THE DEVELOPMENT OF A PEDAGOGICAL FRAMEWORK FOR THE INTEGRATION OF BUILDING INFORMATION MODELLING IN THE ARCHITECTURE DEGREE PROGRAMME IN MALAYSIA

By

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A thesis submitted to the University of Strathclyde

in fulfilment of the requirements for the degree of

Doctor of Philosophy

Department of Architecture

University of Strathclyde

Glasgow, UK

2018

DECLARATION OF AUTHENTICITY AND AUTHOR'S RIGHTS

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination, which has led to the award of a degree.

Signed: Date:

For the Ummah

ACKNOWLEDGEMENT

Too many people have helped me throughout my PhD journey and I am very grateful for all of the support I have received from the first day I arrived at the University of Strathclyde to the day I submitted this thesis. I would first and foremost express my sincere gratitude and appreciation to my kind supervisor, Dr. Michael Grant, for his time, energy, continuous support, and guidance. I have known him since 2003 when he was the supervisor for my Master's degree, also at the University of Strathclyde, and the excellent experience I previously had with him made me seek for his expertise again for the second time. As expected, again on this challenging journey, he had never stopped pushing me and motivating me to reach a point that I never knew existed. I am very grateful to have him as my supervisor and what I have learned from him will always stay with me throughout my life. I would also like to thank people from the Malaysian architecture industry and also fellow academicians from UKM, UM, UTM, UPM, IIUM, UiTM, and USIM for the kind support given to me during primary data collection. Dr. Zaharah Yahya, Dr. Roslina Sharif, Ar. Najib Salleh, Dr. Hisyamuddin Kassim, Mr. Azari Yasir, Mr. Asrul Razak, and Dr. Elina Husini, thanks very much for your kind assistance. I would also like to thank Ms. Aileen Alexander, Dr. Andrew Agapiou, Ms. Catriona Mirren, the late Mr. Harry Stokes, and rest of the Department of Architecture staff for all the behind-the-scenes help. I am also thankful to have very kind friends like Maryam, Callum, Bryce, Amira, Walid, and Adel whom have always been helpful and made it a joy to work at the PG suite. I would also like to single out my best mate, Syahrull Hi-Fi for every kindness that he has given me and my family. Last but definitely not least, I would like to thank Mama, Baba and my beautiful wife Zatil Bayani, both my sons, my brothers and sister, who all have been incredibly patient and have encouraged me at every step of the way.

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LIST OF ABBREVIATION

2D	2 Dimensional
3D	3 Dimensional
4D	4 Dimensional
5D	5 Dimensional
AEC	Architectural, Engineering and Construction
AIA	The American Institute of Architects
BIM	Building Information Modelling
CIMP	Construction Industry Master Plan of Malaysia
CIDB	Construction Industry Development Board of Malaysia
CREAM	Construction Research Institute of Malaysia
DOS	Department of Statistics Malaysia
EPU	Economy Planning Unit of Malaysia
GDP	Gross Domestic Product
IBS	Industrialised Building System
ICT	Information & Communication Technology
IFC	Industry Foundation Classes
ISO	International Organisation for Standardisation
IT	Information Technology
IPD	Integrated Project Delivery
LAM	*Lembaga Arkitek Malaysia* (Malaysian Institute of Architects)
PAM	*Persatuan Arkitek Malaysia* (Malaysia Board of Architects)

PWD	Public Work Department of Malaysia
R&D	Research and Development
RM	Ringgit Malaysia
RIBA	Royal Institute of British Architects
SIRIM	Standards and Industrial Research Institute of Malaysia
WAI	Weighted Average Index

ABSTRACT

Within the last decade, the architecture world has seen the rise of a new digital technology called Building Information Technology, or BIM, that has constituted a paradigm shift to the profession. Although the last few years have shown promising results in the implementation of BIM despite a sluggish start a decade ago, researchers posit that the uptake rate of the technology could have been better if not for the lack of a holistic and consistent approach taken by tertiary education in supplying their graduates with industry compatible knowledge of BIM. This thesis explores the desired factors in developing an effective way to implement BIM into architecture education with the aim to propose a framework of recommendations that is able to support the integration of BIM principles into the Part I and Part II architecture programmes in Malaysia in accord to the needs of the local industry.

Existing research often engages either only the industry or the Higher Education Institutions (HEI)s, but seldom both, to reformulate its curriculum to accommodate BIM. Even a number of research that claimed to have engaged both parties, have only done so on a selective basis rather than nation-wide scale. The current research on the other hand have engaged both the industry and all the accredited public architecture schools in the country through survey questionnaires from the initial stage of the research to ensure the framework of recommendations is tailored to suit both ends of the profession; hence, balancing the needs and desires of the industry with academic expertise and aspirations of the HEIs.

Significant findings from the results of the various surveys taken on both the industry and HEIs have shown that the BIM uptake in Malaysia's architecture industry is relatively low at approximately 20% and CAD is still the gold standard for the industry

and government. However, BIM awareness is very high and the majority in the industry are strongly considering to adopt BIM in the future. Current BIM users in the industry were in favour of continuing utilising BIM in the future despite admitting that BIM has brought certain challenges to the practice that needed to be addressed effectively. Contrary to the industry, the public HEIs have fared better with all but just one have already introduced BIM into their curriculum. However, these HEIs have not adopted a much aligned and coherent approach in integrating BIM into their curriculum. Most of the HEIs have developed their BIM syllabus in-house without formal engagement with the industry or other HEIs.

Inferences gained from the analysis of findings from both surveys were appraised and cross checked with the literature review, accreditation requirements by *Lembaga Arkitek Malaysia* (LAM) and Malaysia Qualifications Agency (MQA), and subsequently used to develop and construct a theoretical framework of recommendations for BIM integration into the architecture programme in Malaysia. This theoretical framework was then presented and validated by the various HEIs before being refined prior to the establishment of the final framework that will later be presented to LAM as a tool that can be used to assist and guide HEIs to integrate BIM into their curriculum. Apart from that, the framework should also be able to provide LAM with additional insights in regards to developing the accreditation criteria for BIM syllabus in architecture curriculum.

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

For the past three decades, the rapid achievements of the architecture world have been immensely supported by digital technologies. In relation to this, computers have also been widely used by almost every individual in the current architectural and design line, be it fresh graduates who just entered the workforce, senior designers and managers, or owners of related companies. Hence, the important role of computers in conducting the daily design tasks for architectural firms can never be denied, considering whether it is utilised only as a tool or a 'working partner'. Moreover, the Architecture, Engineering and Construction (AEC) industry has shown great progress over the years, but it is crucial to acknowledge that the ever increasing complexities of the construction techniques and process has led to increased amount of new invention and development of digital technologies with the purpose of accommodating the high demands, which in this case refers to Building Information Modelling (BIM) technology.

In the present world, BIM is the centre-stage of the AEC industry all over the world. BIM is regarded as one of the means to overcome the traditional difficulties in communications and information management that have plagued the architecture industry for decades. The latest tools built for BIM technology provide the ability to simulate and evaluate building designs, applied technologies, thermal properties, visual properties, energy use, and schedules of operations. These can be performed without having to construct the artefact being modelled, thus further promoting BIM to gain considerable attention from the industry in response to the ever-growing awareness of sustainability and green design.

Nevertheless, Malaysia has failed to achieve similar results as most developed nations such as the United States and western European countries considering that they have managed to show promising results in the implementation of BIM. The lack of consistent approach and cultural aspects have led to a low rate of BIM usage. Meanwhile, innovation and change have brought numerous challenges to the traditional ways of working and thinking. Overall, it is safe to say that this has not only affected the industry, but also the tertiary education which is known as the main supply of compatible and competent workforce for the industry. However, there is a growing need for higher education to step up with a better pace in order to provide the industry with graduates that possess the right set of skills and knowledge considering that the AEC industry has been struggling to keep up with the global change. Therefore, the present research is deemed necessary as it helps to establish the right approach to develop BIM curriculum that actually adheres to the needs of the local industry. In relation to this, the introductory chapter describes the justification and reasoning for the research as well as the process involved in conducting this study.

1.2 RESEARCH OVERVIEW

In the general sense, it is undeniable that the construction sector has always been important to the Malaysian economy. Despite Malaysia's economic growth rate was only 4-5% in recent years, which was relatively low for a developing country that used to be Asia's top 5 economic powerhouses, its construction sector has shown significant contrast with a double-digit growth rate of 18.6% (Olanrewaju and Abdul-Aziz, 2015). However, the high growth rate shown by the sector does not evade the fact that there are critical issues that have been plaguing the industry. A study carried out by Endut et al. (2009) revealed that delays in project deliverables is rife considering that only 20.5% of the public projects and 33.35% of the private sector projects managed to be completed within time. Apart from that, another close related problem that is faced by the industry is project cost overruns. According to a study by Shehu et al. (2014), 55% of the construction projects in Malaysia were completed above the original contract sum, which results in variation of orders. The next major problem for the industry refers to the increase of construction waste. In their study, Masudi et al. (2011) reported that the wastage level for major raw materials for most projects in big cities of Malaysia may have reached 10%, which definitely exceeds the 4-5% benchmark of the approved wastage level.

The three major continuing problems that have been stated include delays, cost overruns, and wastage, which have cost the Malaysian AEC industry huge sums of money. The root of the problem comes down to one major cause which can be explained by the fragmented nature of the AEC industry even though all the three problems may have numerous causes and factors that are unique to their own. Several established studies including a report provided by Malaysia's Construction Industry Development Board (CIDB) tend to posit that the industry is highly fragmented with limited effort in closing the gaps between the involved parties (CIDB, 2003). This further highlights the inherent practice of traditional approach to construction that is highly dependent on the old conventions of building techniques and processes (Kamal et al., 2012). Subsequently, this situation has urged the industry to leverage on IT technology as the means of overcoming the problem, which complements one of the strategic thrusts in CIDB's Construction Industry Master Plan (CIMP) 2006-2015 (CIMP, 2007). The Malaysian government further recognised the capabilities of advanced IT technology as a result of the announcement made by the Public Works Department (PWD) on 27th of August 2007 which states that Building Information Modelling (BIM) is to be formally introduced and implemented in Malaysia's AEC industry (JKR, 2013).

The notion of BIM has been claimed to have started in the 1970s, but its formal introduction and development to the industry did not start until 1987. The launch of ArchiCAD by Graphisoft in 1987 paved the way for the start of a technological shift in the AEC industry; a new digital technology termed as 'Virtual Building' (Quirk, 2012, Brewer et al., 2012). On the other hand, the introduction of Revit in year 2000 had managed to establish a technology presently known as Building Information Technology (BIM) (Autodesk, 2002). Prior to the introduction of BIM, the industry was using Computer Aided Design (CAD) which is a computer software solution that offers basic functions such as 2D drafting and 3D visualisation tools. However, CAD does not possess the ability to 'test' a design or be effectively utilised in the operational phase of the building. The advent of BIM started to change the game considering the enhanced capabilities possessed by BIM which include the ability to 'construct' building virtually prior to the actual construction, run test and simulation on building thermal and energy performances, synchronise design and data between team players, detect conflict and inferences, and utilise data rich digital models to inform the operation, maintenance, refurbishment, and even demolition phases. These advanced qualities have enabled BIM to integrate design development, project management, and facilities operation management which helps the project team to have a very reliable support and assistance in the process of decision-making throughout the life cycle of the building.

However, BIM may possess numerous perceived benefits but the transition from CAD to BIM has not shown a great progress considering the challenges that come with it. There are several factors that prevent the implementation of BIM in developing countries like Malaysia which include high cost of BIM technology as a result of weaker currency; cultural norms that lead to the resistance to change; lack of research to provide confidence and guidelines for technology adoption; and limited number of skilled staff. The industry cannot be left alone in its effort to widely implement BIM as what had been previously done with CAD. However, the same is expected in the implementation of BIM by taking into account the success of academia in helping the industry to adopt CAD 20 to 30 years ago. Nevertheless, the process of equipping students with BIM skills is totally different from CAD skills. The function of CAD is only as drafting and visualisation tool which is definitely different from BIM that plays a major role throughout the life cycle of a building starting from the schematic design phase all the way to decommissioning phase. Therefore, it is not enough to merely supply students with procedural skills of using BIM because the students need to be 'educated' with architectural knowledge throughout the utilisation of BIM. As the saying goes, *Training teaches people how to do, while education teaches people how to think*. Anecdotally, the undergraduate and postgraduate degree programmes of architecture in Malaysia seem to be less productive in responding to the needs and demands of BIM, which further emphasises the need to implement BIM in the country.

1.3 PROBLEM STATEMENT

Needless to say, in the early stage of CAD development during the 80's and 90s, academic institutions played a big role in assisting the development and promotion of the technology. They also assisted by providing the Architecture, Engineering and

Construction (AEC) market with a wide range of research that guides and aids the setting up of standards, including providing the market with workforce that is equipped with the necessary skills and ability to operate these tools. Hence, the same is expected of academia to adequately help in the process of BIM adoption.

The Malaysian government is fully aware of the growing importance of BIM and have also recognised the need for education to assist the industry to elevate new technologies into the mainstream. In relation to this, CIDB has clarified the importance of BIM to the industry and academia; subsequently taking this into consideration when developing the national roadmap towards the adoption of BIM. In 2015, CIDB presented Malaysia's first comprehensive BIM Roadmap and established the pursuit of *Education and Training by Academia* as its third of the seven pillars for the roadmap (Haron et al., 2015). The task-force for the roadmap emphasises that strong participation of the government and academia is crucial to escalate BIM adoption in the country. Higher Education Institutions (HEIs) throughout Malaysia have been strongly recommended to incorporate BIM courses into the curriculum of their programmes.

However, BIM technology does not share the same nature with CAD; hence, it is not the best option for the HEIs to use the same formula in formulating the curriculum of degree programmes. BIM is widely perceived as a technology that requires and also produces substantial changes to the practice (Bouazza et al., 2016, Azhar, 2011, Azhar et al., 2008b). As suggested by BIM, every party in a particular construction project need to fully participate to ensure that the project is well delivered throughout the whole life-cycle of a building. Therefore, it is expected for HEIs to develop a curriculum syllabus with an improved way of teaching in the effort of preparing students that are compatible with the new working culture and practice in the industry. In response to this, this research is deemed necessary to explore the desired factors in developing an effective way to integrate BIM into the architecture degree programmes in Malaysia in accord to the demand of the industry.

1.4 RATIONALE FOR THE RESEARCH

In the year 2013, BIM was declared by the Malaysian government to be implemented for all its public funded projects by 2016 (CREAM, 2014). However, the take up of BIM in the industry remained low and the government failed to mandate the use of BIM within the expected time frame, except for a few high-profile projects (Latiffi et al., 2013). As a result, the government decided to revise their strategy and presented the BIM Roadmap in the year-end of 2015 considering the difficulties to implement BIM. Apart from that, the shifting of BIM mandate for government projects by the year 2020 strongly emphasises the role of HEIs in assisting the industry to adopt BIM (Haron et al., 2015). This marks the government's recognition that HEIs are capable of championing the use of BIM by equipping BIM-skilled and minded graduates to the industry. However, there are still misconceptions on the needs and priorities related to the transition of traditional process to BIM process, particularly from the architecture point of view. The absence of a proper strategic planning of BIM implementation at tertiary education level by the Malaysian Board of Architects, or *Lembaga Arkitek Malaysia* (LAM) tend to exacerbate the situation. The accreditation process of architecture degree programmes by LAM states that BIM is still not required to be implemented, either as core modules or elective modules despite acknowledging the importance of BIM through the discourses that were jointly organised with CREAM and CIDB. If the HEIs are to evolve their curriculum to cater to the need of BIM;

hence, a thoughtful review is required to fully understand what is expected of BIM by the industry in the short term and long term, including how BIM is used within the current practice of the local industry. This is crucial because the syllabus for architecture degree programmes are already known to be dense; hence, any future changes or additions should be minimal yet effective as long as it is practical and tailored to the needs of the industry. Finally, the most important aspect that needs careful consideration when integrating BIM into the current curriculum is to articulate an approach that balances both the required principles of BIM and principles of design thinking.

"There are two competing philosophies: BIM is inherently answer-driven, design thinking is question-driven" (Cheng, 2006)

1.5 AIM AND OBJECTIVES

The aim of this research is to propose a framework that is able to support the integration of Building Information Modelling (BIM) principles into the architecture degree programmes in Malaysia. This research could also help trigger and guide academic institutions in ensuring the graduates are equipped with the right skills, adequate understanding, and way of thinking to enable them to carry out the duty of an architect in response to the adoption of BIM.

Technology is known to develop and upgrade from time to time, which further explains its major part in changing many facets of life and influencing the daily task of individuals. Hence, this further implies that changes that are caused by technological advancements which seem to affect the life of individuals from time to time to a certain level are inevitable. However, adopting a technology that can best suit the reality of this particular context is vital in ensuring that it can bring maximum positive changes. For this to happen, it is very important to identify, examine, and understand its process, practicalities, and feasibility within the context. Therefore, this leads to the following seven objectives of this research.

<u>Objective 1</u>

To explore, appraise, and synthesise relevant literature related to Building Information Modelling (BIM) from both international and local perspectives.

<u>Objective 2</u>

To explore, appraise, and synthesise relevant literature related to BIM by focusing specifically on the professional practice – architecture education relationship and the effects on each other.

<u>Objective 3</u>

To identify the current trends and practices among architectural firms in utilising digital technologies to perform project deliverables.

<u>Objective 4</u>

To evaluate the impact of BIM opportunities and challenges on design strategies, associated management structures, and cultures within architectural practices.

<u>Objective 5</u>

To explore how the HEIs equip their graduates with the capabilities to make the most out of digital technology in response to the latest market needs.

Objective 6

To identify the enablers and barriers in the implementation of BIM principles and concepts into architecture programmes in government-owned public HEIs in Malaysia.

Objective 7

To propose a framework that will facilitate the re-evaluation and re-formulation of the current curriculum syllabus for the purpose of incorporating BIM.

1.6 CONTEXT AND LIMITATION

The present research explores the supply and demand relationship between the industry and academia; hence, the context of this research will cover both markets. On another note, the context of this research is limited to architecture firms that are currently running active projects as well as registered as professional members of the Malaysia Board of Architects or *Lembaga Arkitek Malaysia* (LAM) and Malaysian Institute of Architects/*Pertubuhan Arkitek Malaysia (PAM)*. Obviously, other practitioners with no professional affiliations will not be part of the research samples. On the other hand, the context of this research also stretches to cover all architecture schools at the public HEIs in Malaysia which have been accredited by the LAM and offer digital technologies knowledge in their teaching syllabus. This research will consider the *direct relationship* between architecture education and the AEC industry in terms of the development of digital technologies, particularly BIM.

1.7 RESEARCH METHODOLOGY

The detailed elaboration of the research methodology is provided in Chapter 4; however, it can be generally summarised that the present study adopts the mixed-methods approach. The data collection process is carried out by conducting survey questionnaires analysis on two sets of different samples as the main components of the overall deductive research approach. The current research focuses on the delineation of effects on the architectural design practices and education with respect to the current implementation of the associative parametric technology of BIM as well as the requisite cognitive shifts in design thinking. Therefore, this research seeks to obtain a range of data on issues and considerations obtained from the samples of two different contexts that are inter related within the context of this study. This study will also take into account the needs of BIM within the industry as well as the integration of BIM into HEIs in response to the demands of the industry. One significant advantage of adopting the mixed-methods approach can be explained based on the inter-supportive goals and objectives, which is the result of the different nature of two contexts that require different approaches.

"The claim that qualitative research uses words while quantitative research uses numbers is overly simplistic. A further claim that qualitative studies focus on meanings while quantitative research is concerned with behaviour is also not fully supported since both may be concerned with people's views and actions. The association of qualitative research with an inductive logic of enquiry and quantitative research with hypothetic-induction can often be reversed in practice; both types of research may employ both forms of logic" Brannen (2005)

The process of conducting research makes it crucial to identify and understand the philosophy that underlies the research. This is important because it is believed to greatly influence the process and direction of the research, and help to figure out how an inquiry of knowledge is able to develop and turn raw data into valid knowledge. From the *ontological* point of view, this research leans towards objectivism rather than subjectivism. The reason behind this can be explained by the main subject of this research which is the BIM system, while the participants only act as a 'responder' that provides feedbacks about the effect posed by the system on their organisations. In terms of *epistemological* stance, this research seems to heavily lean towards *positivism*. The whole reason of this is that the inquiry is largely based on the effects of BIM system on the professional practice, which makes it an 'objective' and 'value free' survey because it does not require inputs from participants' emotions and feelings. These two assumptions further lead the theorisation of this research points towards a *deductive* process. Deductive research is often known to engage quantitative approach for data collection; however, this research adopts a mix-methods approach and the design is based on a process termed as *convergent parallel design* by Creswell and Clark (2011).

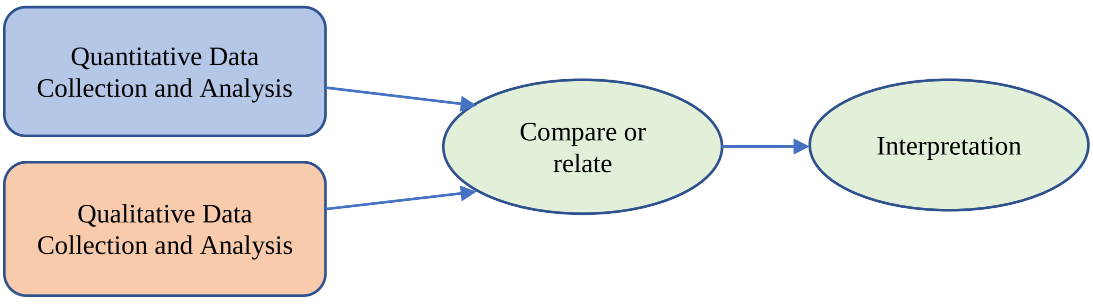


Figure 1.1: The convergent parallel design.

The research process started with the literature review which comprises two parts, namely Chapter 2 and Chapter 3. The purpose of the first part of the literature review is to form knowledge on the current issues and challenges that are brought by the development of digital technologies, which in this case refers to BIM. Generally, this section is concerned about the local and global AEC industry, which include forming initial ideas to identify research problems and develop research aim and objectives. Meanwhile, the second part of the literature review elaborates the development and issues pertaining to BIM in architecture education and its relation to the industry, which acts as a continuation from the previous part with the purpose of providing a wider and deeper understanding of the issue at large. More importantly, the research problems are strengthened and research aim and objectives are formed at this point. The literature review continued by focusing on the theoretical and fundamental concept of developing a curriculum module. This section is summarised by presenting the theoretical research framework that can later be used by local HEIs to develop a BIM centred curriculum module based on the demand of the industry. Overall, the framework establishes the scope of exploration and guides the research process to reach the completion stage.

The theoretical research framework sets out that survey questionnaire is the most suitable instrument for this research. In relation to this, it is recommended to be developed based on the specific categories outlined by the framework in order to collect the primary data from two samples of different backgrounds and contexts, namely Survey A for the architecture industry and Survey B for architecture education. The first instrument is Survey A, and it is in the form of a self-completion questionnaire developed using an online survey tool with a total of 20 close-ended questions that were allotted into five segments, namely Demographics Information, Applied Computer Technology, BIM in Practice, General View towards BIM, and Role of Academia. The second instrument is Survey B which is also developed using an online survey tool with a total of 12 close-ended questions and 12 open-ended questions that was categorised into four segments, namely Demographics Information, Applied Computer Technology, BIM in Architecture Education, and General View towards BIM.

