a network or cloud-based application to strengthen the collaborative process with a single source of information. Figure 2.4 illustrates the BIM process of development and implementation.

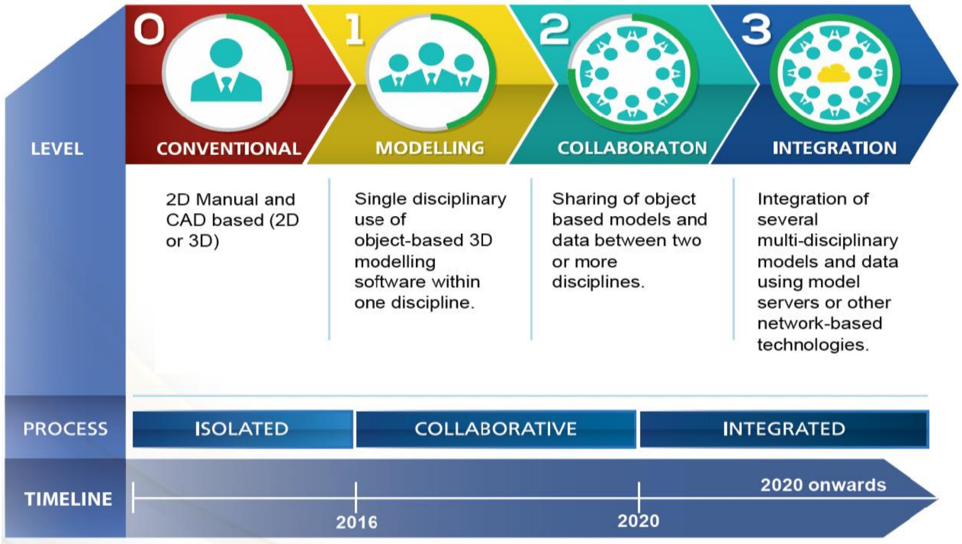

Figure 2.4 BIM process of development and implementation.

Source: CIDB, 2016

The process of developing a digital model requires all disciplines to work together. This will ultimately increase the productivity and efficiency of a building process (Latiffi et al., 2013). BIM enables the development of accurate and enriched data as early as the design stage, which will be used throughout the life cycle of the project (CIDB, 2016b). The BIM process is circulating a project’s life cycle. For building construction, the process typically starts from the planning and design stage, followed by the construction stage and finally the facility management stage. The cycle will start over if the building needs renovation works. The planning and design stage consists of programming, conceptual design, detail design, and analysis. Documentation, fabrication, construction 4D/5D, and construction logistic are in the construction stage. The final stage, the facility management stage, includes operational management and renovations. Figure 2.5 shows the BIM life cycle by stage (syncronia, 2011).

Figure 2.5 BIM life cycle by stage

Source: syncronia, 2011

Construction drawings are made from 2D graphic elements (represented by lines, hatches, and texts) using conventional process (2D-based design practice) (Dobelis, 2013). It includes the unstructured and distributed management of several files. Therefore, it is imperative that documentation and layout changes be managed manually. The BIM method, on the other hand, allows files to be systematically handled. An architect can construct a 3D model with integrated building data by introducing BIM, which essentially models a building's structure and function in the same way as it is designed (CIDB, 2016b). Any modifications will be automatically followed up and reviewed throughout the process. This measure encourages better communication, enhances data management, strengthens teamwork, and improves efficiency and quality of the company (N. A. Haron, Harun, et al., 2017). Figure 2.6 illustrates the conventional process and the BIM process.

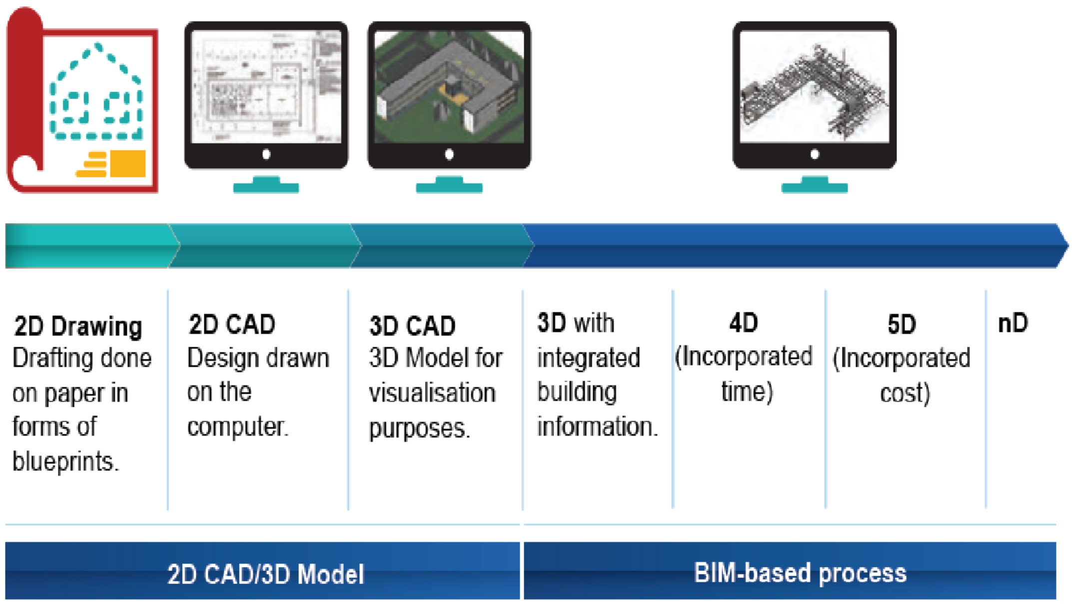

Figure 2.6 Conventional process and BIM process

Source: CIDB, 2016

Traditionally, every construction process involves a complex network of construction players and causes the exchange of information processes to be fragmented and not coordinated in a systematic manner (Aryani et al., 2014). This leads to various issues of inefficiency, inconsistency, and redundant documents. BIM adoption can make it easier for clients, consultants, contractors, and all stakeholders to work together more efficiently. BIM allows building players to move from a disconnected communication process to a systematic process of communication, collaboration, and coordination (Latiffi et al., 2013). Figure 2.7 shows BIM collaboration between all the disciplines.

Figure 2.7 BIM collaboration between all the discipline

Source: CIDB, 2016

The completeness of BIM process with involvement of all the discipline complete BIM system that gives many benefits to building construction industry.

2.2.4 Building Information Modelling Tools

BIM is a combination of process and technology. The technology part involves different software that is applied by different players. The software is used as a tool to deliver work for the process.