The research progressed into the data collection phase following the development and construction of the instruments for primary data collection. Survey A was distributed through emails to a total of 535 architecture firms all over Malaysia that were registered as professional members to the Malaysian Institute of Architects or *Pertubuhan Arkitek Malaysia* (PAM) as well as the Malaysian Board of Architects or *Lembaga Arkitek Malaysia* (LAM). Meanwhile, Survey B, which is also in the form of questionnaires was electronically distributed through emails to all but one accredited architecture school of the public HEIs in Malaysia with the total of six universities, namely Universiti Malaya (UM), Universiti Sains Malaysia (USM), Universiti Teknologi MARA (UiTM), Universiti Teknologi Malaysia (UTM), International Islamic University Malaysia (IIUM), and Universiti Putra Malaysia (UPM) (Rahman, 2010). However, it is worth to acknowledge that there are many more HEIs with architecture schools in the country but they are either not accredited by LAM or private HEIs. The private HEIs were left out considering that it is common for private establishments to comply to the educational policies implemented in public HEIs in Malaysia. All the returned response data from both surveys are then compiled and arranged in the cloud-based database provided by the same online survey development software.

In general, the research has adopted a deductive route that entails the survey instruments to be objective and structured; however, there are some obvious differences between Survey A and Survey B which may affect the analysis of data collection. The collected data for Survey A were developed to be characteristically quantitative; hence, they are analysed and described using descriptive statistics. In this case, three basic statistical measures are utilised, namely distribution, central tendency, and dispersion. Meanwhile, the survey questionnaires for Survey B consist of a mixture of quantitative and qualitative approach with the integration of both open-ended and closed-ended questions. The collected data for Survey B are analysed and described using descriptive statistics despite the mixed-method approach. However, the only obvious distinction between both surveys is that Survey B utilised descriptive coding to analyse the response to all open-ended questions in order to ensure that the survey remains objective. The results from the analysis of both surveys are then counter checked with the literature review discussed earlier and also the accreditation requirements by *Lembaga Arkitek Malaysia* (LAM) and Malaysia Qualifications Agency (MQA), while the findings from this exercise are utilised to develop and construct a theoretical framework of recommendations for BIM integration into the architecture programme in Malaysia. This theoretical framework is then presented and validated by the HEIs before being refined prior to the establishment of the final framework. The process flow of the research is described in detail in Chapter 4 with the help of Figure 4.6 and Figure 4.7; Chapter 5; and Chapter 6, respectively.

1.8 CONTRIBUTION TO KNOWLEDGE

The researcher was the academic staff in-charged of matters related to digital technologies in the Department of Architecture of Universiti Kebangsaan Malaysia (UKM) at the time he applied to embark on the PhD journey. The department was still a very young department considering that it was about to take their fourth batch of students for their Part I architecture degree programme. In 2009, LAM was invited to assess the curriculum syllabus for the architecture degree programme of UKM for the very first time. The review made by LAM have touched on numerous things concerning the syllabus, particularly for the courses of *Architecture Computer Application* and *Digital Media* which are known to be the core courses for the degree of *Bachelor of Science in Architecture*. The highlights of the review stated that majority of the HEIs in Malaysia only teach traditional 2D drafting and 3D visualisation software, and have not strictly considered exploring new dimensions in architecture digital technology. Hence, a recommendation was made by stating that it is better for UKM to explore new dimension in this subject and offer something new and different to the architecture education in the country considering that it was still a young department that was just starting out a new programme. Moreover, LAM was also looking at the prospect of BIM and applications for building performance simulation to be introduced into the tertiary education level to fully prepare graduates to adhere to the trends of the industry by taking into account that there may be a possibility of a shift from CAD to BIM. However, adopting BIM was not officially in LAM's immediate plan of action; hence, it would be very helpful to the architecture education in the country if a research can be carried out to produce a suggested framework in the effort of developing BIM curriculum for the architecture education in Malaysia. The framework which is the end product of this research will be proposed to LAM to be part of its accreditation criteria for future assessments of architecture Part 1 and Part II degree programmes.

1.9 STRUCTURE OF THE THESIS

In reference to Figure 1.2, it can be clearly seen that the thesis write-up for this study is divided into the following eight chapters for the purpose of creating a traditional flow of a thesis: Introduction, Literature Review I, Literature Review II, Methodology, Data Analysis and Findings I, Data Analysis and Findings II, Framework for BIM curriculum in Architecture Degree Programme, and Conclusion and Recommendations.

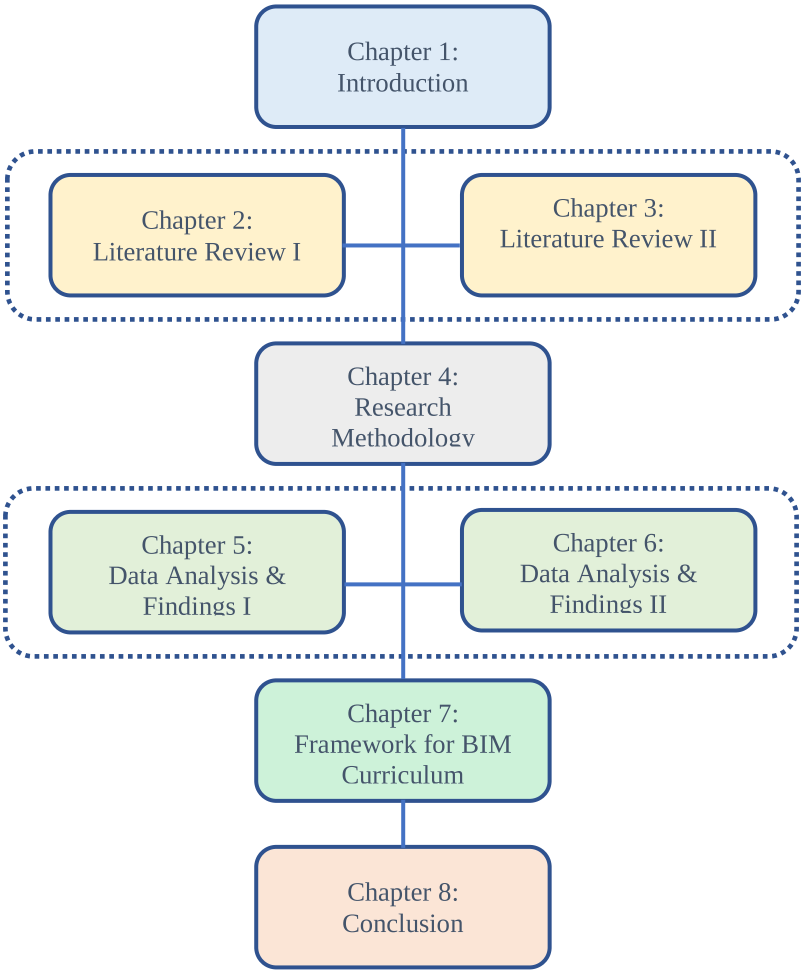


Figure 1.2: The structure of the thesis

Chapter 1 – Research Introduction: This chapter presents the background of the research, including the introduction of research topic. The first section of this paper briefly explains the research overview, research questions, research aim and objectives, research context, research methodology, and flow of thesis.

Chapter 2 – Literature Review I: This chapter concerns the first out of two phases of literature review. The aim of this section is to provide a general overview of the Malaysian Architecture, Engineering and Construction (AEC) Industry, which acts as the background of the research theme. The general discussion revolves around the need to address the issues related to the industry and the need for digital technologies within the context of the country.

Chapter 3 – Literature Review II: The second part of the literature review continues to discuss related matters and issues to gain a deeper understanding of the subject matter. This chapter begins by looking into various definition and terminologies adopted in the digital technology world, including the evolvement and progress of these technologies over the past years. The review then continues to explore, appraise, and synthesise relevant literature pertaining to BIM in professional practices and academia; particularly the relationship between the industry and academia. The chapter is summarised by quantifying the findings of the literature into an outline that builds up the case for knowledge inquiry, which is subsequently used to develop the theoretical framework for this research.

Chapter 4 – Research Methodology: This chapter highlights the philosophical and methodological concerns that are related to the applied research techniques. This section also outlines the research design and process flow that builds up the framework for the overall process of knowledge inquiry for this research. Moreover, it describes the relevant factors and considerations that support the notion as to why surveys are a feasible research instrument in achieving the objective of a descriptive research.

Chapter 5 – Data Analysis and Findings I: The fifth chapter focuses on Survey A which refers to the data collection process for primary data from the industry. Several important aspects are described which include the questionnaire survey, the planning that was considered prior to undertaking the process, the steps involved in the process of analysing the data with more emphasis on technical procedures, and finally the report on the findings.

Chapter 6 – Data Analysis and Findings II: This chapter on the other hand focuses on Survey B, which was the data collection process for primary data from the architecture schools of public HEIs. It describes the questionnaire survey, the planning that was considered prior to undertaking the process, how it was conducted and analysed with more emphasis on technical procedures, and finally followed by the report on findings.

Chapter 7 - Framework for BIM curriculum in Architecture Degree Programme: The following core recommendations refer to the key findings of this research, with the purpose of outlining the necessary requirements in developing BIM-enabled architecture degree programmes in Malaysia.

Chapter 8 – Conclusion and Recommendations: The purpose of the final chapter is to discuss the results obtained during the course of the research and the subsequent analysis. This chapter also aims to reflect on the extent of this study by revisiting and discussing the research aims, outline, objectives, questions, methods and process.

Finally, it presents the conclusions deduced by the attainment of the research objectives, specifying the limitations of the study and lastly suggests recommendations for future research. The related references and appendices are presented at the end of the thesis.

CHAPTER 2: LITERATURE REVIEW I – MALAYSIA: FROM CAD TO BIM

2.1 INTRODUCTION

The purpose of this chapter is to discuss several matters and issues in order to gain an in-depth understanding on the subject matter. The discussion is further divided into two parts. The first part of this literature review provides a general overview of the Malaysian Architecture, Engineering, and Construction (AEC) Industry which is regarded as the background of the research theme. The discussion generally involves several issues related to the Malaysian industry, including the need for digital technologies to overcome the mentioned issues. A wide range of common problems and challenges that appear to exist in the industry include the lack of coordinated information and collaborative design processes, fragmented nature of project team players and industry playmakers, absence of sustainable character in designs, and unsatisfactory aspects of quality, including time and cost overruns are highlighted prior to the development of relevant plan and action that should be taken by the Malaysian government in addressing these issues. In addition, the discussion further describes the position of digital technologies within the country's road map and master plan to improve AEC industry, which is also a part of Malaysia's effort to achieve its target to be a fully developed country in the next decade.

Meanwhile, the second part of the literature sets out to explore numerous established definitions and terminologies employed in the world of digital technology as well as to discover how these technologies have evolved and progressed over the past years. In general, most terms are known to be related to one another; however, CAD, CAAD, CAM, CABD, BPS, and BIM are recognized and distinguished to a certain degree based on their various qualities and characters. The plot of this discussion is narrowed down to only Building Information Modelling (BIM) which acts as the focus of this research. The review is continued by explaining how the development of BIM has affected the professional practice and academia, which is followed by the discussion on the benefits and barriers related to the implementation of the technology.

"Today's scientific landscape is quite different. Academics deliberately avoid the thicker part of the wood, and if they encounter challenging problems, they give up in a heart beat to move on to other problems that are more likely to produce publications. Unfortunately, this kind of science leaves numerous challenging problems behind, some of which cut into the very guts of commercial CAD systems". (Piegl, 2005)

Most of the resources for the literature review are gathered from academic publications which include white papers, online databases, and technical reports from major vendors of BIM related applications. Apart from that, the guidelines and reports generated by governments and other regulatory bodies such as RIBA and AIA are also considered in this review. Finally, a number of articles taken from respectable online newsletters and magazines that provide information on the most recent development of BIM are also included in the overview of the present study. The first part of this chapter is viewed as significant because it provides the secondary data for the development of research framework for the purpose of this study.

2.2 MALAYSIA: BACKGROUND AND ITS AEC INDUSTRY

2.2.1 THE BACKGROUND OF MALAYSIA

Malaysia is a federal constitutional monarchy in South East Asia which covers an approximate area of 329, 758 square kilometres, thus making it the 67th largest country by total land area. The country is separated into two regions by the South China Sea, namely Peninsular Malaysia and the island of Borneo. Specifically, Peninsular Malaysia consists the most number of states which include Johor, Kedah, Kelantan, Melaka, Negeri Sembilan, Pahang, Perak, Perlis, Pulau Pinang, Selangor, Terengganu, while the island of Borneo is made up of only two states known as Sabah and Sarawak (Ministry of Tourism Malaysia, 2014). On top of that, Kuala Lumpur as the largest city also acts as the capital city of Malaysia, followed by the establishment of a new federal administrative centre in 2001 known as Putrajaya, located 25 kilometres southward. According to the report by the Department of Statistics of Malaysia in 2010, the population of the country stood at 28.3 million (22.6 million on the Peninsula) with the approximate distribution of ethnic groups recorded as follows: Malay/Indigenous (67.4%), Chinese (24.6%), Indian (7.3%), and other ethnic groups (0.7%). Hence, it is obvious that the Malays are the predominant ethnic group in Peninsular Malaysia among the Malaysian citizens, which constitute a total of 67.4% of the entire Malaysian population (Department of Statistics [DOS], 2010).

Malaysia has had one of the best economic records in Asia since its independence in 1957, with the growth of GDP recorded at the average of 6.5% for a duration of almost 50 years. The economy of Malaysia was fuelled by its vast natural resources and agriculture during the early years, but has now expanded to the sectors of commerce, manufacturing, tourism, and has recently become the world's largest Islamic banking and financial centre. According to the Department of Statistics, the GDP per capita (PPP) of Malaysia in 2012 stood at USD14,774, while its GDP (purchasing power parity) was estimated at USD501.5 billion, which then ranked the country the 30th place in the world (DOS, 2013b, C.I.A, 2014). The decent performance of the nation economy also caused several positive results to the country which include being the 6th most integrated economy in Asia Pacific, 10th most attractive destination for FDI, and 14th most competitive countries in the world (MIDA, 2008, MAMPU, 2014).

Table 2.1: Growth of Gross Domestic Product and Gross National Income at Current Prices, 2000 – 2012, Malaysia (DOS, 2013b)

Tahun *Year*	**KDNK** *GDP*	**PNK** *GNI*	**Penduduk** *Population*	**KDNK per kapita** *GDP per capita*	**PNK per kapita** *GNI per capita*
	RM (Juta / *Million*)	**RM (Juta** / *Million*)	**('000)**	**RM**	**RM**
2000	356,401	327,492	23,495	15,169	13,939
2001	352,579	326,956	24,031	14,672	13,606
2002	383,213	358,152	24,543	15,614	14,593
2003	418,769	396,232	25,038	16,725	15,825
2004	474,048	449,646	25,542	18,560	17,605
2005	543,578	519,635	26,046	20,870	19,951
2006	596,784	579,490	26,550	22,478	21,826
2007	665,340	651,355	27,058	24,589	24,072
2008	769,949	746,915	27,568	27,929	27,094
2009	712,857	698,642	28,082	25,385	24,879
2010	797,327	770,993	28,589	27,890	26,969
2011e	884,456	862,650	29,062	30,433	29,683
2012p	941,237	905,213	29,518	31,887	30,667

As shown in Table 2.1 above (DOS, 2013b), the country managed to achieve a moderate growth rate for both Gross Domestic Product (GDP) and Gross National Income (GNI) with the average of 4.6% to 5.0% between 2000 and 2012. However, two occasions of minor decline against the rising trend were detected, particularly with a more substantial record from 2000-2001 and 2008-2009. According to CIDB (2009), the global economic crisis that happened in 2008 found its root in America, and was later spread to other parts of the world which significantly impacted Malaysia's economy. However, the contraction of economy by 1.7% in 2009 was the result of the sharp and rapid fall of global demand and collapse of world trade, which also affected Malaysia's export and industrial production. Notwithstanding, the rapid fall did not last long when a slight growth managed to be recorded in the following year, thus further signifies a slow but steady recovery of the country's financial state as a result of strong public spending and sustained private consumption (Chan, 2009). In 2011, the economic growth increased steadily at the rate of 5.1% with a GDP of RM884.5 billion (USD269.9 billion)(DOS, 2013b).

2.2.2 THE BACKGROUND OF MALAYSIAN ARCHITECTURE, ENGINEERING AND CONSTRUCTION (AEC) INDUSTRY

The development of architecture, engineering and construction (AEC) industry in Malaysia started before independence in 1957, which is in accord to the work of Lewis (1955) that states the AEC industry usually takes more than half of the country's capital formation. At that time, the industry was low-tech, labour intensive crafts based industry (Kamal et al., 2012). According to the initial economic plan (1956-1960), it is clear that a fairly substantial amount of budget was allocated for the industry as part of the development expenditure plan (Ibrahim et al., 2010). As a new independent country, it was crucial to develop proper infrastructure for the purpose of providing a strong platform that is expected to support and expand the country's economy as well as to enable better competition with other rising Asian countries. On top of that, the AEC industry's output was known to be relatively small in comparison to other sectors in the country such as manufacturing and services; however, the government was well aware that the industry will definitely be extremely important to the country based on the industry's strong growth push as a result of its extensive backward and forward linkages with the rest of the economy (Ibrahim et al., 2010).

The present Malaysian AEC industry has progressed and developed significantly, in which its achievements have taken the country into a respectable position in the Asia-Pacific region. The present industry has become more advanced, modernized, and well-equipped, which allows it to better deliver complex heavy infrastructure and state-of-the-art high-rise building projects using sophisticated mechanized techniques. The construction started to boom in the early 1990s in conjunction with the rapid execution of high profile projects which include the world tallest twin towers known as Petronas Twin Towers in 1996 (US$2.9 bn); the Kuala Lumpur International Airport in 1998 (US$3.5 bn); North South Expressway from 1982 onwards (>US$20 bn); Penang Bridge I & II in 1985 and 2014, respectively (US$300mil & US$1.3 bn, respectively); Stromwater Management and Road Tunnels in 2007 (US$520mil 2007); Light Rapid Transit (LRT), Monorail and Mass Rapid Transit (MRT) from 1996 onwards (>US$15bn); Commonwealth Games stadiums and village in 1998 (>US$1bn); the administrative city of Putrajaya (>US$10bn), Malaysia's Multimedia Super Corridor (US$6.5bn), and numerous other projects that have turned the AEC industry into a very important and productive sector for the Malaysian economy (Ibrahim et al., 2010). On top of that, Malaysian architects and contractors have also completed international projects outside the country such as Burj-al- Arab (Dubai), International Formula 1 Circuit Bahrain, New Doha International Airport, Khalifa Olympic Stadium, Dukhan Highway in Qatar and numerous others around South East Asia (Hasan, 2012). Overall, Malaysian companies had completed 652 building projects around the world between 2000 to 2010, which accumulates a total value of US$26.5 billion (RM92.14 billion) (Mustaffa et al., 2012).

Table 2.2: Principal Statistics of Construction Industries, 2000 – 2010, Malaysia (DOS, 2013b)

Tahun *Year*	**Nilai output kasar** *Value of gross output* **RM ('000)**	**Nilai input perantaraan** *Value of intermediate input* **RM ('000)**	**Nilai ditambah** *Value added* **RM ('000)**	**Jumlah pekerja pada bulan Disember atau pada tempoh gaji terakhir** *Total number of person engaged during December or the last pay period*	**Gaji & upah yang dibayar** *Salaries & wages paid* **RM ('000)**	**Nilai harta tetap yang dimiliki pada akhir tahun** *Value of fixed assets owned as at end of the year* **RM ('000)**
2000	39,872,025	26,647,632	13,224,393	458,580	8,722,298	6,688,178
2005 [B]	53,960,259	34,963,423	18,996,836	551,775	10,867,665	7,486,517
2010 [B]	91,341,685	59,400,380	31,941,305	974,488	19,841,387	14,476,140

Nota/*Note*:
B = merujuk kepada tahun Banci / *refers to Census year*

The AEC industry in Malaysia has been seen to develop and elevate into a very important and productive sector within the country's economy since the 1990s. Table 2.2 illustrates all the key indicators in this sector that had increased within the decade between the three reference years. The gross output started with US$12.1 billion in the year 2000, which is then increased to US$16.5 billion in 2005, and followed by an increment recorded as US$28billion in 2010. The increment of the sectors output provides an average annual growth of 5.9% and 11.1% between 2000 to 2005 and between 2005 to 2010, respectively. In line with the growth in output, the value of intermediate input in 2000 is observed to increase by US$10 billion which provides a new record of US$18 billion with the average annual growth of 11.2%, thus resulting in a value added of US$9.7 billion in 2010 (DOS, 2011).

Meanwhile, the total workforce engaged in this industry was found to be 458,580 in the year 2000, while the number of personnel in 2005 was observed to increase by a total of just 93,195 personnel, which accumulates to 551,755 personnel in total. However, the total workforce substantially grew in the next 5 years given that the total workforce in 2010 was 974,488 personnel, which represent an increase of 422,733 personnel (12.0%) from the total number of 551,755 personnel in 2005. In tandem with the expansion of total workforce, the total salaries and wages allocated also illustrated an increase of US$2.7 billion (12.7 %), which records a total of US$6 billion in 2010 in comparison to US$3.3 billion in 2005. On another note, the value of fixed assets also expanded from US$2.0 billion in 2000 to US$2.3 billion in 2005, and with the latest recorded amount of US$4.4 billion in 2010 (DOS, 2011).

Table 2.3: Employment by category of workers and their salaries & wages, 2010 (DOS, 2011)

Category of workers	Full-time employees		Salaries & wages		Average salaries & wages received per annum (US$)
	Number	% share	US$ million	% share	
TOTAL	**946,108**	**100.0**	**5,965**	**100.0**	6305
Professional Consultants	35,616	3.8	749	12.5	21026
Technical and supervisory	38,521	4.1	409	6.9	10615
Clerical	37,866	4.0	233	3.9	6141
Construction/operative workers	811,980	85.8	4450	74.6	5481
General workers	22,125	2.3	124	2.1	5605

Table 2.3 illustrates that out of 946,108 full-time employees in mid-2010, only a total number of 811,980 personnel (85.8%) are categorised as construction or operative workers, which in turn represents the biggest employment category. However, their average income per annum amounts to only US$5481 despite having the highest number of personnel. On the other hand, the professional consultants group such as architects, engineers, and surveyors are only represented by 35,616 personnel (3.8%)

with the average income of US$21,026 per annum. In this case, it may seem coherent that professionals tend to earn more than construction or operative workers on site; however, low cost labour and the absence of minimum wage policy in the country are the reason that leads to the wide gap between the two groups. Nevertheless, the government's introduction of minimum wage of US$300 per month starting from 2012 expects to observe the changes in trend, and it makes it crucial for the industry to find alternative means if the profit margin is to be kept at the same rate.

Table 2.4: Value and Number of Construction Projects by Sector and Type (CIDB, 2013)

Sector and Type of Project	Value US$ billion	Number
	Year 2012	
Total Private Sector	**30.7**	**5,380**
Residential	9.1	1,929
Non-Residential	10.7	2,199
Social Amenity	0.9	197
Infrastructure	10.1	1,055
Total Public Sector	**5.4**	**1,860**
Residential	0.4	187
Non-Residential	1.0	318
Social Amenity	1.1	628
Infrastructure	2.9	727
Grand Total	**36.1**	**7,240**

As can be observed from Table 2.4, the ratio of construction projects between private and public sector in the country is relatively healthy, whereby the major contribution comes from the private sector with the domination of 85.2% out of all projects which amounts to US$30.7 billion, while the remaining projects (14.8%) amounting to US$5.4 billion are held by the government. In terms of the number of construction projects, it is clearly stated that a total of 5,380 construction projects are delivered by the private sector, while the public sector contributes to only 1860 construction projects. Hence, this further implies that the AEC industry has now been driven by the private sector without having to rely on the government, which is a decent progress compared to the situation following independence in the 1960s and 1970s. In parallel to the ever-growing economy, private investment activities have received a wide attention which has led more developers to embark on new construction projects. Overall, it is important to acknowledge that government's investment in mega projects and infrastructure in the 1990s has managed to push the private sector as the main driver of the economy, especially in the AEC industry.

2.2.3 THE CHALLENGES IN THE AEC INDUSTRY

The remarkable progress, constant growth, and significant contribution of the AEC industry to the economy are widely acknowledged; however, it is part of the constant demand for the industry to improve its performance in ensuring that it is on par with other developed Asian nations such as Japan, Singapore, and South Korea. According to the CIMP (2007) report, the AEC industry is described as adversarial, disorganized, and incompetent, which emphasizes the need of structural and cultural reform. In relation to this, a considerable amount of literature has been published on the problems faced by the AEC industry all around the world. However, the most important weakness lies in the fact that the research carried out by the academics, practitioners, and industry players has been very limited, which seem to affect the local AEC industry. According to Ibrahim et al. (2010), the problems and issues faced by the AEC industry among developing countries in local and international journals, conferences, and conventions has received very little attention.

Furthermore, it is unavoidable to dismiss the issue of delay and cost overrun when it comes to the issues concerning the AEC industry. The Ministry of Housing and Local Government (KPKT) of Malaysia described project delay as any delays that take place during the construction period where the gaps between the actual in-progress sites work and the work scheduled goes between 10% to 30% (KPKT, 2010). On the other hand, cost overrun is defined as extra cost that exceeds the agreed cost between clients and contractors during the signing of the contract (Endut et al., 2009). According to Sambasivan and Soon (2007), one of the most critical issues in Malaysian AEC industry revolves around project delay in the delivery of project, whereby nearly 20% of all public funded projects were considered in bad shape (more than 3 months of delay or abandonment). On another note, a study by Endut et al. (2009) reported that only 20.5% and 33.35% of the public projects and private sector projects were completed within time, respectively. The issue of project delays in the AEC industry is a global phenomenon, and only fully developed countries have been observed to be coping with it better compared to developing and third world countries. However, it is also important to note that the key to successful project delivery includes timely delivery of projects within budget and the acceptable level of quality standard specified by the client. Moreover, there could be various unexpected negative consequences related to the failure of completing projects within its targeted time, budgeted cost, and specified quality. The common consequences of project delays include the disruption of work and loss of productivity, which will incur additional cost and normally goes way beyond the contingency allowance cost permitted by the contract (Pheng and Arain, 2006, Asadi et al., 2015). The cost overruns resulted by the mentioned issues is quite alarming, and Endut et al. (2009) discovered that only 46.8% and 37.2% of projects in the country managed to be completed within the given budget for the public and private sector, respectively. A more recent study by Shehu et al. (2014) proves that this issue is still ongoing when it was found that 55% of local construction projects were completed above the original contract sum. However, the worst-case scenario would be the abandonment or termination of contract which happened to 3% of the entire housing projects in the country (Dahlan and Mariappan, 2012). A survey conducted on construction firms and consultants in the country by Sambasivan and Soon (2007) found several reasons that lead to project delay which include the lack of communication between parties, contractors' improper planning, mistakes during the construction stage, time overrun, and cost overrun. Alaghbari et al. (2007) conducted a survey based on the viewpoints of four (4) different trades, namely consultant factors, contractor factors, owner factors, and external factors, and the findings seem to strengthen Sambasivan's findings. According to the survey, despite the slight difference in the opinions provided by the four different trades on the factors contributing to the delay of project deliverables due to different nature of their tasks and job scope, it was found that three out of the four trades share the same view on one thing, which states that coordination problems between team members is one of the main contributors of delays and cost overruns.

Meanwhile, a survey done by Abdul-Rahman et al. (2006) reveals that 45.9% of delays mostly happened during the construction stage. It was also discovered that a substantial 34.6% of parties expressed their dissatisfaction regarding the unclear design and design details by consultants that further contribute to project delay. Moreover, the survey by Alaghbari et al. (2007) found that incomplete design documents by consultants seems to interfere with site progress and contributed to projects delays, which is consistent with the findings of Abdul-Rahman. Apart from change of plans or scope by owners, research by Pheng and Arain (2006) from the National University of Singapore found that errors and conflicts in consultants' drawing documents resulted by the change in design and specifications as well as omissions in design are considered as the top causes of variation orders and delays of project deliverables. The findings were based on Spearman's rank correlation which also states that design complexity and inadequate working drawing details as the number five top causes of delays. The conventional design or construction drawings which consist of mainly 2D drawings of multiple files are individually passed around to be shared among consultants. However, it has always been prone to errors due to the fact that data and information from various trades of consultants does not fully integrate and coalesce with each other. There is little to no correlation or intelligent connection between them as these drawings were created separately, thus any changes or updates of the drawings need to be done and passed upon from one consultant to the other before formally submitting it to the owner and contractor. This may not be a huge problem if the project is small and simple, but changes and alterations for a huge size project can be hundreds in numbers due to its complexity. Moreover, to keep updated with every change or alteration without discrepancies and errors would be very difficult. Frequent occurrence of the above will result in confusion and misinterpretation of the actual requirement may lead to major construction errors, variations, delays, project cost, and overhead expenses in the project deliverables (Pheng and Arain, 2006).

2.2.4 THE ROOT OF THE PROBLEMS TO THE CHALLENGES

The three main problems that have been stated include delays, cost overruns, and design related problems. These problems are major continuing problems that have cost the Malaysian AEC industry a huge sum of money since independence in 1957. The root of the problem comes down to one major cause which is fragmentation even though all the three problems may have numerous unique causes and factors of their own. According to CIDB (2003) and Abdul-Rahman et al. (2014), fragmentation is the main problem in the industry. Several studies have been conducted in relation to the problem of fragmentation within the AEC industry in Malaysia, and most of the findings agreed with CIDB's concern that the industry is highly fragmented and that there is a separation between parties involved in the project, namely client, consultants, main contractors, sub-contractors, and workforce on site (Kamal et al., 2012).

One of the main contributions to fragmentation lies in the traditional approach of construction that the country has embraced for so long, which refers to high dependence on old conventions of building techniques. According to CIDB (2003), the team players exchange information among them in a sequential and fragmented approach in a typical traditional project life cycle practiced in the country, and the problem arises when accurate interpretation of information decreases from one stage to another throughout the process and progress of the projects. As a result, it leads to higher risk of errors due to misinterpretation and misunderstanding of information, and the overall accomplishment of the project is most likely to be reduced. According to Nawi et al. (2013), Malaysia's fragmented approach to project delivery and its failure to form effective teams have created a number of issues such as reworks, time delay, lack of communication and coordination, and wastages that intervene the quality issues and the inefficiency of project delivery times, poor performance, rising costs, and client dissatisfaction of products delivery. A study conducted by Nima et al. (2001) added that there is a gap between the design team and the construction team from as early as the design stage which prevent each other from appreciating the other's work. This matter will definitely lead to a separation and fragmentation between the various stages of the construction life cycle. Evbuomwan and Anumba (1998) echoed this by stating that the problem of fragmentation has led to an inter alia; an adversarial culture, whereby the design and construction information with information produced at one stage may not be automatically available to be re-used downstream; and the lack of real-life cycle analysis. Hence, it is strongly suggested to utilise advanced information technologies to overcome this issue as shown by other construction industries in developed countries as well as other sectors within Malaysia (Nima et al., 2001). The use of advanced IT technologies will greatly help to overcome the problem of fragmentation into specialized roles in this field, which will also enhance the design and the constructability process with improved project deliverables.

The AEC industry in Malaysia is also known to be highly dependent on unskilled foreign labour. As reflected by the current practice of the industry, Kamal and Flanagan (2012) from the University of Reading found that the majority of the construction companies in Malaysia, especially the Small to Medium Enterprises (SMEs) still operate within the traditional way based on their choice of using cheap unskilled foreign labour. According to the Department of Statistics as of June 2013, the Malaysian Construction industry employs 1,163,700 foreign labour or about 10% of the country's total employment of 12,723,200 (DOS, 2013a). Hence, foreigners occupy nearly 70% of the construction labour (Hamid et al., 2011, CIDB, 2008). The use of unskilled foreign labour for the AEC industry has led to the adoption of construction systems that are inefficient, inept, time-consuming, and labour intensive. Many contractors regard it as being low risk and most affordable and profitable method for their business regardless of the negative impacts of using unskilled foreign labour, but they did not deny that this may be true only on short-term basis. Kamal and Flanagan (2012) added that the main motivation is only to survive and complete any on-going project as there is no guarantee of a continuing workload. Hence, this prevent them from investing in new and high technology methods or systems, which is currently witnessed by the industry. Moreover, there are many other problems related to the usage of unskilled foreign labour such as lack of experience and training, low productivity, poor quality of work, communication barriers, and limiting jobs opportunities to the local population. Marhani et al. (2012) further added that the worst long-term effect would still be the lack of initiative to adopt more productive methods of construction and new modern technology, which seems to limit and hinder the development and progress of the industry. If the country had not allowed the massive influx of foreign workers; hence, local manufacturers and builders would have been forced to innovate, automate to boost productivity to maintain their competitiveness so that they could move up the value chain (Kok, 2011). For the government to reduce the industry's reliance on cheap unskilled labour or human capital, the industry must be driven to invest in technology and capital-intensive construction including digital and information technology, mechanization, prefabrication, and creative use of new construction project management techniques (Ibrahim et al., 2010).

Another issue related to Malaysian AEC industry that directly correlates to the influx of unskilled foreign labour is low productivity. The productivity level of the AEC industry in Malaysia by mid-2013 was worth US$6755 (RM 21765), which observed an increase of 15.5% from the previous years. The growth rate was the highest but the industry's productivity was still the lowest compared to other main industries, namely agriculture, mining and quarrying, manufacturing and services, and the GDP per worker was about half that of other industries (MPC, 2013). This issue has been highlighted as a serious problem by the Construction Industry Development Board (CIDB) master plan for occupational safety and health (DOSH, 2004), and one of the major causes that contributed to this matter can be explained by the lack of emphasis in the utilization of new technologies, innovative approaches, and research and development (R&D). In consideration of this issue, the CIDB in collaboration with the Building Industry President's Council of Malaysia have held a CEO and Presidents Roundtable Discussion with all the major leaders and players within the industry in June 2003 to address this issue and provide proposals to list out the solutions to the problem. The suggestions and proposals that came out from this discussion state that AEC industry should use automation, prefabricated products, new construction methods and techniques, and new modern technology in order to improve productivity and restore the image of the industry. The above forum was followed by the Roundtable Consultative Forum with Captains of Industry in April 2006 and the Special Meeting with the Secretary General of Ministry of Works in May 2007 was held in order to formalize the establishment of the Malaysian Construction Industry Master plan (CIMP) that initially proposed the enactment of an ACT that partly addresses the issue of productivity of the industry (Ali and Fong, 2008).

However, it was not really successful despite all the efforts and initiatives by the government and the CIDB to improve the situation. According to Ibrahim et al. (2010), the AEC industry is still using the traditional construction technique unlike other major economic sectors that have advances in the utilization of modern technology and innovation. On a similar note, Kamal and Flanagan (2012) study found that there is a mismatch between the introduction of new technology and the ability for the industry to absorb, use, benefit, and apply in the production phase. The slow progress that the industry is facing in its effort to improve the productivity of the industry can also be reflected by its level of seriousness in pursuing innovation. In this case, the performance of innovation is measured by R&D expenditure, thus this confides that the industry is far from being exemplary in the case of productivity improvement. The level of funding for construction R&D is a paltry US$37 (RM120) per US$0.3 million (RM1 million) of construction output based on a budget of US$1.9 million (RM6 million) for construction research and a construction output of approximately US$15.5 billion (RM50 billion) a year. Contrastingly, data from the UK and other European countries indicate that construction R&D spending increased from £586 per £1 million of construction output in 1991 to £953 in 1998 (Chan, 2009). This clearly shows that the AEC industry in Malaysia is still far from achieving the standards of practice adopted by other construction industries of developed countries. If the government is serious in fixing the problem of low productivity that the industry is facing, it is encouraged for the government to ensure that the industry undertake public education about the situation and invest more in technology and research and development (R&D) to improve the design and operational performance in project deliverables. The development of construction techniques together with the progress in technology utilization will reflect the government and industry's level of concern to pursue innovation as a driving force that will not only solve the current problems, but also to improve and develop the industry to a level on par with other developed countries.

2.2.5 MALAYSIAN GOVERNMENT INITIATIVE

The development of most industries in Malaysia including the AEC industry has been observed throughout the years to be in accordance to the development and implementation of the country's economic policies. On another note, the execution was mostly based on the long-term perspective plan and medium term 5-year development plan called the Malaysia Plan. The construction activity during Phase 1 was mainly brought about by economic development programmes in agriculture, basic infrastructure, rural development, and the growth in capital expenditure on urban and rural housing which started from independence in 1957 to 1969. At that time, the country was young and its economy was still in the process of learning to stand on its own two feet; hence, this explains the reason why most of the construction work took place in the public sector. After the nation's first post-independence turmoil that happened in 1969 together with the discovery of oil and gas in the country, the government had to revise the long-term perspective plan and introduced a new policy for Phase II in 1970 known as the New Economic Policy.

Phase II which spans from 1970 to 1990 had observed the expansion of construction activities with the acceleration of public sector development expenditure, mainly in infrastructure projects in order to accommodate the growing migrants to urban areas, the expanding economic activities, and the increase in foreign direct investment in the late 70s. Moreover, residential projects were always in high demand especially in the expending urban areas; with the increase of growth in private investment has led to the increase of factories as a result of the expansion of industrial and manufacturing sector. It was during this phase in 1972 that the government introduced the Architects Act, Engineers Act, Quantity Surveyors Act as well as formed the Board of Architects, Board of Engineers, and Board of Quantity Surveyors. The Malaysian Institute of Architects (PAM) and the Institution of Engineers Malaysia (IEM) were formed much earlier in 1920 and 1959 respectively, with the purpose of representing the architects and engineers of the country; however, it was the statutory authority like the Board of Architects that represents the government and the profession to ensure that the government policies for the industry are implemented.

Phase III was known as the New Development Policy (NDP) and covered the duration period from 1991-2000. The purpose of its introduction was to set pace to enable

Malaysia to become a fully developed nation by the year 2020. The prime minister at that time, Mahathir Mohammad, kick started this new phase by introducing a vision called Vision 2020 with the hope to transform the country into a fully developed country in terms of national unity and social cohesion, economy, social justice, political stability, system of government, quality of life, social and spiritual values, national pride, and confidence (Mahathir, 1991). The government envisions that by the year 2020, Malaysia will be a united nation with a confident Malaysian society, which is infused by strong moral and ethical values, living in a society that is democratic, liberal and tolerant, caring, economically just and equitable, progressive and prosperous, and in full possession of an economy that is competitive, dynamic, robust, resilient, and socially just (National Print Department [NPD], 1991, NPDM, 1991, EPU, 2008). The government realized that the AEC industry's dynamic nature with its extensive backward and forward linkages with the rest of the economy plays an important role in providing the socio-economic infrastructure for economic growth and amenities that will improve living standards of the society in order to achieve the status of industrialized and fully developed country. Hence, the government had invested heavily in upgrading and modernising the infrastructure of the main cities in the country which have caused a construction boom in the country with huge scale projects which include infrastructure projects, housing, schools, hospitals, commercial and industrial buildings. In parallel to this, the government also realized that any heavy investment in any particular industry shall carry a comparable amount of risk, thus making it important to make sure that the execution of these projects are in the best forms in order to minimize the risk and ensure a fruitful outcome.

Sophisticated projects such as the Petronas Twin Towers, Kuala Lumpur International Airport, and the new administrative city of Putrajaya have provided new challenge to the AEC industry because they were required to be designed and built within a more advanced, comprehensive, and up-to-date approach and protocol. Therefore, it was time for the government to take a huge step in improving and enhancing the whole AEC industry. In facing these new challenges, the industry needed an urgent shift of paradigm from traditional methods to a more novel and ingenious method that will not only provide solutions for sophisticated projects design and development, but will also increase productivity, improve operations, and enhance product quality for the industry as a whole (Zaini, 2000). The government formed the Construction Industry Development Board (CIDB) Malaysia in 1994 in an attempt to address these challenges. The Construction Industry Development Board of Malaysia, or better known as CIDB was established under the Construction Industry Development Board Act (Act 520) as the statutory body that develops the capacity and capability of the construction industry through the enhancement of quality and productivity with a great emphasis on professionalism, innovation and knowledge in the effort to improve the quality of life (CIDB, 1994a). In simple words, CIDB is the custodian of Malaysian industry that represents the industry to the government and private sector. Since its foundation, the CIDB has put in a lot of effort in improving the industry including registering builders, helping to advance the knowledge base of the industry, and promoting awareness, and providing assistance in training, safety, and education.

The introduction of the National Vision Policy (NVP) in 2001 marks the second phase of Malaysia's journey to realize Vision 2020 that the country had embarked upon in 1991. It was during this period that CIDB managed to reach its first milestone when it produced and presented the first Construction Industry Master Plan (CIMP) 2006-2015 to the AEC industry in 2007. The master plan was developed jointly with Malaysia's Ministry of Works and the Public Works Department, relevant government agencies, and industry stakeholders. Moreover, the objective of its development was to overcome the weaknesses that were inherent in the construction industry (as stated in the preceding subchapter) for the purpose of transforming the industry into a dynamic, productive, and resilient enabling industry; supporting sustainable wealth creation and value creation that is driven by technologically-pervasive, creative, and cohesive construction community (Sundaraj, 2006). These objectives were formulated in tandem with the objectives and goals of Vision 2020, and they act as a guide for the formation of the master plan based on the Seven (7) strategic thrusts stated as follows:

1. Integrate the construction industry value chain to enhance productivity and efficiency.

2. Strengthen the image of construction industry.

3. Strive for the highest standard of quality, occupational safety and health, and environmental practices.

4. Develop human resource capabilities and capacities in the construction industry.

5. Innovate through research and development and adopt new construction methods.

6. Leverage on information and communication technology in the construction industry.

7. Benefit from globalization including the export of construction products and services.

CIMP also provides 20 recommendations with 56 suggested action plans to achieve every strategic thrust at the implementation stage (Sundaraj, 2006). Apart from CIMP 2006-2015, the CIDB has also produced two comprehensive roadmaps to promote and establish Industrialised Building Systems (IBS) which is also known as pre-fabrication in the country. The first one is called the IBS Roadmap 2003-2010 which was formulated based on the CIMP and part of the effort to transform the AEC industry towards innovation and modernization to ensure the successful achievement of Vision 2020 (Shaari, 2006). The main goal of this roadmap was to turn the industry into an industrialized construction industry and achieve Open Building Concept by the year 2010 (CIDB, 2003). On the other hand, the new IBS Roadmap 2011-2015 which was a follow up effort to the previous roadmap was introduced to impose high-level intended outcomes for IBS implementation. Based on its 4 action plans and 37 action steps, it is hoped that the roadmap will path the way forward for sustainable IBS adoptions, with the goals of sustaining the existing momentum of 70% IBS content for public sector building projects through to 2015 as well as increasing the existing IBS content to 50% for private sector building projects by 2015 (Din, 2012).

Other notable efforts taken by CIDB during this period include the introduction and establishment of the Construction Labour Exchange Centre Berhad (CLAB) in 2003, the Construction Research Institute of Malaysia (CREAM) in 2004, the Masterplan for Occupational Safety & Health in Construction Industry 2005-2010 in 2005, the Malaysian Construction Industry Payment and Adjudication Act (CIPAA) in 2008, and the Green Assessment System together with the Green Building Index (GBI) in 2009 in conjunction with the Malaysian Institute of Architects and Association of Consulting Engineers of Malaysia.

2.2.6 DIGITAL TECHNOLOGIES IN MALAYSIAN AEC INDUSTRY

The discussions in preceding sub-chapters has led to the notion that innovation is highly needed by the AEC industry to provide solutions to numerous issues concerning the industry and spur the industry to progress towards achieving the goal of becoming a fully developed nation by the year 2020. As has been previously described, modern and advanced technology brings the much-needed innovation to the industry and the enabler for these are information and communication technology, computing, and information management, or simply known as digital technology. Studies and reports emphasised on the importance of effective communication to closely oversee and control projects activities according to the projects' plans and to achieve projects' goals. Moreover, this is possible to be achieved through the adoption of digital technology as it provides builders with advanced tools to improve collaboration, communication and information among the team players (Ahuja et al., 2006). In addition, digital technology is observed to support the most advanced construction systems and techniques such as the Industrialised Building System (IBS) (also known as pre-fabrication), 3D Volumetric Construction (also known as modular construction), Automatic Construction System Based on Robotic Cranes, and hybrid systems. For example, digital technology supports the differences in IBS processes by enabling more accurate documents, thus allowing the optimal conditions for an effective production to detect mistakes early and complications in the manufacturing and assembly phases to be averted (Ern and Kasim, 2012). In conclusion, digital technology has been widely regarded as the tool to increase and enhance innovation, creativity, productivity, efficiency, and performance (New Straits Times, 2007b, Corso and Paolucci, 2001, Davenport, 2013, Dibrell et al., 2008, Love and Irani, 2004, Boland Jr et al., 2007).

The influx of unskilled foreign labor in the country has definitely grabbed the attention of the government. Moreover, the government is well aware that over-reliance on foreign workers can cause detrimental consequences to the industry because continuous dependence on foreign labor will prevent local companies to automate and innovate as it is necessary to drive the industry to higher productivity levels (Ministry of Finance, 2014). The government has taken steps to promote and increase the utilisation of digital technology within the industry. In 1999, the government launched the Electronic Government initiative which is generally known as e-Government with the purpose to reinvent itself to lead the country into the Information Age. E-Government aims to improve the convenience, accessibility, and quality of interactions between the public and businesses at large, which further enhance the information flow and processes within the government (Shafie, 2007). Digital technology was given prominence by the government under the National Vision Policy (NVP) (2001- 2010), whereby the government had generously allocated a substantial US$1.5 billion (RM5.2 billion) to the digital technology-related programs and projects for the period 2001-2005 (Ali and Nor, 2010, New Straits Times, 2007b). Recently, the government have further accounted US$350 million (RM1.1 billion) for the improvement of digital technology applications within government departments and agencies. Moreover, the contribution of digital technology sector to the Gross National Income (GNI) was expected to grow to 17% or US$91 billion (RM294 billion) and total domestic spending on digital technology would reach US$54 billion (RM175 billion) by 2020 (Ministry of Finance, 2013).

At the strategic level, the government of Malaysia through its Economic Planning Unit (EPU) has mandated SIRIM Berhad, which is a corporate organisation owned wholly by the Malaysian government under the Minister of Finance Incorporated, to formulate an IT Strategic Plan that provides guidelines, proposals, and recommendations for the AEC industry (Sulaiman et al., 2005). Apart from that, there are seven strategic plans posted by CIDB based on the framework of the Construction Industry Master Plan (CIMP 2006-2015) with the purpose of alleviating and improving the conditions of the AEC industry in Malaysia. Digital technology was identified as one of the 7 Strategic Thrusts to contribute to the betterment of the industry. The increased leverage of digital technology is expected to permeate various industries and is considered as a major drive for improvement in the aspect of performance and cost efficiency. Hence, recommendations were given in order to encourage information sharing in the industry for the purpose of improving work implementation and developing software or system for the local AEC industry (CIMP, 2007).

The first recommendation suggested that CIDB should introduce an information portal for the AEC industry as a platform for information sharing. Currently, the information portal has eight core branches, namely e-services, Resources, News & Events, Directory, Knowledge Share, Exchange Centre, Industry Initiatives, and Interactions. On the other hand, the second recommendation revolves around the need for CIDB to team up with several other companies and organisation in the digital technology industry to develop its own local construction software and system. In 2001, CIDB together with the Malaysian Institute of Microelectronic Systems (MIMOS) and Multimedia Development Corporation (MDeC) ventured into forming E-Construct Services Sdn Bhd in order to assist the AEC industry community in the areas of digital technology by offering software development packages and services, fully integrated ICT solutions, consultations and training, and multimedia content development and publications (E-Construct, 2001).

Apart from the above, the government has also launched e-Government initiative for the AEC industry. Together with CIDB and its various agencies in the industry, many applications systems related to the AEC industry conducted through a comprehensive online and paperless method were introduced which include the Construction Industry Centralised Information System (CIS), national e-procurement, national e-tendering imperative, national e-submission, national e-draughting, Project Monitoring System, Land and Property Application System, the G2E portal, the Local Government system, and the Integrated Financial Management System (New Straits Times, 2007b, Daud et al., 2013, Mansor, 2010). The Public Works Department and CIDB also offer trainings, guidance, and advises to the public on the usage of the above e-government services as these tools are still new to the industry (Mukelas and Zawawi, 2012, CIDB, 1994b).

However, digital technology has not achieved its full potential and the level of adoption by the industry players is still relatively low despite the tremendous potential of digital technology and various initiatives introduced by the government and organizations for the industry to embrace its usage (New Straits Times, 2007b, Ern and Kasim, 2012, Latiffi et al., 2013). The economic report by the Ministry of Finance stated that most small and medium enterprises (SMEs) including those in the AEC industry are still hesitating to fully adopt digital technology, which caused the adoption rate by Malaysian SMEs to remain low at 20% in 2012 (Ministry of Finance, 2013, Ministry of Finance, 2014). CIDB also acknowledged that the players in the AEC industry have not been taking advantage of the capability of digital technology and optimizing the performance in daily operations. Meanwhile, the New Straits Times reported that these players do not prioritize digital technology skills development nor are they employing experts to assist them in using the technology as a solution to collaboration and coordination task (Sundaraj, 2006, New Straits Times, 2007a). A study by Ern and Kasim (2012) investigates the e-readiness of digital technology uptake in Industrialised Building System (IBS) strengthens the notion, and it was found that the progression of digital media has been stagnant for the past decade in the country and that even IBS manufacturers have not fully implemented digital technology, let alone builders.

There are many aspects as to why the adoption of digital technology in the AEC industry is still lagging after all the efforts by the government. One of the main reasons concerns the cost of the technology. Established studies and reports found that limited financial resources and high cost of technical team and software applications seems to be a hindrance (Both, 2012, Gledson et al., 2012, Hetherington et al., 2010, Liu et al., 2010, Crotty, 2013). The cost of hardware might be cheap because Malaysia is one of the major producers of computer hardware in the world, but software are imported from America and Europe, which makes it quite expensive due to the lower currency value of the ringgit. Another prominent aspect of resistance revolves around human and cultural factor. The study by Ern and Kasim (2012) revealed that most of the developers and manufacturers lack the mindset to innovate, which influence their preference of employing cheap unskilled labour because they failed to see the needs and benefits of digital technology. Hence, they resist to shift from the old technology to the new ones.

The lack of proper planning and studies has also contributed to this problem. According to a survey by Kareem and Bakar (2011), 50% of the players in Malaysia’s AEC industry failed to carry out any feasibility study when making the decision to implement digital technology. These players decided to adopt digital technology regardless of the challenges and needs that comes with it. The herd mentality of following others without proper evaluation and planning was very obvious when their decision to adopt new technology was mainly influenced by the positive feedback provided by a few players (Mui et al., 2002). However, not all players end up successful because most of them failed to fully utilise the technology and found that it was difficult to keep up with the challenges and needs of the technology. Adding up to this, the study by Gaith et al. (2008) investigates how digital technology can improve builders performance in Malaysia, and it was found that there is no clear understanding among the builders of how to use digital technology to enhance performance and productivity.

Uncertainty seems to be another huge barrier to the adoption of digital technology. Even though a builder would have an idea of the benefits and advantages of digital technology, the builder could still be very hesitant to proceed with the investment and adoption because they are not clear about the true extent of the benefits and the challenges resulted by the adoption, whether in terms of technical features, operational cost, the required changes due to adoption, and most importantly the return of investment. Most people expect direct and tangible profits from any investment they make, especially involving huge investment (Kareem and Bakar, 2011). However, this might not always be the case with digital technology. It is true that some benefits may have immediate, direct, and tangible effects on productivity and output, but others might require more time for maturity and to produce intangible results in terms of effectiveness and performances.

The Malaysian government realized that it is important to take action in facing the above shortcomings on the pace of the adoption and implementation of digital technology within the AEC industry in the country, including the need to turn CIMP master plan into reality with the hope of moving the industry forward and achieve Vision 2020. The government as the biggest property holder has decided the needs to promote and advocate a type of digital technology that is holistic, comprehensive, advanced, and capable of providing a solution to numerous issues that have been holding back the industry towards achieving its goal for an advanced, modernized, and well-developed industry. On 27th of August 2007, Judin Abdul Karim, who is the Director of the Public Works Department (PWD) that is mainly responsible for the development of all public funded projects and acts as the client on behalf of the government for projects, announced that Building Information Modeling (BIM) is to be formally introduced and implemented in Malaysia's AEC industry (JKR, 2013, Latiffi et al., 2013). Following that, a committee within the PWD was established to choose the right BIM platform to ensure interoperability, identify construction project processes involving BIM implementation, lead the way to introduce BIM standard manual as a reference for the industry, provide training and advisory assistance to project teams in using BIM tools, and produce BIM components for the government's pilot project that implements BIM (JKR, 2013).

The first conference conducted on BIM was held in August 2009, and the Director of PWD again reiterated on the importance of adopting an integrated software system and standardisation that assist multidisciplinary collaboration and effective workflow across the construction disciplines in project development and deliverables (The Star, 2009). In 2010, the National Cancer Institute building in Putrajaya was delivered by the PWD as the first BIM pilot project in Malaysia (CREAM, 2014). This was followed by other projects, namely the Multipurpose Hall of Universiti Tun Hussein Onn Malaysia (UTHM), Educity Sports Complex in Johor, and Ancasa Hotel in Pahang (Latiffi et al., 2013, Utusan, 2012). Other on-going projects that use BIM include Healthcare Centre Type 5 in Pahang, the Administration Complex of Suruhanjaya Pencegah Rasuah Malaysia (SPRM), Primary School in Perak, Primary School in Melaka, and a few with the total amount of 12 projects altogether (Latiffi et al., 2013, JKR, 2013). Later in 2013, a seminar and workshop titled *BIM for SMEs* was conducted by the Construction Research Institute of Malaysia (CREAM), focusing on the research and development (R&D) arm of CIDB (CREAM, 2014). The discussion revolves around the barriers and benefits of BIM and the need to develop a string of initiatives and incentives to assist in the government's goal of fully implementing BIM on public projects by 2016. The initiatives that will be taken by the government through PWD and CIDB include offering awareness and motivation programme, provide training programmes and grants for training, prepare for BIM standard, certification and accreditation licences, set out BIM technology centre and BIM portal, while the incentives would be in the form of tax and levy reduction, recognition, and awards.

The decision and initiatives taken by the government to fully adopt BIM by the year 2016 has shown that BIM is considered as an advanced technology that will bring a lot of differences as well as leading the industry forward towards innovation, with the hope of increasing quality and productivity in parallel to the goal of achieving vision 2020. However, studies conducted by Zahrizan et al. (2013) and Baba (2012) state that BIM remained in its infancy and the government's effort to promote BIM has not provided the expected outcomes. The next sub-chapter will discuss the attributes and benefits of BIM in general because it is considered as a silver bullet that will secure the future of AEC industry, not just in Malaysia but also globally. This is then followed by discussion on various issues concerning BIM that may have prevented the full adoption and implementation of the technology.

2.3 THE EVOLUTION OF DIGITAL TECHNOLOGY

2.3.1 HISTORY: THE EVOLUTION FROM CAD TO BIM

In 1962, Ivan E. Sutherland, a doctoral student at the Massachusetts Institute of Technology, had developed the Sketch Pad system which is the first program ever to utilise a complete graphical user interface using an x-y point plotter display and a computer input device called the light pen (Sutherland, 1964). His research known as "Sketch Pad: A Man Machines-Graphics Communication System'' has set the bases for interactive computer graphics with a data storage structure that accurately represent the relations among various objects on the screen. Following it, a new technology that was going to revolutionise the industry was created known as Computer Aided Design (CAD). The fact that Sketch Pad was never produced for commercial use did not stop the ideas on Sutherland's thesis to become eminently influential for future development of CAD. This technology at the time, which uses vector-based graphics to depict the intended objects was majorly employed for drafting purposes, mainly for 2D objects. In other words, it acts as a replacement for pen, pencils, rulers, and t-squares that have been conventionally used by architects and engineers since the beginning of the profession. The main captivation at that time was the ability to automate repetitive drafting tasks that was considered to be an extremely daunting task to be done manually by hand drafting. Since then, CAD has been developed to carry out tasks related to design, creation, modification, analysis, and optimisation in numerous industrial areas. Any computer program that includes a graphic interface and build to be used for any of the tasks mentioned are considered to contain CAD software (García et al., 2007).

CAD did not completely revolutionise the AEC industry until 1981 when IBM started selling personal computers (PC) to the public and Autodesk releasing AutoCAD Release 1 (Gerfen, 2007). CAD technology was mainly used by huge multi-corporations in the aerospace, aviation, and transportation industry such as McDonnell-Douglas, Ford, Lockheed, General Motors, Mercedes-Benz, Nissan, Toyota, and a few others throughout the 60s and 70s. In the 1990s, the PC explosion that was caused by the growth of IBM clones has made PC to be more affordable for the public. At the same time, the introduction of Microsoft's Windows 3.0 operating system had seen Autodesk realising AutoCAD Release 13, a software that was equipped with 3D Solid Modelling functions. This software had driven the widespread of AutoCAD and made it the most sought after CAD software in the market, with more than 1 million licenses sold globally that generated revenues of more than US$300 million. Hence, this software quickly became the tool of choice, and clearly adapted as the industry standard for various areas such as architecture, engineering, construction, and manufacturing. With this new industry standard in place, industry players became more confident to adopt and implement the technology, with some happened to consider it as a marketing tool to portray the innovative approach and advanced image of their establishment (Mohd-Nor et al., 2009).

A decade into the new millennium, CAD managed to firmly establish its importance in 2009 due to the results of a long study poll among AEC industry leaders published by the Architects Journal which states CAD as the ‘greatest advance’ in the construction history (Wynne, 2009). Initially, it was a hard struggle for CAD to be well distributed to the masses in the industry as a result of limited functions, new risk, and liability fears it posed at that time (Smith, 2007, Jordani, 2008, Joannides et al., 2012). However, the tremendous development of CAD throughout the years had made the industry players to recognize it as a technology that is very helpful in achieving the aims of modern and increasingly efficient AEC industry. Furthermore, not only huge corporations and architects' firms such as Boeing, Skidmore, Owings & Merril, and Frank Gehry implemented CAD in their product and project deliverables, but CAD was also adopted by medium and small firms all around the world (Mohd-Nor et al., 2009, Rivard, 2000, Doherty, 1997, Samuelson, 2008). This further shows that CAD truly help to increase productivity, quality of goods, and services produced, including the yield of high return of investment; establishing it as a technological advancement.

The production of faster and cheaper computers throughout the 1990s have been the mark of CAD software being proliferated with many new players offering various new packages that created strong competitors to Autodesk. It was during this decade that 2D CAD had advanced well into becoming a 3D CAD with 3D solid modelling function. The introduction of the first Non-uniform rational basis spline (NURBS) modeller for PC in 1993 and boundary representation (B-rep) kernel system earlier had seen the rapid establishment of competitor software which include Parasolid, ACIS, SolidWorks, SolidEdge, Microstation, CADKEY, Form-Z, and many others. At this stage, CAD was no longer merely considered as a drafting tool because industry players started to look at it as a design tool that enables architects and engineers to design and for builders to build structures with a more complex geometry (Wynne, 2009). On top of that, it is hard to imagine the number of buildings that could be designed and built before the advanced 3D CAD era by Frank Gehry, Zaha Hadid, Morphosis, Asymptote, Peter Cook and Colin Fournier, Foster and Partners and others. Some CAD manufacturers even began to develop niche capabilities such as a new form of prototyping called digital prototyping. This technique allows CAD models to be generated by the computer by scanning the physical prototype or model with an industrial CT scanning machine. In relation to this, a similar technique that often referred to as “reverse engineering” was popularized by Frank Gehry through many of his building designs. The process was performed by scanning through each surface of the physical model with a laser pen, creating a pattern of points called the “point cloud”, with the pen simultaneously transferring these points into a 3-dimensional space in the computer to generate a solid model on the computer screen (Kolarevic, 2003).

The late 1990s also observed the dissemination of complex modelling programs and third-party programs which were also known as plug-in. It was created in the form of history-based parametric modelling CAD tools, history-free explicit/direct modelling CAD tools, and even a hybrid breed that claims to combine the benefits of both approaches. The parametric approach captures the intended behaviour which results in a powerful and automated way to create complex models. Meanwhile, the explicit/direct approach reduces design data of each individual part to ensure a better overall utilisation of their computer memory results in faster and instant modelling, whereby modification of complex forms and surface can be done without the need of remodelling in contrast to 3D CAD programs (Stackpole, 2009). This capability allows any imaginable form to be modelled on the computer, thus allowing buildings to be built on those complex 3D models. In addition, CAD software continues to further develop to become Internet enabled. The dot.com bubble, which was triggered when Amazon.com had completed its Initial Public Offering (IPO) in 1997 has observed its market cap to be raised to US$17 billion the following year. Hence, this led most industries including CAD software industry to formulate strategies to become Internet-enabled. The development of Internet features in CAD and CAD features on the Internet has certainly helped in the development and materialization of numerous new and exciting tools (Wynne, 2009). In response to this, Autodesk released AutoCAD 2000i in mid-2000, which was their first Web enabled CAD software that was equipped with the ability to produce drawings that could be viewed on Internet browser and also enabled online collaboration using Microsoft Net Meeting (Patil, 2007).

Meanwhile, research and development continued in other parts of the world while 3D CAD developed into becoming a mainstream software throughout the AEC industry, which eventually become the industry standard technology application throughout the 1990s into the new millennium. In the United States, Charles Eastman from the Carnegie Melon University developed two software known as the Building Description System (BDS) and Graphical Language for Interactive Design (GLIDE). These software break down architecture into constituent components or library of objects that can be retrieved and added to a model, thus allowing user to retrieve information categorically by attributes including material type and supplier (Bergin, 2012). This program was developed based on the notion that modelling buildings into a database of components would reduce the cost of design because redundancies can be avoided because there is no need to re-draw the whole model for every little change made. In 1988, Paul Teicholz and his team of PhD students at Stanford University marked another milestone with the development of ‘four-dimensional’ building models with time attributes for construction (Sawhneya et al., 2017, Kunz et al., 2002). The use of the term 4D is intended to refer to 3D CAD models with the fourth dimension, and in this case is ‘time’, or design, procurement, and construction schedules (Fortner et al., 2008).

The developments were happening rapidly in North America, while Europe had two programming prodigies who were developing a program of the same concept that is expected to bring digital technology forward into a new dimension. Gábor Bojár, a physicist in Budapest, Hungary began a private company called Graphisoft in 1982 and started to develop Radar CH, a software developed based on a concept similar to the Building Description System (BDS). However, this software creates both 2D drawings and parametric 3D models which include both the geometry and non-geometric design and construction information. Radar CH, that was eventually renamed ArchiCAD, was released in 1984 for personal computers that work on Apple Operating System platform. It became the first software of digital technology that is currently known as Building Information Technology, or BIM. The other prodigy, Leonid Raiz, together with Irwin Jungreis, started Charles River Software in 1997 and began developing an architecture-based software known by the name of Revit in C++ on the Microsoft Windows platform. In 2000, the company released Revit to the public and was later bought over by Autodesk in 2002. Revit continued to grow into becoming the most widely used Building Information Modeling in the world with Autodesk's prowess in R&D and marketing. According to Michael S Bergin of Autodesk, Revit had successfully revolutionized the world of Building Information Modeling by creating a platform that utilizes a visual programming environment for creating parametric families and enables a time attribute to be added to a component for the purpose of allowing a 'fourth-dimension' of time to be associated with the building model. Hence, this would be very beneficial as it enables contractors to generate construction schedules based on the BIM models and simulate the construction process (Bergin, 2012).

2.3.2 TODAY: BIM AROUND THE WORLD

The idea of BIM was claimed to have started in the 1970s with Charles Eastman's Building Description System (BDS) and formally introduced to the industry with the release of ArchiCAD in 1986. However, the technology failed to gain popularity and support from the AEC industry until the new millennium (Bergin, 2012). During the 1990s, the development of conventional 3D CAD had to go through a slow pace because most of the software vendors concentrated on its web-enabled functions but with no fundamental technology breakthrough. Moreover, the issues revolved around the lack of productivity, constant delays, and cost-overruns, which include fragmentation as part of the problem faced by the AEC industry globally. On the other hand, the influx of unskilled labour and low innovation have also affected the development of countries like Malaysia.

However, the scenario started to take turn with the publication of three (3) study reports in the United States that has brought BIM into centre stage within the AEC industry. The first report was published by the National Institute of Standards and Technology (NIST), and it stated that inadequate interoperability and data management had costs the construction industry an approximate total of US$15.8 billion a year, or 3-4% of the total industry revenue (Suermann and Issa, 2009) (Gallaher et al., 2004). The report concluded that a new delivery model which addresses collaboration, integration, and interoperability is highly needed to optimise value for the whole project rather than only focusing on the tasks. Another study that elevated BIM was conducted by the Centre for Integrated Facility Engineering (CIFE) at Stanford University in the same year. The study compared the productivity within the U.S construction industry based on the measurement of constant contract dollars of new construction work per hour in relation to all non-farm industries from 1964 to 2003. According to the study, the productivity in the construction industry was observed to gradually decline by the rate of -0.59% annually over the past 40 years, while the labour productivity in all non-farm industries increased by 1.77% per year over the same period (Teicholz, 2004). The study found that this issue came up as a result of most of the CAD applications utilised by the industry tend to run in a stand-alone mode that does not promote collaboration by the project team, and the alternative solution to this problem was only to adopt 3D parametric object-based CAD (BIM). On the other hand, the third report was published by the Construction Industry Institute (CII) at the University of Texas, in which it was estimated that up to 57% of the construction spending was non-value added effort or waste (Diekmann et al., 2004). Hence, the study suggested to adopt lean construction approach in the effort to reduce wastage because it takes a holistic pursuit of concurrent and continuous enhancements in all aspects of the built and natural environment which include design, construction, maintenance, salvaging, and recycling. Moreover, this implies that lean construction requires full collaboration from all parties including owners, architects, designers, engineers, constructors, and suppliers throughout the lifecycle of the project.

As has been discussed above, all the three reports have suggested one thing in common, which is collaboration. This is the result of the ever-growing complexity of construction projects over the years, which emphasise the need of extensive collaboration between all parties involved throughout the whole design and construction process to achieve effective project delivery. This situation had prompted the AEC industry to critically consider solving the fragmented nature of the industry by adopting a collaborative and integrated approaches such as Integrated Project Delivery (IPD). IPD is a collaborative alliance of people, systems, business structures, and practices into a process that harnesses the talents and insights of all participants to obtain several benefits which include to optimise project results, increase value to the owner, reduce waste, and maximise efficiency through all phases of design, fabrication, and construction (Eckblad et al., 2007, Roberts, 2008, Alexander, 2008). On the other hand, BIM has been widely regarded as the effective tool to facilitate and efficiently achieve the collaborative and integrated attributes required for IPD (Kent and Becerik-Gerber, 2010, Denzer and Hedges, 2008). Therefore, BIM have come into the light and received attention from the AEC industry as a probable solution to numerous issues concerning the industry. The AEC industry around the world is led by the United States and a lot of effort has been put to adopt the technology. On another note, governments around the world have started to recognise and mandate the implementation of BIM, which has effectively elevated the technology to replace CAD as the industry standard for advanced digital technology. The following table illustrates the global adoption rate of BIM based on national BIM reports:

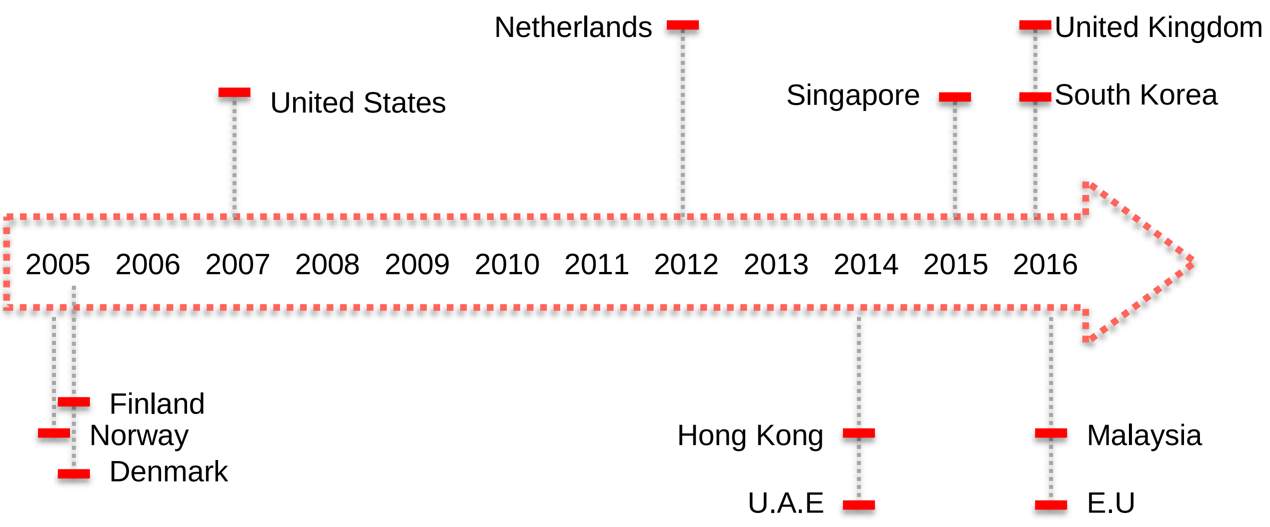
Table 2.5: Adoption of BIM by countries and year (McGraw-Hill, 2007, Arch-Vision, 2013, NBS, 2015, NBS, 2014, McGraw-Hill, 2011, McGraw-Hill, 2012a, McGraw-Hill, 2010, McGraw-Hill, 2009, Sawhney, 2014, RICS, 2013, CREA, 2011, AECOM, 2013, McGraw-Hill, 2014c, Nikkei, 2011, McGraw-Hill, 2012b, Kiviniemi et al., 2008).

	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
United States	28%		49%			71%	
Canada						64%	64%
United Kingdom				13%	31%	39%	54%
France				38%			
Germany				36%			
Netherlands							51%
South & Central Europe					14%		

Finland	13%						65%
Norway	10%						
Sweden	33%						
Denmark	10%						
Australia							51%
New Zealand					34%	57%	57%
Middle East				25%			
China					6%		29%
India							22%
Japan					33%		
South Korea				29%		58%	
Iceland							5%

It is evident from the table above that BIM has gained popularity and prominence all around the world with higher interest in developed countries, which is led by the United States and followed by Canada. According to the SmartMarket Report by McGraw-Hill McGraw-Hill (2012a), the adoption rate of BIM in the United States has grown from just 28% in 2007 to 71% in 2012 in just less than a decade, thus demonstrating impressive growth despite the recent economic downturn. On the other hand, Europe seems to be more careful in its approach to adopt BIM, with the adoption rate in France to stand at 38% and Germany at 36%, as reported by the SmartMarket Report by McGraw-Hill McGraw-Hill (2010) in 2010, the only report available to date. Meanwhile, BIM adoption rate in the UK was surveyed and reported by the National Building Specification (NBS), with the first rate recorded at just 13% in 2010, but is observed to remarkably increase to 54% in 2013. The popularity of BIM does not seem to wane even for countries as far as Australia and New Zealand as both countries have registered more than half of its AEC players to adopt BIM technology. However, BIM fails to be the main choice of technology for the majority of Asian countries except South Korea which manages to record a rate of 58% BIM users, as reported by the SmartMarket Report by McGraw-Hill in 2012. Meanwhile, China as the largest construction market in the world with a total spending of US$1.2 trillion in 2012 shows an adoption rate of only 29% for BIM (AECOM, 2013). The reported surveys for the above countries might not come from the same source and may have different methods of data collection; however, the reports still give a clear idea on how BIM has gained popularity as the current preferred technology for the AEC industry and widen its user base across the globe.

Figure 2.1: Government mandate of BIM by countries and year.



The increase of BIM adoption around the world has seen both the AEC industry and government to acknowledge the powerful influence of BIM to fully replace CAD as the standard technology for design and procurement. Hence, most countries have started to take steps to partially or fully mandate the use of the technology for public funded projects based on the potential benefits that BIM could bring to the AEC industry, with the hope that it will spur the whole industry including the private sector to fully adopt BIM to ensure maximum benefits can be achieved through complete and comprehensive implementation in the AEC industry. The first country to lead with the implementation of BIM is Norway in 2005, when its civil state client Statsbygg (public buildings) decided that it would start using BIM for the whole lifecycle of their buildings (McGraw-Hill, 2014b). Second to follow suit are Finland, Denmark, and the United States. BIM is made compulsory in Finland when its states property management Senate Properties started to fully utilised BIM for all its projects starting from 2007 onwards, while Danish state clients such as Palaces & Properties Agency, the Danish University Property Agency, and the Defence Construction Service made it necessary for BIM to be utilised for all their projects starting in the same year. In the United States, the General Services Administration (GSA) has mandated the use of BIM for spatial program validation, which is to be submitted prior to final concept presentation on all its projects starting from 2007 (Khemlani, 2012, Hagan et al., 2009). The fifth country to mandate BIM is Netherlands, in which their Ministry of Interior decided that all large building maintenance projects must utilise BIM from 2012 onwards (Fortner et al., 2008).

In the same token, the United Arab Emirates have also announced that in 2014 BIM will be mandatory for all buildings 40 stories or higher; facilities/buildings with 300,000 sq ft or larger; all hospitals, universities and other similarly specialised buildings, including all buildings that are being delivered by international parties (John, 2014). Within the same year, Hong Kong have also started to require BIM for all residential projects (Wong and Fan, 2013, Fung, 2017). Singapore requires BIM to be implemented for all construction projects starting from 2015 onwards, which have led a multi-agency effort in 2008 to implement the world's first BIM electronic submission (Smart, 2011). South Korea has stated that it will make BIM compulsory for all private sector projects over S$50 million and for all public-sector projects by the year 2016, while the United Kingdom has confirmed to mandate the use of BIM Level 2 for all construction projects, including public and private funded projects by the same year. In the case of Malaysia, BIM has also been announced to be implemented for all its public projects within the same year of 2016, though that has later been revised and shifted to 2020 (The Star, 2016). Moreover, the latest to have announced the mandating of BIM is the European Parliament based on its agreement to recommend the use of BIM on all its members for publicly funded construction and building projects in the EU by 2016 (Construction Week Online, 2014). Down South, a national report by building SMART Australia has indicated that it has recommended to the Australian government to implement BIM on all public projects by 1 July 2016 (Week, 2014).

With the adoption rates and government mandates of BIM described above, it is clear that the technology has made progress to become the chosen platform for the generation and management of digital representations of buildings and structures around the world, particularly among fully developed and developing countries. The next sub-chapter will brief on the developments of digital technology, particularly concerning BIM within academia.

2.3.3 DEVELOPMENTS WITHIN ACADEMIA

The relationship between academia and the industry has always been significantly recognised whether formally or informally, given the fact that academia plays a major role in supplying the industry with skilled and knowledgeable graduates for all these while (Roberts, 2000, Zwieg et al., 2006, Gonzales and Keane, 2009, GRIP et al., 2004). In relation to this, it is undeniable that education is one of the reliable approaches that helps to equip individuals with the necessary skills and knowledge that are hoped to fulfil the need of the industry, society, and country. The fact that governments' expenditure for tertiary education goes beyond 30% of GDP per capita on each student (e.g. Sweden 43%, Norway 41%, Denmark 51%, France 35%, Germany 38%, United Kingdom 31%, India 49% and Malaysia 50%) reflects the governments' trust and hope towards tertiary education in supplying the industry and society as a whole with compatible and reliable workforce that will enable the country to progress forward (The World Bank, 2009-2014). The close relationship between the two sectors will implicate any development or regression on any one of the involved sides. In addition, similar needs are required by the academia based on the progress of AEC industry and development of digital technology within the last decade. Even though it started out very slowly, most architecture schools by now have embraced the challenges and opportunities that digital technology has brought to the design method and process, which further include design software into its curriculum and make it a core feature of today's contemporary architectural education (Giddings and Horne, 2008, Isenstadt, 2008, Pektas, 2007).

Furthermore, the embracing of digital technology among architecture schools has somehow brought changes to the architecture education, with the development of a new design paradigm that is popularly known as digital architecture or digital design. As has been discussed, a wide range of important theoretical writings within the last decade have been focusing on the area of digital architecture, which further suggests that digital technology-based architecture has become central to today's design theory and the strong influence of the emergence, migration, and crystallization of digital design-base concepts on the current architectural language and discourse (Oxman, 2008a). According to Oxman (2008a), the approach and technique provided by digital architecture have somehow reinforced the traditional processes and order of conventional design because it increases certain capabilities of generative and performative processes that could not be performed using the traditional methods (Oxman, 2008b). Design activities have been observed to improve with digital technology usage to a significant level through CAD's *visualisation* and *representation* feature during the mass inception of CAD into academia in the early 90s, which include two-dimensional drafting and three-dimensional visualisation of forms and spaces (Mohd-Nor et al., 2009, Sabongi, 2009). Hence, this marks the beginning of digital architecture or digital design, which brought a new paradigm shift to the design process and theories. However, the introduction of calculative, parametric, and simulation base digital technology has caused BIM to act as a sole software and a platform for third party application within the past decade, which also enhanced design activities to another leap forward that triggered a new body of language, theories, methods, and processes as stated earlier by Oxman (2008a) Oxman (2008b), Zuo et al. (2010), Fasoulaki (2008), and Sabongi (2009). With this, the issue of BIM has received considerable critical attention among academia and researchers, hence, debates and academic discourse on BIM proliferates and are best to be conducted through conferences of organisations and institutions.

Architecture schools in many parts of the world have started to investigate BIM and most of them are in view that BIM has become relevant to the field of design. Higher demands for BIM skilled graduates has been observed since its introduction to the industry, which has further strengthened the relevance of teaching BIM to students (Rundell, 2005, Crumpton et al., 2008, Ibrahim, 2007, Khemlani, 2012). Several countries such as the United States, Hong Kong, and Singapore have also encouraged academic institutions in their countries to equip their graduates with BIM skills (Wong, 2013, Khemlani, 2012, Wong et al., 2011a). Following it, HEIs began to restructure their curriculum to incorporate BIM formally, which involves the change from conventional CAD to BIM. On top of that, major vendors are aware of their important role in the implementation of BIM; hence, they take part in supporting both students and academic institutions considering that BIM is significantly different from CAD. In relation to this, Autodesk Inc. established Autodesk Education Community which allows academic institutions and students to download personal learning licenses of the technologies with free access for 13 months, including the option of upgrading the most recent version for another 13 months in case that the license expires before graduation (Brown and Peña, 2009). Their website also offers students and academic institutions to access their own structured curriculum and e-learning tutorials, which was created in partnership with the institutions (Brown and Peña, 2009). The same applies to other major vendors such as Bentley, Vectorworks, and Graphisoft considering that each of them have their own specific supports being offered to HEIs and students alike. Several HEIs such as Purdue University was discovered to utilise lecture notes and training modules prepared by vendors in teaching BIM (Schmelter and Cory, 2009).

These ongoing progress and development within the HEIs further shows that academia is catching up with the latest development within the AEC industry, particularly in digital technology. The discussion concerning the benefits and disadvantages of BIM will be discussed at the end of this paper. On another note, the next chapter will discuss on the definition, concept, and qualities that have driven the development and success of BIM.

2.4 SUMMARY

This chapter has widely explored the current scenario of the Malaysian Architecture, Engineering and Construction (AEC) Industry in relation to the development of digital technologies and the impact of the technologies on the industry. Apart from that, this chapter has also reviewed various definitions and terminologies adopted in the world of digital technology, including the discussion on the evolvement of digital technologies within the global scale; for example, from CAD to BIM. In the next chapter, the current literature on BIM will be further investigated to evaluate how the industry and the HEIs handle the reaction towards the potential opportunities and possible challenges related to BIM.

CHAPTER 3: LITERATURE REVIEW II – BIM: PRACTICE AND EDUCATION INTERWINED

3.1 INTRODUCTION

This chapter sets out to discuss the second phase of literature review with the purpose of obtaining a deeper understanding related to the subject matter that has been previously reviewed. The previous chapter provided a general view of the Malaysian Architecture, Engineering and Construction (AEC) Industry, including the background of research theme, various definitions and terminologies used in the world of digital technology, the progress and development of these technologies over the past years.

The first part of this chapter aims to explore, appraise, and synthesize relevant literature pertaining to Building Information Modelling (BIM) in both professional practices and academia. Moreover, the development and issues pertaining to BIM in academia and how it relates to professional practices and vice versa are thoroughly discussed as a continuation from the previous part. Meanwhile, the second part of this chapter quantifies all the literature findings into an outline that builds up the case for knowledge inquiry, and subsequently utilised to develop the theoretical framework for this research.

This chapter is viewed to be very significant with respect to the framework because it provides the secondary data for the development of research framework. The research framework is used in the research as the baseline framework in order to guide the research inquiry and develop the main instrument of the research, which is survey questionnaires. Hence, this whole chapter lays down the area and limitation of exploration of the survey in order to determine the attributes needed for the creation of the final outcome which will be further discussed in Chapter 5 and 6.

3.2 DEFINITION, CONCEPT AND DRIVERS OF BUILDING INFORMATION MODELLING

3.2.1 TERM AND DEFINITION

It is worth noting that throughout the years there had been many terms that describes the object/components-based parametric modelling of the BIM concept used by BIM developers and vendors. Referring to table 3.2.1, there were Graphisoft's "Virtual Building", Bentley Systems' "Integrated Project Models", Charles Eastman's "Building Product Models", Fiatech's "Asset Lifecycle Information System" and many more terms, with many having slightly differing terminology, capabilities and limitations despite the fact that all of it were object/components-based parametric modelling software (Cao and Zheng, 2014). Although the concept of BIM has existed since the 1970s, it was only in 1992 that the term Building Information Model first appeared written in an academic article by G.A. van Nederveen and F. P. Tolman from TU Delft in the Netherlands (Van Nederveen and Tolman, 1992, Eastman, 1974). Even with that, it was Autodesk's white paper entitled "Building Information Modeling", followed by usage of the same term for its BIM-platform software Revit, both in 2002, that had popularized the terms Building Information Model and Building Information Modeling (including the acronym "BIM") (Autodesk, 2002, Khemlani, 2012).

Table 3.1: Terms and definitions of BIM

Terms	Organisation or Researcher	Reference
Asset Lifecycle Information System	Fully Integrated & Automated Technology	(Fiatech et al., 2005)
Building Information Modelling	Autodesk, Bentley Systems, Vectorworks, Nemetschek and others	(Autodesk, 2014) (Eastman et al., 2008) (Systems, 2014) (Forbes and Ahmed, 2010) (Anderson, 2003)
Building Product Models	Charles Eastman	(Eastman, 1999)
BuildingSMART™	International Alliance for Interoperability	(Guttman et al., 2006)
Integrated Design Systems	International Council for Research and Innovation in Building and Construction (CIB)	(Ilal, 2007)
Integrated Project Delivery	American Institute of Architects	(Eckblad et al., 2007)
Integrated Project Models	Bentley Systems	(Howell and Batcheler, 2005) (Bentley and Workman, 2003)
nD Modelling	University of Salford — School of the Built Environment	(Kagioglou, 2003)
Virtual Building™	Graphisoft	(Graphisoft, 2003)
Virtual Design and Construction & 4D Product Models	Stanford University— Centre for Integrated Facility Engineering	(Kunz and Fischer, 2009)

		(Fischer, 2006)

At that time, Autodesk was a giant CAD vendor that was having substantial stakes in the CAD market. The situation had popularised the BIM term to a certain extend; however, the BIM term was still not accepted as the industry's standard in describing object/components-based parametric modelling. This situation occurred because other vendors preferred to use their own terms for their object/components-based parametric modelling software. Given the fact that most vendors were not ready to sacrifice their own term to adopt the 'BIM' term from rival companies; however, it was undeniable that it is very important to have a universally accepted term for the new post-CAD technology in order to move forward on the development and adoption of the technology rather than to dwell endlessly on the issues related to the term. Therefore, it was very important to have a convenient umbrella term that is precise and explicit enough for users to comprehensively recognize the significance of its interface, geometric representation, and several other benefits, and at the same time broad enough to imply and carry all specialized and subordinate variations.

In 2002, Jerry Laiserin who used to work as an industry analyst and member of the national board of directors of the American Institute of Architects (AIA) as well as the AIA's College of Fellows has helped to popularise and standardise the 'Building Information Modelling' term and BIM acronym as a common name for object/components-based parametric modelling through his web portal famously known as *The Laiserin Letter*. According to him, the word "building" is loose enough to hint at the notion of design, construction, operation and management, while "information" only able to hint at digital application that handles beyond geometry alone. Together, "building information" implies a strong sense of the lifecycle of a building, from design to operation. On the other hand, “Modelling” seems to suggest the description of a system(s) as well as the process of description or representation that provides the foundation for performance simulation and management of information for building or structure (Laiserin, 2002). Therefore, Laiserin concluded that “building information modelling” is better suited to describe the next generation of design software following the famous CAD compared to other terms that were offered by other CAD vendors. After a few months of debating, discussing and persuading, Bentley Systems as well as Graphisoft that are known as the other two main BIM vendors had eventually agreed to replace their in-house term for object/components-based parametric modelling with “building information modelling”. Therefore, considering that the three biggest BIM vendors controlling more than 80% of the market share have agreed to fully adopt the BIM term, thus the domino effects have fallen into place and it is safe to say that the BIM term has been accepted globally by the AEC industry (Laiserin, 2002).

Nevertheless, there are still some differences in opinion regarding the definition of the BIM term despite the fact that it has more or less been universally accepted by the AEC industry to describe object/components-based parametric modelling. The BIM Task Group, which was formed in 2011 by the UK government to drive government departments to adopt BIM by 2016, stated that BIM is “such a wide open subject with interpretations differing throughout the supply chain that we could have spent a year just trying to define BIM” (BIM Task Group, 2011b). Not only there were differing opinions on the definition, but some quarters even argued to the point of suggesting the replacement of certain words for the BIM acronym. Martin Simpson from the University of Salford reported that there were debates among scholars and industry players as to whether BIM is ‘Building Information Management’ or ‘Building

Information Modelling' (Simpson, 2013). Meanwhile, Adrian Malleson from the National BIM Standard (NBS) UK stated that BIM could have different nuances of meaning from one country to another by citing New Zealand as a case in point where BIM is mistakenly equate with 3D CAD and software rather than treated as the object/components-based parametric modelling (Knutt, 2014). The same cycle happened to BIM, similar to the scenario of CAD 30 years ago, which involved various proposals for definition of BIM.

Some scholars or industry leaders define BIM solely as a building information model, i.e. a tool, or an object. According to Paul Morrell who is the Chief Construction advisor for the UK Government, BIM is just a tool that enables integrated and collaborative culture, which is believed to be very beneficial to the fractious and fragmented nature of the AEC industry (Morrell, 2011). On the other hand, Randy Deutsch from the American Institute of Architects (AIA) regards BIM as a tool to manage building information. According to him, the adequate information of the building project allows architects to effectively and efficiently lead projects (Deutsch, 2011). On another note, Socha and Lanzetti (2012) seems to agree with the idea that BIM is just a tool by stating that BIM is actually just one part of a bigger solution despite being regarded as the only means to answer the problems of productivity and collaboration. A survey by Zuppa et al. (2009) was found to support the above theory, whereby nearly half (43.1%) of its respondents define BIM as a tool for visualizing and coordinating building project work that is used to avoid errors and omissions. Willem Kymmell in his book, *Building Information Modeling: Planning and managing construction projects with 4D CAD and simulations* describes that building information model tends to represent projects virtually through digital models which include 2D, 3D, 4D (time element-scheduling), 5D (cost information), or nD (energy, sustainability, facilities management, etc., information) representations of a project that are closely connected to the project lifecycle from planning to decommissioning. Therefore, it is appropriate to regard BIM as a comprehensive ‘tool’, albeit loaded with information that may help throughout the project lifecycle (Kymmell, 2008).

While some describe BIM as a tool or an object, others look at it as an *activity*, or a *process* (Sive, 2007, Nielsen et al., 2009, Eastman et al., 2008). According to Eastman et al. (2008), BIM should be seen as a verb or an adjective phrase to describe tools, processes, and technologies that are facilitated by digital, machine or a readable documentation about a building throughout its whole lifecycle. In this manner, BIM will be indicated as an activity rather than an object or tool. Autodesk, the largest BIM vendor in the world also states that BIM is also more of a process rather than a tool as it involves creating and using an intelligent 3D model that allows the process of design, visualization, simulation, and collaboration to inform and communicate project decisions, thus providing greater clarity for all users from the design stage to completion (Autodesk, 2014). Note that as a software vendor, Autodesk emphasises that the process or activity that revolves around the intelligent 3D model acts as a platform that enables all the above functions. The British Standard Institution (BSI) supported this by stating that BIM is the process of designing, constructing, or operating a building or infrastructure asset using electronic object orientated information, or in other words, the intelligent 3D model (B.S.I, 2014). BuildingSMART, a worldwide organisation formerly known as the International Alliance for Interoperability (IAI), states that BIM is a business process for generating and leveraging building data to design, construct, and operate the building during its lifecycle, which permits all users to have access to the same information in real-time through the interoperability between technology platforms (Young et al., 2008).

As has been discussed above, it is obvious that some leading players within the industry described BIM as an *object* or *tool*, while some others look at it as a *process* or *activity*. Nevertheless, it is also reasonable that the essence of BIM could stretch to being *both* technology and work processes. The past few years have seen an increased number of organisations and bodies from around the world adopting similar definitions of BIM that define it as both technological tool and process, though the wordings and structure of sentence may differ from one another. This research intends to do the same; hence, it has chosen to adopt the definition of BIM similar to definition employed by the American Institute of Architects (AIA), the National Institute of Building Sciences - United States (NBIMS-US), BuildingSMART, the Construction Project Information Committee of UK (CPIC), the Australian Institute of Architects, the New Zealand Institute of Architects (NZIA), the National Building Specification (NBS), the US General Services Administration (GSA), the International Organization for Standardization (ISO), and most importantly the Royal Institute of British Architects (RIBA). The mentioned organisations and bodies defined 'Building Information Modelling' or 'Building Information Model' as a *digital representation of physical and functional characteristics of a facility or project, thus creating a shared knowledge resource of information about the formation of a reliable basis for decision-making during its life cycle*, from the earliest conception to demolition (International Organization for Standardization [ISO], 2010) . It is worth to note that Malaysian architecture and architecture education was modelled after the British system, and this has remained largely the same up to the present despite some changes and innovations that has been introduced to suit the national interest (Hassanpour et al., 2011). Therefore, it is best to adopt a definition of BIM that is in line with RIBA considering that this research is based in Malaysia and the outcome will be implemented within the architecture education in Malaysia.

3.2.2 BIM CONCEPT: COMPARING BIM TO CAD

While the introduction of CAD 30 years ago changed the way architects work by replacing pens, pencils, rulers and t-squares, the introduction of BIM within the last decade has not only brought further changes to the way architects work, but it changed how the whole project team works, from architects to contractors to clients. The fact that the scholars and experts kept on looking for a new name that best suited BIM technology during its introduction instead of perceiving and categorising it merely as an advanced CAD or upgraded CAD further illustrates a huge distinction between the two technologies, which also suggest that the CAD term may have outlived its usefulness. In the case of CAD, the use of lines and geometries enables to create the representations of architectural components such as walls and windows that were not able to correspond to architectural components in an applicable and pertinent manner (Johnson, 1998). CAD functioned as a computerised drafting tool that failed to bring any huge change or transformation in the way architects work because its whole purpose is only to automate the existing practice (Birx, 2005). Given that data and information can be inserted into CAD geometries and lines as well as linking external data to graphical representations, these operations are only considered as extended or add-on procedures which is not central to the main function of CAD related to its productivity. Likewise, these are used to construct geometric entities that only function as a representation of data even with the availability of extensive modelling tools in CAD applications. Khemlani (2004) made it clear by stating that while "traditional 2D CAD and generic 3D modelling programs internally represent data using geometric entities such as points, lines, rectangles, planes, etc., and that while these applications can accurately describe geometry in any domain, they cannot capture domain-specific information about entities". In this regard, 3D models alone without parametric data will only remain as mere graphic depiction of the design and construction intent at best, which clearly does not qualify as BIM models considering that a 3D geometric representation is only a part of the BIM concept (GSA, 2007).

Unlike CAD that was regarded as a drafting tool, BIM on the other hand is a process that is in essence the opposite of CAD as it is described to be theoretically monolithic, integrated, and cooperative (Nielsen et al., 2009). The main difference between CAD and BIM concept lies within BIM's underlying computation technology, which is described as the use of 'object oriented programming' and parametric modelling. Object oriented programming is defined as a programming paradigm that allows objects to include both data and functions with specified relationships between the object and other objects (Guidera and Mutai, 2008). On the other hand, parametric modelling is a concept whereby objects are defined by parameters, which requires consistent relationships between components to be maintained as the object is created or manipulated, which further implies that if an object is modified, then those associated with it will also be automatically altered (Wolf et al., 2017). Together, BIM is utilised to form a prototype of the building which is a precise replica of the intended built environment, which is fully resolved for means of construction. This prototype model does not only contain geometry, relations and attributes that covers spatial relationships, geographic information, quantities and properties of building components, but it also includes information that can be used by other building analysis applications to perform simulations on energy, daylighting, computational fluid dynamics (CFD), space planning and building code checking as well as applications for project management and post-construction facilities management. Significantly, it is the "I" of BIM, which stands for information is considered the most critical to BIM. This is further pointed out by the US GSA (GSA, 2007):

"BIM is a data rich digital representation cataloguing the physical and functional characteristics of design and construction. It can serve as a shared knowledge base that is directly manipulated (computable)."

The above statement highlights the significance of BIM that is driven by the ability for an object or project model to store both qualitative and quantitative information, provide an open interchange of information across platforms, and transmit and the utilisation of the project information right through design, construction, operation and finally demolition (NHBC, 2013). These qualities allow BIM to integrate design, development, and project management, including the need of providing the project team with a very reliable support and assistance for decision-making through out the life cycle of the building. So much that BIM differs to CAD in relatively every aspect and how it changes the way architects and engineers work and deliver, it is coherent that many have now regard BIM as a paradigm shift to the industry that constitutes new methodology rather than just introduction of a new tool (Mandhar and Mandhar, 2013, Shelden, 2009, Azhar, 2011, Denzer and Hedges, 2008, Arayici et al., 2012a).

3.2.3 THE BENEFITS OF BIM

According to Kaner et al. (2008), numerous establishments within the AEC industry have experienced frequent problems due to the complexity of CAD design as well as drafting errors, which consequently leads to low productivity and low cycle times for design review. The introduction of BIM and its benefits are expected to enhance the condition of the AEC industry (Azhar, 2011). The discussions on previous sub-chapters have indirectly touched on some of the benefits and drivers of BIM; however, it is imperative that the benefits need to be clearly listed and discussed to further understand the universal motivation of BIM adoption. Moreover, a clear understanding of BIM advantages will guide this research in identifying the attributes of BIM that are suitable for the Malaysian context, which is believed to be helpful in forming the contents of the instruments to collect data for this research.

As has been previously mentioned, the publication of three reports in 2004 by the National Institute of Standards and Technology (NIST), Center for Integrated Facility Engineering (CIFE) and Construction Industry Institute (CII) had gathered all the attention of AEC industry towards BIM. These reports are unique from one another in terms of its context, but they conclude down to one thing which is cost (Gallaher et al., 2004, Teicholz, 2004, Diekmann et al., 2004). On another note, it is true that the reasons of using BIM are highly dependent on the roles of the company (Kiviniemi et al., 2008); hence, it is without doubt that the selection of any type of technology, including BIM software is for the purpose of reducing cost and increasing profits to the involved party, specifically to the project itself in general and the industry as a whole (Smith and Tardif, 2012, Sive, 2007). Several studies have shown to reduce and minimise inadequate drawings and specifications, number of requests for information and change order, late issuance of construction drawings, mismatch or internal contradictions in the content of documents; with a bigger hope of increasing productivity, streamline workflow, increasing the quality of goods and services produced, reducing operating costs, and finally increasing profits and return of investment (ROI) (Eastman et al., 2008, Kaner et al., 2008, Smith and Tardif, 2012, Sive, 2007, Issa and Suermann, 2009, Becerik-Gerber and Rice, 2010). Studies conducted by the University of Florida in 2007 on a total of 104 members from across the AEC industry revealed that "Cost-Overall" was the third highest rated BIM KPI with 84% of the respondents agreed that BIM has managed to lower the overall cost of the BIM related projects (Suermann and Issa, 2007). The case study by Kaner et al. (2008) went further by figuring out that BIM has enhanced the productivity and quality of design production and drawings for the firms, thus yielding gains between 20% to 47%, depending on the size and complexity of the project. A survey performed in 2009 by The University of Southern California further supports this notion when it revealed that the respondents who implement BIM on all their projects gain 73% increase in profitability and only 3% of loss (Becerik-Gerber and Rice, 2010). The same survey also revealed that 55% of the respondents agreed that BIM has helped to cut project costs, with 50% of the total respondents specified that project costs can be lessen by up to 50%. Comparatively, another survey done by Stanford University on 32 major projects that utilised BIM has shown that BIM provides savings of 10% from the project's contract value (Fischer and Drogemuller, 2009). Findings from a case study by Bryde et al. (2013) on another 35 major projects around the world that have been utilising BIM further strengthens on the cost saving benefits of BIM when it was found that 60% of the projects managed to experience the overall cost savings at the rate between 9%-9.8%.

Table 3.2: Global market research reports on Return on Investment for BIM usage.

Report	Year	Country	% Positive R.O.I	% Rate of Returns > 50%	% Rate of Returns > 100%
SmartMarket Report (McGraw-Hill, 2009)	2009	USA	72	19	10

SmartMarket Report (McGraw-Hill, 2010)	2010	Western Europe	74	11	9
SmartMarket Report (McGraw-Hill, 2011)	2011	Middle East	26	n/a	n/a
National BIM Report (NBS, 2011)	2011	U.K	53	n/a	n/a
National BIM Survey (Masterspec, 2012)	2012	New Zealand	33	n/a	n/a
SmartMarket Report (McGraw-Hill, 2012a)	2012	USA	62	9	5
SmartMarket Report (McGraw-Hill, 2012b)	2012	South Korea	59	17*	3*
National BIM Report (NBS, 2012)	2012	U.K	49	n/a	n/a
National BIM Survey (Masterspec, 2013)	2013	New Zealand	38	n/a	n/a
National BIM Report (NBS, 2013)	2013	U.K	46	n/a	n/a
NBS International BIM Report (NBS et al., 2014)	2013	Finland	27	n/a	n/a
Digicon / IBC National BIM Survey (IBC and NBS, 2013) (NBS et al., 2014)	2013	Canada	43	n/a	n/a
National BIM Report (NBS, 2014)	2014	U.K	52	n/a	n/a
SmartMarket Report (McGraw-Hill, 2014a)	2014	Global	75	n/a	n/a
SmartMarket Report (McGraw-Hill, 2014c)	2014	Australia New Zealand	76*	n/a	n/a

*AE firms (excluding contractors/clients)

Apart from direct cost-savings in terms of construction cost or contractual cost, the cost-benefit of BIM is also equally measured in terms of return on investment (ROI). There is no single established way of formally calculating a firm's return on its investments (ROI) in BIM, but it is possible to obtain a clear perception on the extent of monetary expansions and gains received by users based on their BIM usage (McGraw-Hill, 2014c). According to the above table, more than half of the market research reports on BIM around the world have shown that majority of BIM users recorded a return on investment, with some gaining more than 100% returns as result of BIM usage. The reports show that the United States, which had started championing the use of BIM earlier than most other countries, had recorded higher percentage of ROI compared to the others. According to the SmartMarket reports, this situation was the result of broader experience and higher level of expertise among the users who generally see more value in BIM compared to those with less experienced and lesser expertise (McGraw-Hill, 2014a, McGraw-Hill, 2014c).

Apart from market research reports that measure the industry's perception of BIM's ROI through surveys and interviews, there has also been case study projects and in-depth studies investigating BIM's ROI which was conducted by experts and scholars (Giel et al., 2010, Giel and Issa, 2011, Giel, 2009, Aranda-Mena et al., 2009, Azhar et al., 2012, Shen and Issa, 2010, Bryde et al., 2013, Barlish and Sullivan, 2012). Meanwhile, a detailed case studies by Giel et al. (2010), Giel and Issa (2011) was performed on four projects that adopted BIM, and it was showed that the ROI spans from 16.2% to 376%, which indicates a significant increase in parallel to scale and complexity of the projects. In 2013, Giel (2009), Giel and Issa (2013) conducted two more case studies on projects that utilised BIM whose scale and contract value were approximately 500% more than the previous case studies. The findings revealed that the ROI for these projects was in the range of 299.9% to 1653.9%. Despite the difference in the uniformity of the ROI rates, these researches had confirmed the overall high return of investment on BIM, thus constituting a strong basis to further explore and possibly adopt the technology.

The cost-saving benefit of BIM that acts as the main driving force in the adoption of the BIM technology is known to be achievable as a result of numerous contributing factors, but it was narrowed down to mainly the needs of increasing design/production efficiency, increasing productivity, and reducing project duration, in which all of them correlates to each other to a certain extend (Autodesk, 2009, McGraw-Hill, 2009, McGraw-Hill, 2011). The benefits of BIM that were gained from these three categories are as follows:

i. Improving Design Quality

Two SmartMarket reports have shown that BIM's capability to improve collective understanding of design intent that leads to improved design quality as the most recognized benefit by BIM users (McGraw-Hill, 2010, McGraw-Hill, 2012b). It is in stark contrast to CAD considering that a BIM model contains geometry and data that are three-dimensional altogether; hence, a detailed 3D view can be generated from any angle, at any section, and at any time during the design process. With the parametric and information rich attributes, BIM has taken a giant leap ahead of CAD and is fundamentally altering the *how* and *what* of architecture design (Ambrose, 2012). Apart from that, BIM is able to increase design quality as it facilitates sustainable design by providing *built-in analysis* tools and functions as a platform for other building analysis applications to perform various simulations and multidisciplinary analysis on the design in order to achieve optimum performance (Ambrose, 2012, Middlebrooks, 2008, Welle et al., 2011). With the rapidly emerging goals of sustainable design, the ability to perform simulations and analysis (also as platforms) on building construction and architectural assemblage is the promise and potential of BIM that cannot be taken lightly by the AEC industry.

ii. Collaboration and Communication

The three study reports by NIST, CIFE, and CII in 2004 had suggested collaboration as the solution to the wastage problem that seems to be beleaguering the industry for a long time. The construction of buildings has become increasingly complex, while design and construction tasks have also become more sophisticated and unique. This requires building information to be transferred and corresponded across more parties and boundaries; hence, needing the industry to acquire tools that can facilitate these activities effectively and efficiently (Neff et al., 2010). This is where BIM comes in as a tool that enables effective collaboration and communication between all parties by supplying or exchanging building information through a single information exchange standard (Smith and Tardif, 2012, Neff et al., 2010). With BIM, all documents, information, and software applications employed during design, construction, operation, and management are integrated into a single electronic source or model (Hardin, 2011, Cramer, 2007). According to the SmartMarket reports, the agreed ability of BIM to facilitate true collaborative work practices and improve communication have been considered as key benefits of BIM

(McGraw-Hill, 2014c, McGraw-Hill, 2011) as well as an important reason to adopt and implement BIM. As stated by Sive (2007), this changes the previous workflow with CAD because BIM reorganizes and restructures the sequence, timing, and duration of the design process, which results in a new scheme of continual, detailed communication that permits full collaboration throughout the project lifecycle; a practice that might change the principle roles of project players involved. Middlebrooks and Behrens (2009) went further ahead by stating that the collaborative nature of BIM has produced a new digital workflow consisting of three major stages, namely information gathering and input, modelling and visualisation, and simulation and analysis.

iii. Reduce Errors

As has been previously discussed, research conducted by the National University of Singapore found that the conventional design or construction drawings mainly consist of 2D drawings of multiple files, which are individually created and passed around to be shared among consultants. On another note, it has always been prone to errors due to the fact that the data and information from various trades of consultants does not fully integrate and coalesce with each other, thus resulting in variation orders and delays of project deliverables (Pheng and Arain, 2006). There is always a risk of error and adverse outcomes relating to design conflicts, omissions, and reworks in regard to the advancement of construction technology and increased workloads and project complexity, coupled with the fragmented nature of the industry. The introduction of BIM as an intelligent parametric software that automatically updates all related components and data of any changes made has helped to reduce design, documentation, and construction errors, omissions and rework altogether, which also permits full collaboration and communication between all parties involved in the project from the design stage to operation (Aranda-Mena et al., 2009, Love et al., 2011, Porwal and Hewage, 2013).

Another feature that differentiates BIM from CAD is known as automatic *clash detection* tools that helps to reduce errors. With this tool, cost overruns can be avoided by integrating the models for analysis and resolve clashes in the early stage, which is expected to reduce clashes between building components. According to a study done by Stanford University's CIFE on 32 major projects utilising BIM, the clash detection tool has been an efficient tool which is able to save the project's contract value by up to 10% (Fischer and Drogemuller, 2009). A study by Alabdulqader et al. (2013) conducted on 25 firms in Australia revealed that BIM users regard the clash detection feature as an important tool because it is helpful in reducing clashes and errors. Leite et al. (2011) study on BIM clash detection feature on models with high level of details (LoD) conceded that there is no doubt that BIM helps to provide a clear identification of clashes and avoid costly field detected clashes despite the level of precision of the tool that may be questioned.

To conclude this, the SmartMarket report revealed that BIM users in North America, Australia, New Zealand, and the Middle East, ranked BIM's ability in reducing design, documentation, and construction errors, omissions and rework as its top benefit, while at the same time being second ranked in South Korea, and third ranked in Western Europe (McGraw-Hill, 2011).

iv. <u>Reduce Rework</u>

Construction reworks often caused by design errors are frequently discovered once construction is underway instead of during the earlier stage of design development (Builders Protection Group [B.P.G], 1967). However, the intelligent parametric nature of BIM, together with its features that supports true collaboration and communication, and automatic clash detection tools; allows consultants to increase design quality, devout more time to design rather than drafting, and acknowledge design conflicts early enough to eliminate design/production errors that may lead to the need of reworks (Woo, 2007, Oyewobi and Ogunsemi, 2010). SmartMarket reports indicate that BIM's ability to reduce reworks was the third most valued benefit of BIM in North America, Australia, and New Zealand (McGraw-Hill, 2012b, McGraw-Hill, 2014c). Apart from that, it was also regarded as the 4th most valued benefit to Western Europe's BIM users, 6th in South Korea, and 7th in the Middle East (McGraw-Hill, 2012b, McGraw-Hill, 2011, McGraw-Hill, 2010).

v. <u>Fewer RFI</u>

Request for Information or RFI refers to a procedure that is utilised for the purpose of confirming the interpretation of a construction document or securing clarification from architects that is needed to continue work. This often happens when there is omission or misapplication of a product; lack of information, uncertainty, or errors in construction documents; and error in design (Love et al., 1999, Meadati, 2009). As a full 3D-based intelligent parametric modelling software, BIM acts as a solution as it provides very detailed 3D renderings that include 2D, 3D, 4D (time element-scheduling), 5D (cost information), or nD (energy, sustainability, facilities management, etc., information) representations of the building, which can be easily generated from any angle at any time, thus providing comprehensive and better 3D visualization for all users (Kymmell, 2008). Numerous case studies have shown that BIM usage has drastically reduced RFI due to the amount of information and ease of retrieving information that helps to understand the intent of the design (Smith and Tardif, 2009, Hardin, 2011, Kymmell, 2008, Chelson, 2010, McCartney, 2010, Fan et al., 2014). Detailed studies conducted by Fan et al. (2014), Carbasho (2008) and Fortner et al. (2008) revealed that BIM tend to reduce RFI by 90% and beyond the normal expectation.

vi. Reduction Waste Material

As mentioned earlier in the NIST report, there is approximately 30% waste in the processes and delivery methods, with an approximate amount of US$15.8 billion yearly lost, or approximately 3-4% of the total industry's revenue (Suermann and Issa, 2009, Gallaher et al., 2004). In the UK, waste produced by the AEC industry accounts for 32% of total waste generation (DEFRA, 2011). Generally, design changes, on-site management and planning, leftover material scraps, non-recyclable/re-useable packaging waste, design/detailing errors, and poor weather could constitute to construction waste (Liu et al., 2011, Faniran and Caban, 1998). Therefore, approaches such as integrated information management, integrated design, and integrated project delivery (IPD) should be adopted as solutions to minimise waste. These approaches will enhance communication and collaboration, subsequently increasing efficiency and reducing errors, which in turn will reduce resources, energy, materials, and in this case, waste (Liu et al., 2011, Dinesan, 2008, Glick and Guggemos, 2009, Krygiel and Nies, 2008). As for that matter, BIM comes in as it facilitates for the above approaches with the function and tools it offers (Glick and Guggemos, 2009, Zhiliang and Jiankun, 2011).

vii. Reduce Project Duration and Cycle Time of Specific Workflows

The SmartMarket report revealed that BIM users in North America rated the ability of BIM to reduce project duration as the second most important benefit to users, which include the same rating given by users from other parts of the globe who acknowledged the importance of this benefit of BIM (McGraw-Hill, 2012a, McGraw-Hill, 2012b, McGraw-Hill, 2011). A study by Stanford University's CIFE conducted on 32 major projects that adopted BIM found that 7% reduction in project time is achievable with the use of the technology (Fischer and Drogemuller, 2009). A survey by Becerik-Gerber and Rice (2010) collected feedback from 424 respondents of professional organizations from the AEC industry, added that 58% of the respondents found that the overall project duration was cut by up to 50% with BIM. Apart from reducing project duration as a whole, the SmartMarket report and other studies also stated that BIM is able to reduce the cycle time of specific workflows, which further allows leaner practices and improved productivity (Eastman et al., 2009, Jupp, 2013, Hao et al., 2008).

viii. Quantity Take-offs

The term quantity take-offs refers to a key task in the preliminary stages of construction process that involves measuring and quantifying building elements to produce cost and workload estimation for the project. It is traditionally a manual process based on human interpretation that is greatly prone to error and time consuming. However, the introduction of BIM, which features application tools that can automatically estimate cost and produce quantity take-offs, can help in improving the overall construction process by greatly reducing the time and expenses for quantity take-offs production (Monteiro and Poças Martins, 2013). McGraw-Hills SmartMarket report has confirmed two most valued benefits of BIM which include improved quantity take-offs and better cost control/predictability with 43%-53% votes in Western Europe and the Middle East (McGraw-Hill, 2011, McGraw-Hill, 2010).

ix. Improve Project Quality

According to the SmartMarket report, between 62%-64% of BIM users in the Middle East and Western Europe have identified *improved quality control* and *improved overall project quality* as the most valuable benefits of BIM, making them the second and third most popular perceived benefits of BIM respectively in both regions (McGraw-Hill, 2010, McGraw-Hill, 2011). Elsewhere, BIM users in Korea perceived the mentioned attributes to be the 5th most valuable benefit of BIM (McGraw-Hill, 2012b). This comes to no surprise concerning the benefits of BIM mentioned earlier including BIM's ability to improve design quality, offer true collaboration and communication features, reduce errors, rework, RFIs, provide proper waste material, decrease project duration and cycle time of specific workflows, as well as to improve quantity take-offs. Generally, those benefits have resulted in an improved and increased quality control, productivity and overall project quality (Li and Gu, 2014, Fitzpatrick, 2012, Han et al., 2012, Kunz and Gilligan, 2007, Gu and London, 2010).

x. Prefabrication

Prefabrication is one of the current construction methods and technologies that has gained popularity worldwide. It is recognised for numerous essential benefits that it offers which include reduction in time, health and safety risks, environmental impact, and defects, including the increase in predictability, productivity, quality, and profitability (Pan et al., 2012). However, one of the decisive aspects for successful utilisation of prefabrication refers to effective collaboration among all team players right from the early phase of the project (Azhar et al., 2013). The introduction of BIM which supports and facilitates full collaboration among its users seems to allow lean planning that is inter alia among all team players involved. It is important to allow everyone to be involved from the start of the project as it allows more rooms for error detection, better planning and coordination, seamless connection between design and fabrication, which will result in easy implementation. According to a number of studies, BIM has helped to evolve prefabrication substantially by taking into account that BIM contains precise and detailed information which helps engineered building components to be manufactured or fabricated faster with better accuracy, precision, and without waste (Gohmert, 2013, Lu and

Korman, 2010, McGraw-Hill, 2012b, Sive, 2007, Russell et al., 2013, Sacks, 2008).

xi. Facility Management

In recent years, the AEC industry have witnessed a growing interest in the adoption of BIM in facilities management (FM), as it has been seen to increase efficiency (Sive, 2007). Most of the FM information systems tend to employ various FM application areas which include checking maintainability, facilitating real-time data access, space management, emergency management, and controlling and monitoring energy including supports FM practices individually; however, the manual process of entering the required data is often laborious and inefficient, thus resulting in fragmented data between the systems (Becerik-Gerber et al., 2011b). In respond to this issue, BIM has come into action by providing solution through the supply of accurate, precise, and detailed building data to the FM information systems, which further supports and enhances other functions of FM through its advanced visualisation and analysis capabilities (Becerik-Gerber et al., 2011b).

Nevertheless, there are numerous other benefits of BIM, but the above benefits are the eminent ones that are commonly reported by users in the AEC industry, which helps to further distinguish the advancement feature of BIM ahead of CAD technology. On top of that, these benefits have helped to continuously increasing BIM awareness within the industry, which then allows the industry to better recognize the potential and importance of the technology in overcoming various problems that has plagued the industry for quite a duration. The present evidence seem to suggest that the clients and contractors are fast becoming primary drivers for the adoption of technology instead of only relying on consultants (Joannides et al., 2012). This is not a surprising finding given the fact that BIM tend to offer clear benefits to users, and with the effort taken by governments from all over the world to mandate the usage of the technology in their respective countries, confidence has grown within the industry to adopt the technology. Moreover, it is crucial for stakeholders to cope with the latest technology and be updated as buildings and structures have become more complex and sophisticated by years, including producing sustainable design as well as advanced deliverables of the end product which is the building.

The rapid increase of awareness and adoption of BIM globally further emphasise the importance of BIM, and the risk of not being considered for projects due to the reduced project quality, increased construction duration, and the costs will be higher if BIM is not implemented (Yori, 2011). Therefore, the progress, development, and implementation of BIM within the AEC industry is extremely important despite the potential challenges and barriers that may come with it. There is an increased number of consultancy firms and companies that have adopted BIM and in parallel to that, demand for BIM expertise as well as staff with BIM skills has become higher in order to meet the needs for the application of new technology. Presently, consultant firms are recruiting fresh graduates with not only skills and knowledge in graphic and design, but those who also have construction visualization and BIM skills (Schmelter and Cory, 2009). A survey by Azhar et al. (2008a) further supports this notion that almost 75% respondents consider employment candidates with BIM skills as they have an added advantage over candidates who lack BIM knowledge (Azhar et al., 2008a). BIM has increasingly becoming a need for the present AEC industry with more governments mandates globally which has led to the increase in awareness of BIM and its advantages, escalation in BIM adoption and implementation, and increase in demand for BIM skilled manpower and graduates; hence, it is very crucial to meet the demands for BIM skilled workforce.

3.3 BIM IN THE ARCHITECTURAL PRACTICE

3.3.1 MATTER OF CONTENTION: BIM FOR ARCHITECTURAL PRACTICES

As previously described in this research, by 2013, the adoption rate of BIM has exceeded 70% in the United States and 50% in many developed and developing countries including the United Kingdom, Canada, Netherlands, Finland, Australia, New Zealand and South Korea. In addition, according to a survey conducted by Building Design+Construction magazine for its Top 50 BIM Adopters ranking, 83% of its respondents have been reported to have at least one BIM seat license in their houses, which shows the increase in the number of BIM adoption in North America (Construction, 2010). Nonetheless, while BIM has been relatively well received and adopted in these countries, the result is different with other countries, especially those in Asia, South America, Africa, and parts of Europe. Meanwhile, China which is known to have the world's largest population and second biggest economy was discovered to have BIM adoption rate at only 29%, whereas India which is the world's second most populous country and 10th largest economy stands at only 22% for BIM adoption rate. In addition, BIM uptake in the Middle East is on the rise, but only stands at just 25% (Construction Week Online, 2012). This seems to be in agreement with the statements made by Teo Jen Sen from DP Architects Pte., a prominent architect firm in Asia, and Paul Doherty of the Digi Group Inc., that BIM is not so popular in

Asia (Horwitz-Bennett, 2007). The last report on the adoption rate of BIM was provided by Western European countries which include Germany and France in 2010, and the findings revealed that only 36%-38% of its AEC industry have utilised BIM (McGraw-Hill, 2010). Less developed European countries like Iceland have a poorer uptake on BIM with only 5% adoption rate (Jensen and Jóhannesson, 2013). However, it took nearly 20 years for countries with high BIM adoption rate since the release of ArchiCAD by Graphisoft in 1984 to be widely accepted by the AEC industry and to reach their current adoption level (Watson, 2010). It has also been argued that it would be unfair considering that BIM only started to become known to the industry when Autodesk decided to formally use the Building Information Modelling term in year 2000 after it bought Revit from Charles River Software; however, it still took more than 10 years for the technology to reach the above level of adoption.

The design process in the AEC industry has barely developed and progressed compared to other industries within the last century (Forgues et al., 2011b). Moreover, the AEC industry is well known to be conservative and slow when it comes to adopting and embracing new technology (Love and Irani, 2004, Ahuja et al., 2016, Peansupap and Walker, 2006). This has always been the case for the industry even from the time CAD was introduced. On top of that, it wasn't until 1997 that the 2D-based technology became the industry standard and used throughout the world when AutoCAD was introduced in 1982 (Deutsch, 2011). In addition, the change from producing drawing manually with pens and pencils to the adoption of CAD was not an easy and smooth task, considering that architects and engineers in the industry had to struggle to get a hold of the new technology which literally transformed the way they had been producing drawings for hundreds of years (Ibrahim and Pour Rahimian, 2010, Andia, 2002, Joannides et al., 2012). In relation to this, the transition proved to be troublesome and painful to many parties especially in its early years even though CAD managed to revolutionise the industry and its benefits were made known to the stakeholders in the industry as well as academia (Simmonds and Senker, 1989b, Simmonds and Senker, 1989a, Baba, 1999, Joannides et al., 2012, Sampaio et al., 2010). In fact, it would not be surprising if some quarters expect the transition to BIM to be more painful and unpleasant by taking into account that BIM represents an entirely new vision and workflow, which involves every party including architects, engineers, clients, sub-contractors, and suppliers.

The trend of BIM's popularity had been observed to increase in North America and seven other countries with more than 50% BIM users. Hence, it is just reasonable and rational that this trend would most likely happen elsewhere. This prompted some leading figures in the industry to believe that similar to other new technology, BIM will completely rise to replace CAD in just a few years' time and the trouble of technology transition will be forgotten swiftly (Millard, 2008, Johnson and Gunderson, 2010). Neeley (2009) who is a BIM consultant, presented a paper at the AIA National Convention in 2009 on the comparison between BIM and CAD in terms of adoption rate in the industry. According to his study, the expected time to achieve 100% utilisation of BIM will be twice as quick compared to CAD (Deutsch, 2011). However, this proves to be inaccurate as by 2012, contrary to what is shown in the graph, BIM adoption in the U.S had reached only 71% rather than >80%, and this only happens in the U.S.

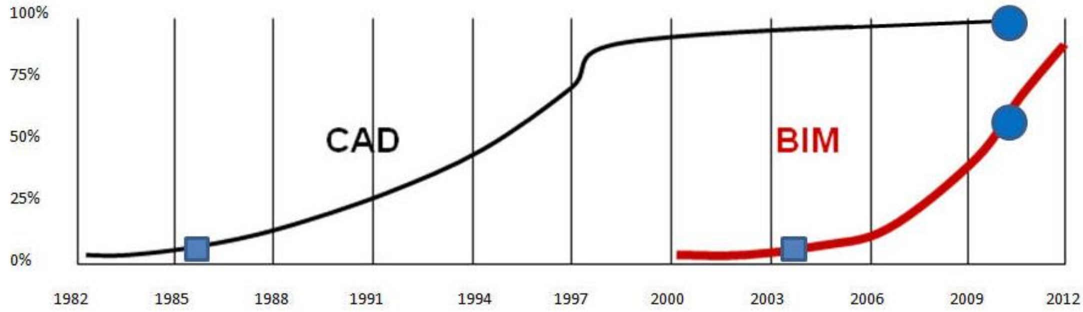


Table 3.3: Trend of CAD and BIM adoption (Neeley, 2009).

A number of BIM SmartMarket reports discussing the development of BIM around the world show varying levels of adoption rate of BIM across the globe, including a slow progress of BIM adoption outside North America. BIM users in the U.S claimed to have utilised BIM, but only 39% are heavy and frequent users (McGraw-Hill, 2012a), while only a total of 14% of the same type found in South Korea (McGraw-Hill, 2014c). In relation to this, it was not surprising when the National Building Specification (NBS) of the UK reported that there were 31% of BIM users in its AEC industry in 2011, while AECMagazine estimated in their report that only 10% of projects in the UK were completed using BIM in that same year (NBS, 2011). This shows that although the adoption rate of BIM had increased, and some would claim that BIM is on the right track to replace CAD as the industry's standard in design and production software; however, the reality on ground might be a bit different than anticipated. Meanwhile, it may be true that the industry has started to use BIM for their project deliverables, but it would not be utterly right to say that the industry has entirely *replaced* CAD with BIM even though majority in the industry are well aware of the numerous benefits and advantages of BIM technology over the age-old CAD.

In response to the above point of view, it can be argued that in the last decade, an increasing number of high profile, large budget, and iconic designs by internationally renowned architects have been designed and constructed with the aid of BIM, which demonstrates confidence in the technology and leading the way for others. Nevertheless, it is true that these high-profile and well-publicised iconic buildings actually adopted BIM technology, but it can be argued that these projects occupy only a very small proportion of the built environment, and cannot reflect the position of the industry as a whole (Giddings and Horne, 2008). Surveys and studies conducted by Architect's Journal in 2010, SmartMarket, and Delft University of Technology in 2012 illustrated that smaller firms and partnerships are less likely to utilise BIM, and the adoption rate among these firms is quite low considering that they makeup majority of the practices (Architects' Journal, 2010, Leeuwis, 2012, Kirby, 2007, Holness, 2008). A more interesting findings found that those firms who claimed to have adopted BIM had in fact failed to utilise BIM to its full potential, while some of them decided to adopt BIM mainly as a marketing strategy only for the purpose of portraying that their establishments are up-to-date with the latest technology (Palos et al., 2013, Mossman, 2010, Embi, 2014, Ramilo and Embi, 2014, Mohd-Nor et al., 2009).

The situation above indicates that the adoption rate of BIM is still not outstanding in most countries outside North America despite being on the rise. On the other hand, CAD, despite being touted as the technology of yesteryears, has not been fully replaced by BIM and continue to be used widely within the AEC industry. Recent studies have suggested that a large percentage of stakeholders within the industry, including architects, are not fully convinced about the value, necessity, and benefits of BIM (Leeuwis, 2012, Fisher, 2011, Nanajkar, 2014, Boeykens, 2012, McAuley et al., 2015, Wu and Issa, 2013b) because they worry that issues and concerns related to BIM usage may outweigh its usefulness, thus affecting the confidence of the industry towards BIM. Some of these stakeholders even conceded that their government's target in their roadmap to mandating BIM in the country is not achievable, as reported by the Pinsent

Masons survey in 2014 for the U.K (Masons, 2014). This condition worsens with the limited number of research and studies regarding digital innovation in architectural practice (Kim, 2011, Becerik-Gerber et al., 2011a). According to Whyte (2011), Aram et al. (2013) and Gu and London (2010), critical analysis on the utilisation of digital technologies including BIM within the industry is relatively limited and this situation may hinder potential users from deciding to invest in new technology. Therefore, it is very important that this research identifies the issues and determines the problem concerning the adoption and implementation of BIM within the architectural practice. The followings issues are categorised into two, namely financial and organisational issues as well as technical issues.

3.3.1.1 FINANCIAL AND ORGANIZATIONAL ISSUES

i. <u>Lack of Awareness</u>

There are several issues and concerns concerning BIM technology, ranging from general to the more technical aspects. Before delving into the more technical aspects, it is important to explore and understand the general issues that affect the masses. In particular, the most general but essential aspect is awareness. Several studies have revealed that there is still a lack of awareness among the stakeholders in the AEC industry in regards to BIM (Gu and London, 2010, Singh et al., 2011, Gu et al., 2008, Prins and Owen, 2010, Hartmann and Fischer, 2008, Whyte and Scott, 2010, Gerrard et al., 2010, Nielsen et al., 2009, Abubakar et al., 2014, Codinhoto et al., 2013, Dong et al., 2014, Li, 2013a). Even though the number of stakeholders that were not aware of BIM has tremendously been reduced over the years (NBS, 2014); however, the next question that follows is concerned with the depth of awareness that would possibly influence stakeholders to adopt the technology. According to Gu et al. (2008) who conducted several workshops and *focus-group interviews* on various sectors of the AEC industry, including academicians and government agencies on the role of BIM as a collaboration platform had found that most of the consultants, contractors, and academicians were not aware of the technical aspects of BIM and its full scale capabilities (Gu and London, 2010). Apart from that, a low-level awareness might not be enough to drive the stakeholder to adopt and implement the technology, which will also deter non-user team players from providing direct inputs on technical requirements needed by BIM-user team players considering that BIM requires more detailed and precise data input (Gu and London, 2010). Overall, it can be said that such situations will hinder the advancement and adoption of BIM.

ii. Resistance to Change

In this case, it is a general fact that the AEC industry is very conservative and slow in adopting and embracing new technology (Love and Irani, 2004, Ahuja et al., 2016, Peansupap and Walker, 2006), which is further reflected by the resistance of architects and engineers to change from CAD to BIM (Silva and Lima, 2007, Muse, 2016). Numerous studies and surveys have shown that architects are still using CAD for their daily job deliverables instead of BIM (NBS, 2012, Mohd-Nor et al., 2009, Silva and Lima, 2007, McGraw-Hill, 2011). According to Yan and Damian (2008), one of the reasons can be explained by human's natural character of social and habitual resistance towards change, in which they tend to prefer the familiar traditional or conventional method rather than trying out something new despite knowing that the later could be better and more beneficial. This comes to no surprise as Piegl (2005) expressed that it took literally years to learn and adapt CAD; hence, to throw away something that individuals have grown accustomed and comfortable, and to start all over again with something new can be very exhausting and repressing. Some might feel threatened by these towering changes (Jensen and Jóhannesson, 2013). Meanwhile, Piegl (2005) in his studies discovered that majority of the users found it difficult to understand 3D and seem to be more comfortable with 2D. This finding contradicts the results obtained by Cockburn and McKenzie (2001) and Mohd and Ahmad Latiffi (2013), which shows that users perceive 3D drawings easier to understand compared to 2D drawings. In the studies conducted by Svidt and Christiansson (2008) and Tardif (2007) showed that a higher number of architects prefer 3D drawings while engineers prefer 2D drawings. These have come to show that there are differences in personal preference from one user to another; hence, those who prefer 2D might find it difficult to change to BIM. Another trend that is being practised by some BIM users is to only utilise BIM for certain purposes such as its 4D renderings, but revert to CAD when distributing and sharing drawings and information to other project team players (Neff et al., 2010, Rubenstone, 2007); this beating the whole purpose of BIM.

iii. Financial Cost

One of the main hindrances that can affect BIM adoption is cost (Mair, 2013, Muse, 2016). The issue of cost has always been a matter of contention to the AEC industry even though leading corporations around the globe in all other industries have increased information technology (IT) spending by double-figure percentages every year (Van Der Zee, 2001). This somehow shows that the AEC industry has been thriftier and more careful on IT spending. This is further influenced by the cost of BIM software which is perceived as expensive and has caused majority in the industry to be reluctant in adopting the technology (Beck, 2012, Denzer and Hedges, 2008, Muse, 2016). Changing from CAD to BIM seems to be more expensive when taking into account several other factors which include software upgrades, new hardware with higher specifications, hardware maintenance, time commitment by users to learn the software and keep up with changes as well as other factors that might arise along the way.

Research investigating the cost have been carried out, and the findings seem to suggest that the added design cost with BIM adoption represents 5% to 10% premium on the architect-engineers (A-E) fees, or roughly 0.25% to 0.5% on construction cost depending on the size and complexity of the project (Holness, 2008, Azhar et al., 2008a, Giel et al., 2010). According to a survey by Becerik-Gerber and Rice (2010), 85% of the consultant firms were found to absorb the cost of BIM implementation which makes it difficult to hand over the implementation cost to clients, despite the fact that clients and contractors normally make the most profit in property development (Hung et al., 2002). Adding to this woe is the lack of formal cost-benefit calculation guidelines (Sulankivi, 2004) and insufficient consistent financial benchmarking associated with the conversion of CAD to BIM (Becerik-Gerber and Rice, 2010, Howell and Batcheler, 2005). Eventhough studies have been conducted to determine the calculation for the cost of investing in BIM, there is still a lack of detailed step-by-step guides, which further results in substantial losses by consultant firms due to misinterpretation and miscalculation (Becerik-Gerber and Rice, 2010). In fact, some BIM users have stopped using BIM for new projects after having to experience this setback in previous projects (Mair, 2013).

iv. Loss of Productivity

In the issue of BIM adoption, the next concern that comes after financial cost is the loss of productivity. Changing from CAD to BIM could lead to a productivity loss of 25-50%, which may take an average of 3-4 months before returning to the previous level of productivity (Construction Week Online, 2012). The transition from CAD to BIM is expected to bring a huge difference in the manner design and production are performed considering that BIM works in a completely different way from CAD. In relation to that, staff will be occupied with the changing process and possible challenges in the effort of adapting to a new system that demands a different way of working. CAD was mainly used for production of drawings, while BIM will be used all the way from design phase to post-construction phase, which demands higher commitment from staff throughout the project life cycle.

v. Change of Roles and Working Culture

As has been described, the transition to BIM compares unfavourably to the transition of CAD 25 to 30 years ago, whereby the previous experience was characterised as painful. Most studies have described that the same is happening with BIM in reference to the change of roles and working culture forced by BIM practices (Joannides et al., 2012, Sebastian, 2011). As described by Deutsch (2011), BIM tends to affect users more socially rather than technically, whereby any switches from CAD system to BIM will influence the organisational culture and calls for new roles instead of looking for new technical skills (Gu and London, 2010). The present architects no longer produce initial designs with sketches and then pass it to technical assistants or draftsmen, which is then transferred into CAD drawings before distributing it to other project team players for their inputs. On the contrary, BIM requires architects to use the application right from the very beginning of design phase as BIM offers tools to simulate the design. This tool is used to test every change made on the design throughout the design phase until the optimum design is achieved. Hence, architects, technicians, engineers, quantity surveyors, and other consultants will have to work together hand in hand throughout the design phase.

Another aspect of BIM is that 2D plans, elevations, sections, details, and walk-through videos can be extruded easily and directly from the 3D master model, thus reducing the roles of draftsmen and graphic assistants. That being said, architects have no choice but to learn and master BIM skills because they are required to use the tools themselves without assistance from draftsmen and graphic assistants. These shows that the scope of work and skills requirements will change to adapt to the new work scope and workflow created by BIM (Becerik-Gerber and Rice, 2010); hence, causing changes to staffing requirements with less draftsmen and technicians needed that will eventually result in less number of staff in the firm. Taking into account that BIM is used throughout the life cycle of a building, there is a possibility that changes in the scope of work and roles will occur throughout every phase of a project life cycle, which could take many team players out from their comfort zone.

vi. <u>Training</u>

BIM is an intelligent parametric modeller that works in an entirely different way from CAD, which is a non-parametric drafting tool. This simply means that any architectural firm that wishes to migrate from CAD to BIM will have to learn many new things, from technical skills to organizational skills advocated by BIM, and not forgetting the time needed to achieve it. The cost associated with BIM training of staff in the industry is high due to the huge syllabus of BIM, which is also one of the biggest issues related to BIM implementation (Zhou et al., 2012, Azhar and Cochran, 2009, Sattineni and Bradford, 2011, Ahmad et al., 2012). In general, the estimated cost to train a member of staff to achieve the intermediate level is £2000 (US$3200), while 'experts' level will involve the cost up to £5,000 (US$8000) per person (Matthews and Withers, 2011). The implementation of BIM does not only mean a one-off investment in training, but it is important to take into account the cost of training materials, technical support, and training following the upgrades of software; not forgetting that as of late, new versions and functions have been constantly introduced nearly every year depending on the need of the software. This makes the cost of training as an ongoing operational expense instead of a strategic investment (Smith and Tardif, 2012).

In addition to the monetary aspects, time aspect should also be considered because BIM courses or modules can take up to 5 to 6 months of training for advanced level (Royal Institute of Chartered Surveyors [RICS], 2014). If one does not wish to train to an expert level, it will still take up to two months of training for the staff to reach an acceptable level which will help the company to save time and costs on their projects (Sattineni and Bradford, 2011). Considering the above factors, the cost of training BIM is considered very high for majority in the industry (Kirby, 2007, Holness, 2008). According to a survey done by Yan and Damian (2008) and an interview by Smith (2014a), most of the stakeholders who do not use BIM believe that BIM training would cost their companies too much time and human resource, which add to their hesitancy in adopting BIM. As a result, there is a current shortage of competent building information modellers despite the growing demands for them (Azhar et al., 2008a).

3.3.1.2 TECHNICAL ISSUES

i. <u>Steep Learning Curves</u>

As stated in this study earlier, training a staff to adopt BIM is not an easy task. This would take a considerably long time for the staff to reach the expert level and cost a lot of money. Cheng (2006) suggested that there has never been any other design tool that was so demanding of its user and that is simply because BIM requires a new way of thinking; some might even recognize it as a new culture – the BIM culture (Zeiger, 2009). In contrast, CAD is about form, whereas BIM is about performance. A competent BIM user must be able to shape-shift between the designs and technical demands of any projects (Zeiger, 2009), hence the users are collectively required to have good command of the technology, sufficient knowledge of the materials and construction methods, and appreciation for professional practice (Cheng, 2006). This is partly because when one creates a BIM model on a computer, he or she is actually *constructing* a prototype of the actual building which is also known as a precise replica of the intended built environment, which is fully resolved for the means of construction. With BIM being a collaborative and communication tool that involve literally everyone in its project life cycle, even the non-users need to have some knowledge of it, at least about what is possible to do with it and what is not (Jensen and Jóhannesson, 2013).

Majority in the industry considered the steep learning curve of BIM as a burden which adds to the reason for their hesitation to adopt BIM (Sive, 2007, Salleh and Phui Fung, 2014). It is quite easy to understand this situation considering that architects and designers have worked within a compartmentalized role with CAD. Specifically, architects design with sketches or 3D sketch software like Trimble's Sketchup, while draftsmen and technicians produce 2D technical drawings or working drawings with specifications, and graphic designers create 3D modelling for 3D perspectives and artistic purposes and many others. With BIM, the same 3D design model that is produced by the architects will also be used for design simulation, performance analysis, and 3D perspectives that will be extracted for working drawings and specification as well as producing cost estimates and work schedules. As BIM is 3D based, other consultants like engineers and surveyors have been reluctant to convert to the technology because they are used to accomplishing their task in 2D format, and therefore might not find 3D models to be an advantage to them (Sive, 2007).

ii. Limited Use of Functions

Majority of BIM users in the industry end-up under utilising the technology due to the lack of awareness on BIM's full capability as well as the steep learning curve required by BIM. According to the American Institute of Architects' (AIA) report on Integrated Practice in 2006, only 34% of the architects who adopted BIM tend to use it for intelligent modelling, while the rest utilise it merely for graphics purposes (Gonchar, 2006, Post, 2006, Sive, 2007). In 2008, a survey done by FIATECH and The Arizona State University revealed that only 50% of the respondents tie schedules to BIM models and only 40% extract quantities from BIM models, which indicates that there was a limited use of BIM functions (Pavelko, 2010). In the following year, the SmartMarket report discovered that 93% of respondents believe that they are barely scratching the surface and could gain more value from BIM, which further implies that majority of the users have not fully utilise BIM to its full potential (McGraw-Hill, 2009). According to another survey conducted in the same year by The University of Southern California, visualization was also found to be the top task BIM is used for (Becerik-Gerber and Rice, 2010). In 2010, a survey by the Pennsylvania State University disclosed that the most popular function of BIM was 3D Visualization/Coordination, which gathered an average value of 60% for the frequency of implementation (Kreider et al., 2010). However, the most frequently used intelligent modelling function was 3D control and planning, which received 34% response rate for the frequency of implementation. This survey (Kreider et al., 2010) that was carried out 4 years after the first survey by the AIA seem to suggest that there was no promising improvement in the utilisation of BIM's full function as the rate from year to year remained similar. Hence, it is safe to say that BIM is still primarily a visualisation tool despite having many other sophisticated tools and functions. By virtue of the above scenario, Smith and Tardif (2012) came to suggest that many of the BIM users in the industry fall back on a desire not to be perceived as lagging behind a growing and inevitable trend. This is definitely a very unhealthy that signals the vagueness of BIM development.

iii. <u>Legal Aspects and Liability</u>

Among all issues concerning BIM adoption and implementation, legal and liability matters have been among the most discussed issues within the industry. In contrast to CAD, BIM have a larger impact on legal relation matters among the project team players due to the depth of the information involved, including the real-time interchange of information throughout every phase of the project on a shared platform (Regner, 2008). The act of sharing information electronically using a new technology which involves beginners without the proper forms of contract may pose new risk and bigger liability to all team players. If proper steps are not taken immediately to overcome this issue; hence, there will be a lengthy list of disclaimers during model sharing (Smith, 2007, Jordani, 2008). The concerns related to the lack of building contracts which takes BIM liability and legal aspects into consideration is also reflected in a recent survey carried out by Masons (2014), whereby the findings stated that two-thirds (66%) consider that the current forms of contract used in the industry is not suitable for BIM related projects. Reformulating forms of contracts for BIM led projects will not be a straightforward effort considering that the integrated concept of BIM will likely increase risk and liability due to the ambiguous and overlapping roles and responsibility of team players involved (Leeuwis, 2012). Apart from that, issues of copyright and intellectual-property also arise under BIM in order to determine who will own and be responsible for the single and comprehensive master model when all the team players including contractors and clients collaborate and work together in real-time (Regner, 2008, Joannides et al., 2012). Prior to the introduction of BIM (and IPD), project stakeholders have been sensitive in exchanging information between themselves and the act is normally guarded. Releasing too much information could lead to inaccurate, imprecise, and unnecessary information, which should be avoided in preventing the liability from possible mistakes later during construction that could lead to costly lawsuits between parties (Nasvik, 2010, Czmoch and Pękala, 2014). Adopting BIM, along with its real-time collaboration and communication features, will prove to be a huge challenge and all parties; from policy makers to industry stakeholders, will have to cooperate and work together in encountering this matter.

iv. Collaboration Tool

As has been previously discussed, the main difference between BIM and CAD refers to the ability of BIM to offer real-time information sharing and collaboration across the organizational boundaries. However, research have shown that although BIM was designed to facilitate real-time collaboration in producing smoother project delivery, it failed to function as intended and expected (Neff et al., 2010, Becerik-Gerber and Kensek, 2009, Masons, 2014, Howell and Batcheler, 2005, Isenstadt, 2008). The survey and workshop conducted by Becerik-Gerber and Kensek (2009) from University of Southern

California in 2009 concluded that BIM has been utilised on a very limited basis in terms of collaboration and integrated practice. A study carried out by Dossick et al. (2009) which included comparative case studies and triangulation interviews strengthens the above notion based on the findings that even with BIM usage, collaboration across disciplinary field is still limited and project team players remain organizationally divided. Further studies by Neff et al. (2010) add that project team players continue to use their own disciplinary-specific software tools in carrying their daily tasks. Howell and Batcheler (2005), the co-founders of buildingSMART, in their analysis of several renowned BIM projects across the globe also pointed out that most of the project team players at that time preferred their own trusted software applications to be employed in their daily work of design and analysis. Neff et al. (2010) and Masons (2014) also found that BIM is only utilised to produce representations and analyses of buildings that remain within its own disciplinary silos. Majority of BIM users still swap models in the form of traditional files instead of adopting a more direct service-oriented or distributed object platforms (Steel et al., 2012). This was largely due to the fact that the interests of parties involved are not easily aligned, including legal and liabilities concern related to real-time information exchange. On top of that, it is difficult for the industry to change the traditional method of collaboration into BIM-based collaboration within a very short time (Masons, 2014, Neff et al., 2010, Baxter and Lyytinen, 2005, Nasvik, 2010).

v. Interoperability

A true collaboration among project team players including those from different disciplinary background is one of the most prominent features that distinguish BIM from the conventional CAD. However, real-time collaboration requires interoperability; the ability to transfer, exchange, interpret and present data between different software packages (Cambridge University Press, 2014, AIA, 2009), which is still one of the significant challenges faced by the current BIM users (Nielsen et al., 2009, Grilo and Jardim-Goncalves, 2010, Becerik-Gerber and Kensek, 2009, Steel et al., 2012). Considerable amount of efforts have been taken to develop and improve interoperability standards, however, the lack of seamless interoperability between software applications still exist within the industry (Aguiar Costa and Grilo, 2015, Karan and Irizarry, 2015). A claim has been made in relation to improvements, but it has been observed that improvements are more successful among software of the same trait or discipline rather than cross traits or cross discipline (Aguiar Costa and Grilo, 2015, Karan and Irizarry, 2015). This situation reflects the sluggish progress in addressing the issue of interoperability within the BIM realm, which is supposed to support collaboration across traits and discipline rather than inter traits and discipline. This can be seen with the *Industry Foundation Classes*, or IFC, that was introduced in 1996 by the International Alliance for Interoperability (now buildingSMART), as the first industry standard or format for the exchange of BIM models. While software application such as electrical, mechanical and structural engineering (including Revit by Autodesk), and steel detailing (including Tekla Structures) are mostly IFC compatible, it is not the case with other software including those for cost estimation, environmental and performance analysis, and facilities management (Steel et al., 2012). There has been effort and progress in developing and implementing IFC; however, many research and seem to suggest that it still has many weaknesses and more improvement is needed to achieve fully effective interoperability (Jeong et al., 2009, Pazlar and Turk, 2008, Zhiliang et al., 2011, de Laat and van Berlo, 2011, Cerovsek, 2011). The lack of effective interoperability will increase cost, waste, and simply impair the main feature of BIM in relation to real-time collaborative delivery, thus making it pointless to adopt BIM.

vi. Lack of Strategy

It is completely understood that in order to maintain or boost one's competitiveness in the realm of business, or the AEC industry for this matter, it is important to invest in state of the art technology such as BIM. However, in any substantial investment made to increase or reinforce business, a coherent planning or strategy is often needed to make sure that the investment is fruitful. Nonetheless, not many business leaders in the industry can produce coherent strategy to treat BIM as a tool that will increase their competitiveness or streamline their operations (Smith and Tardif, 2012). In fact, if the reports on BIM around the world were to be taken directly as an indicator, it would not be surprising if one would come to conclude that majority in the industry might have adopted BIM simply to avoid being perceived as falling behind an emergent trend. This notion is based on the fact that the increasing rate of BIM adoption around the world does not telly with the rate of projects being delivered fully with BIM. As mentioned in previous sub-chapters, not all BIM users have fully utilised BIM potential and a certain percentage is still using it only for the purpose of visualisation and 3D modelling, which can be accomplished using a much cheaper CAD tool. According to Smith and Tardif (2012), majority of the stakeholders in the industry adopt conservative technological implementation strategy brought by CAD, and they are unable to connect BIM implementation to achieve clear business goals. This will eventually produce problems, with the minimisation of innovation to the business. It was further added that the most effective BIM implementation strategies would be those that are based on a contemplative and deliberate analysis of the firm's business processes and workflow, both externally and internally. The lack of research and resources as guidelines to strategize BIM implementation certainly failed to help in improvising the current situation.

3.4 ACADEMIA TO THE RESCUE

Numerous issues concerning the adoption of BIM have been briefly discussed, and it was found that even the most potential of technology will not be easily accepted, adopted, and implemented as it was initially expected. Most of the issues concerning BIM have been pointed down to two notions. The first notion describes the current stage of BIM adoption as a huge investment in terms of money, time, and effort considering that most BIM adopters are big organisations instead of small ones. Surveys around the globe including those conducted by NBS, SmartMARKET, AJ100, Digicon, and Delft University of Technology have shown that the number of BIM adopted in small architectural practices is low, given the fact that smaller firms are less likely to use the technology compared to bigger firms (IBC and NBS, 2013, McGraw-Hill, 2012a, NBS, 2013, Leeuwis, 2012). It was further reported that most of the firms seem to consider cost and time as the main barriers to adoption of BIM (Holness, 2008, Kirby, 2007). This is an extremely huge concern because smaller to medium scale size firms have been observed to make up the majority of architecture firms compared to bigger ones. On the other hand, the second notion draws out the fact that it is difficult for the industry, let alone a single firm, to act alone without any support in the effort of fully adopting and implementing BIM which is known to be a huge investment. An important point that marks a huge distinction of BIM implementation from other technology can be explained based on the demands that BIM requires full collaboration from all project team players, including clients and contractors. Another critical point related to the implementation of BIM is that the firms have to ensure that BIM will be adopted for all projects including future ones, or at least the majority of it. Hence, it is very difficult to expect every team player in a project to invest a lot of money, time, and effort on a technology let alone on every project including future ones.

The effort of introducing new technologies and innovation has not often been an easy task, what more a holistic technology like BIM. Difficult situations have led many governments of developed countries to launch initiatives since the 1970s with the purpose of linking and fostering cooperation between HEIs and the industry in hope that the rate of innovation and technology transfer and adoption will escalate (Mowery and Sampat, 2006, Cohen et al., 2002, Spencer, 2001, Blumenthal, 1994, Lowden et al., 2011). Most often than not, developed countries seem to focus their technological innovations and development largely on their HEIs; hence, the co-operation between HEIs and the industries is deemed crucial with a huge support from the governments (Etzkowitz et al., 2000, Keck, 1993, Mowery and Rosenberg, 1999). Presently, HEIs together with the industry and government have taken the role to become the provider of scientific knowledge for industrial innovations through research, training, and related activities (Gunasekara, 2006, Rosenberg et al., 1995, Mueller and Cantner, 2000, Yusuf and Nabeshima, 2007, Blumenthal, 1994). On top of that, the scope was widely broaden to directly contribute to the development and transfer of new discoveries into innovative technology that can be commercialized and assimilated for the use of mass public (Yusuf and Nabeshima, 2007, Chesbrough, 2003, Veugelers and Del Rey, 2014). Professor Henry Etzkowitz, who introduced the concept of Triple Helix of university-industry-government interactions in the 1990s emphasised that all the three parties must work interactively together if the goal is to produce optimum innovation that can actually be used by the wider public, with the aim of effectively boosting up economic development. Firms need support in terms of facilities, sharing or acquiring of knowledge and expertise, experimental grounds, and higher levels of training as they enhance or develop their technological level. Apart from playing its traditional regulatory role in setting the rules and standards, the government can also act as public entrepreneur and venture capitalist by investing and promoting the innovation or technology (Etzkowitz, 2003). The research further revealed that firms, HEIs, and governments that choose to engage in a holistic way of practice are more likely to achieve more than those who act individually.

The above model for technological innovation at the very moment seems to be lacking when it comes to the development and implementation of BIM, at least in most of the countries around the world. The same could be achieved if it is to be exercised for the development of BIM based on the previous success of the Triple Helix model. As has been mentioned, governments have started to take serious actions in the effort of supporting and promoting BIM adoption within their respective AEC industry (BIM Task Group, 2011a, HKIBIM, 2013, BuildingSMART, 2012, NBS, 2015). Roadmaps, 'bottom up' planning, and foresight exercises that go all the way in the process of mandating BIM have been carried out by governments around the globe. However, academia has been the only one that seems to argue in the pursuit of BIM success (Cory and Schmelter-Morrett, 2012, Macdonald, 2012, Forgues et al., 2011b, Sharag-Eldin and Nawari, 2010, Kiviniemi, 2006, Sabongi, 2009). In response to this situation, it is now high time for HEIs to rise and play their role in ensuring that BIM technology is to be fully assimilated into the AEC industry and used to its fullest potential to overcome its slow adoption rate despite its vast innovative features and huge potential. There are two ways the HEIs can help which include producing in-depth and wide research work on BIM and equipping graduates with the right skills and the understanding of BIM.

3.4.1 ROLE OF ACADEMIA: RESEARCH WORK AS SUPPORTING MATERIAL

Research related to BIM is still low compared to other subjects such as design and engineering (Sharag-Eldin and Nawari, 2010). The amount of critical analysis on the practices of BIM in construction projects has been relatively limited, and the same goes to inadequate amount of literature on this subject matter (Whyte, 2011). Hence, this situation has made it difficult for the industry to adopt BIM due the lack of studies on BIM that can be used as guide and support. As has been mentioned earlier, most of the firms need the necessary knowledge, guidance, and expertise to enable them to produce coherent strategy and planning in order to utilise BIM as a tool that will actually increase their competitiveness or streamline their operations. Eventually, such huge investment in money, time, and effort will pay off and produce a positive return of investment (ROI) for short-term and long-term benefits. The HEIs must respond to this situation quickly and with strict concern if BIM is to be successfully commercialized and assimilated into the industry considering that academic research has become the underlying tool to industrial and technological innovations (Löfsten and Lindelöf, 2002, Mansfield, 1995).

3.4.2 ROLE OF ACADEMIA: PRODUCING WORKFORCE

The same action must be taken with BIM like the initiative taken by HEIs to equip graduates with CAD skills during the early years of CAD 20 to 30 years ago. In fact, it is important to consider that the cost to train BIM is more than it was with CAD, which further proves that BIM has been a burden to the industry that seems to interfere with the progress of BIM as a whole. Hence, it would be very wise for the academia to step up and aid by not only equipping graduates with BIM skills, but to educate them with built environment knowledge through or with the use of BIM. Education is crucial as it teaches individuals the correct way of thinking, which more or less share the same concept to training that teaches skills to individuals. In this case, a holistic technology like BIM certainly needs thinking than just skills alone. It should be a great concern as pointed out in the research by Bybee and Fuchs (2006) which found that even employers in a modern and advanced country like the United States have claimed the crucial need to have a workforce with a much higher level of technological literacy. Needless to say, it has been one of the roles played by HEIs in supplying the industry with workforce (Monck and McLintock, 1988). This further implies that workforce with the desired competencies must be able to perform critical thinking, complex communications skills, and solve semi-structured problems (Bybee and Fuchs, 2006). This is essential as it enables them to carry their duty diligently and face challenges efficiently as demanded by their employers.

In to the case of Malaysia, research by Chew (2005), Hooi (2010) and Almeida and Faria (2014) revealed that most Malaysian firms and organisations often place little emphasis on training needs. Meanwhile, a survey conducted by Gilbert and Sia (2001) on 100 ISO-certified firms in Malaysia discovered that nearly half (45%) of them admitted to inadequate training provided within their firms. The more recent survey by Almeida and Faria (2014) revealed that only 33% of the employees in Malaysia have received some form of training by their employers. In contrast, firms in advanced European countries take on-the-job training much more seriously with more than 50% of its firms were found to be actively engaged in training throughout the year as shown by the following percentages: Denmark with 83%, Sweden with 79%, Finland with 62%, Netherlands with 61% (Cuesta and Salverda, 2009), Norway with 60%, and the UK with 57% (Badescu and Loi, 2010). This comparison reflects that Malaysian firms have put very little emphasis on-the-job training which is known to be a very important element in developing or upgrading their work deliverables.

On top of that, there may be several reasons that may have led to the above condition. Robertson (2003) in his research on the role of training for small and medium firms of developing countries, including Malaysia, added that the unfavourable situation was the result of inadequate knowledge and resources related to the engagement of training programs. Meanwhile, a study by Westphal (2002) found that firms in developing economies need substantial help in acquiring skills and knowledge before they can achieve the best-practice level in application of technologies, especially of new technological applications. One of the main reasons for this is the fact that most medium and small firms lack savings, and the time lag between the point of investment and return of investment may be far apart, thus making full investment in both technology and comprehensive training unaffordable (Westphal, 2002). On the other hand, banks refuse to provide loan for something with uncertain outcome, which in this case refers to knowledge or technical skills that are regarded as intangible (Westphal, 2002). This often happened to most medium and smaller firms, which further explains why medium and small firms failed to provide training compared to larger firms (OECD, 2013). As a result, most of the firms in the industry of developing countries including Malaysia often look upon the government for help and assistance in acquiring the necessary skills and knowledge in order to keep up with the ever advancing technology applications in the industry (Robertson, 2003). Hence, the government is left with no choice but to help the industry to overcome the financial constraints of small and medium firms, and the respond to the demands for development of necessary skills and knowledge through public tertiary education and knowledge-based activities through their agencies (Robertson, 2003). The government's policy of providing the technology skills and knowledge through tertiary education is in line with the responsibility of HEIs in preparing the students for employment (Nabi and Bagley, 1999). However, to equip graduates with the skills needed to use the latest technology is seen as the right move having in mind that they will later fill the voids in the industry that is in need of workers with those skills as well as to overcome the issue of inadequate funds to provide the comprehensive on-the-job training.

3.5 THEORETICAL FRAMEWORK

It is extremely important for HEIs to play their role in assisting innovation and application of technology. The technology in this case refers to BIM which needs to be successfully commercialized and assimilated by the industry, including the importance of utilising it to its full potential, which helped to set up the background of this research. The trend in Malaysia is to rely on the government assistance to equip the industry with workforce that have the updated skills and knowledge of the latest technology through public tertiary education. Hence, the objective of this research aims to suggest the best possible way to equip students with the necessary skills and knowledge. However, the main challenge faced by this research is to figure out the right method and contents that are necessary to achieve optimum results, in the sense that it can function well within the condition of the country. There is a possibility of mismatching the skills that should be acquired at university and the skills needed by the industry without proper research and planning of the necessary knowledge that should be acquired by students (Mason et al., 2009). The resulting possibility for a mismatch of supply and demand is a great concern to both government and the industry as it could result in a huge waste of effort, time, and energy (Zwieg et al., 2006). The research is centred in Malaysia which caused it to be more challenging as described by Westphal (2002) who states the firms in developing countries often require indigenous skills to adapt the technology to local conditions. Therefore, the framework of this research is developed based on the need to produce a curriculum that guides the HEIs to equip students with the necessary knowledge and skills to answer the demand of the firms in the industry. This is in line with the objectives of most HEIs and acts as a response to the prime motivation of majority of students in attending university (Nabi and Bagley, 1999, Branine, 2008), which is to enhance their employment status (Stewart and Knowles, 2000, Lowden et al., 2011).

The process of developing the theoretical framework for this research involves two further steps described as follows: (i) identifying the current issues related to BIM implementation in the academia considering that related industry-academia issues will provide some background to reduce the limitation of the research instrument, and (ii) reviewing seven national level BIM surveys that will act as a precedent study to help form the research instrument for this research.

3.5.1 MATTER OF CONTENTION: BIM IN ACADEMIC INSTITUTIONS

i. <u>BIM status in HEIs</u>

The introduction of BIM into academic curriculum is in certain ways similar to the introduction of CAD into academic curriculum 20-30 years ago. It has been observed that the AEC industry around the world in general has been slow in adopting BIM; however, the education world seems to be even slower with a survey in 2010 revealing that only 12.7% of architecture schools teaching BIM as part of existing modules and only 9.7% as BIM-specific course (Macdonald, 2012, Sharag-Eldin and Nawari, 2010, Barison and Santos, 2010a). A survey by Forgues and Farah (2013) reported that only 19% of the HEIs in Canada have integrated BIM into their curriculum. A more recent survey in the UK by Underwood et al. (2015) showed positive progress with 57% of the HEIs having BIM integrated into existing modules, albeit only 7% have fully embedded it in majority of their curriculum. It is safe to say that changes are not taking place as fast as in the industry (Forgues et al., 2011b, Macdonald, 2012, Sharag-Eldin and Nawari, 2010) despite the considerable amount of attention gained in recent academic literature (Becerik-Gerber et al., 2011a). Studies have shown that there is still a considerable amount of HEIs that have not incorporated BIM into their curriculum (Cory and Schmelter-Morrett, 2012, Forgues and Farah, 2013, Poirier et al., 2016). Furthermore, many of these institutions, including those in countries with strong record of

BIM implementation such as Finland, still stick to the old CAD curriculum, mainly AutoCAD for drafting, visualising and producing appealing presentation drawings (Ibrahim, 2007). In general, therefore, it seems that parametric modelling, simulation, and analytical tools are still far from being fully implemented by majority in academia (Zuo et al., 2010) despite the fact that the industry has started to acknowledge the importance of these tools.

ii. Types of BIM Application

A change from CAD to BIM is not an easy ride because BIM software itself is much more complex than CAD. According to Kymmell (2006); Kymmell (2008), there are three types of BIM linked applications described as follows: (1) the applications which create BIM models, (2) the applications which view and analyse the BIM, and (3) the software applications which process information which may be linked to BIM. On the other hand, Cant (2012) stated that there are only two kinds of BIM software which include the following: (1) authoring software, and (2) coordination software. Meanwhile, even though both Kymmell and Cant have categorised the first two types of BIM software within the same scope; Cant did not acknowledge any software that processes information which can be linked to BIM such as Microsoft Office. BIM also acts as a platform for simulations and management supporting application, thus it would have a wide range of software applications associated to it. Considering the complexity and diversity of BIM software applications; hence, it will be difficult to choose the right software or the right package of software that will provide the right skills to the students in relation to BIM software used by the majority within the Malaysian AEC industry.

iii. Steep Learning Curves

Similar to CAD approximately a quarter decade ago, the current users of both the industry and education find that the present BIM tend to have notoriously steep learning curves (Cheng, 2006, Weber and Hedges, 2008), even though some would argue that the change prior to CAD was more difficult as it involved changes of different mediums; from hand tools to computers. The tools and technical features are not the only differences of the BIM software compared with those in CAD. The process involves changing from surface/solid modelling, which is a set of abstract representations to be interpreted; to BIM's parametric modelling, which on the other hand is a database of information and relationships. The change from these two totally different systems is seen as a paradigm shift, which constitute a new methodology (Denzer & Hedges, 2008). This can therefore become a huge challenge, as new methodology is not only referred to teaching, but also for learning. Teaching experiences and research carried out have acknowledged the challenges and barriers to the teaching and learning of BIM in education which is closely related to the learning curves and complexity of the technology (Denzer and Hedges, 2008, Seletsky, 2006, Ibrahim, 2007, Wong et al., 2011b, Taylor et al., 2008, Gier et al., 2006, Gier, 2007, Woo, 2007, Gu and de Vries, 2012).

iv. BIM Requires Construction Knowledge

BIM is an intelligent parametric modelling technology that allows users to form a prototype of the building, which is a precise replica of the intended built environment. Therefore, it is necessary for the users to have a full knowledge or clearly understand the science of building and construction. Vandezande (2004) who works as CAD/BIM manager of Skidmore, Owings & Merrill has revealed that it was the senior team members in the firm who possess more knowledge and experience in construction matters; hence, they seem to be far better in using BIM compared to junior members who are generally more fluent in computer usage. The same case is applied in education. A survey carried out by Woo (2007) at the Western Illinois University has shown that the lower-level undergraduates students who take BIM related module have admitted to have difficulty in mastering most of the BIM tools because they are associated with parameters that need deep construction knowledge, and cannot be easily understood by lower undergraduates. A survey conducted by Taylor et al. (2008) on his students also revealed the same concern based on the claims that it was necessary to have knowledge in the construction process in order to effectively utilise BIM.

v. Visualization as main purpose of using BIM

As described earlier in the previous sub-topics, many BIM users in the industry have utilised the technology mainly for visualisation rather than other features that sets it apart from the old CAD technology. Unfortunately, the case is the same with education as well. According to a survey conducted by Becerik-Gerber et al. (2011a) on the integration of BIM into the AEC education curricula in the United States, the majority of the architecture program, which is at 80%, was teaching BIM for design and visualization purpose. It is odd that the new features offered by BIM such as constructability, performance optimisation, or real-time collaboration have not been taught to the students, yet the students are taught the design and visualisation features that are readily found in cheaper and older CAD software. Another survey conducted by FIATECH & Arizona State University in 2008 on AEC institutions across the United States seems to strengthen the case as the survey reported that 82% of the institutions used BIM for 3D coordination purpose (Pavelko, 2010). Evidences have also suggested that many still consider BIM as just another 3D modelling software application (Ibrahim, 2007, Abdulfattah et al., 2017, Moser, 2016). This unfortunate situation, which occurs in both the industry and education sectors, must be addressed effectively because if these problems continue, then there is no point on migrating from CAD to BIM.

vi. Threat to Creativity

Creativity is a quality or phenomenon that is closely associated to design thinking, but it has been an issue in regard to the use of BIM. Previous studies by Becerik-Gerber et al. (2011a), Denzer and Hedges (2008), Barison and Santos (2012), and Magiera (2013) on BIM in tertiary education have established that BIM tends to interfere with creativity, thus posing a threat to design thinking. Moreover, students have claimed that it is difficult to create curved surfaces and complex geometrical patterns with BIM tools without any assistance (Sah and Cory, 2008). In addition, Berwald (2008) and Denzer and Hedges (2008) also found that as a result of the above difficulty, students tend to make rapid decisions by opting for limited palette of default predefined material and assembly instead of creating it from scratch and form their own libraries. In relation to this, Ibrahim (2007) discovered that not all the students are equipped with the knowledge on how to customise their own libraries of tools and materials, thus limiting their options. There is a possibility that students would not be confined to the limited predefined components if BIM is taught more deeply and widely to the point where students learn how to customise their own components and libraries, thus allowing them to express their creativity more effectively. On the contrary, Andrzej Zarzycki (2010) from the New Jersey Institute of Technology, prefers to look at it in a different way. He stated that BIM does not necessarily hinders creativity, but rather promotes parametric thinking that bridges technical knowledge with creativity, thus balancing between creative freedom and design integrity (Zarzycki, 2009).

vii. Directions and Philosophies

Directions and philosophies are among the biggest concerns in the integration of BIM that should be included in the curriculum of tertiary education. With BIM poised to replace CAD in the AEC industry (Azhar et al., 2012, Cemesova et al., 2012, Zeng and Tan, 2006, Glema, 2013, Deutsch, 2011), this further leads HEIs to gear up in order to meet the demands of the industry. Hence, it is very important for the academia to revisit their curricular approaches and identify the directions of architecture education based on the current trend. While CAD was more of a drafting tool (McLoughlin, 1989, Navona et al., 1994, Shen et al., 2007), BIM is entirely different; it is rather *a process* or a *way of thinking*, a huge difference to CAD that results in a pedagogical shift. This is in agreement with Ambrose (2012) who stated that academics must develop new methods to develop from three-dimensional to four-dimensional, information driven, thinking and skills, rather than focusing only on software skills. Hence, he suggested the reformulation of the fundamental significance of technology and the comprehensive nature of design by integrating the culture of abstraction in design and the culture of simulation in the software in the process of developing BIM curriculum. However, Cheng (2006) stated that integrated education can be too demanding and overwhelms the subtleties inherent in developing design thinking. It was further emphasised that BIM's answer-driven philosophy and design thinking's question-driven philosophy might collide and pose a risk by affecting design thinking, which is central in architecture education. Cheng (2006) suggested the importance of slowing down the implementation of BIM and not to overwhelm the existing curriculum with BIM integration. In response to this, Seletsky (2006) argues that from a positive outlook, BIM should be integrated into the curriculum as soon as possible considering that BIM's character can enable integration between educational process and simulative practice, thus revolutionising architecture teaching as a whole. The directions and philosophies of BIM within architecture education must be addressed carefully in order to avoid mismatch of supply and demand between academia and the industry.

viii. Conceptual Knowledge Rather Than Procedural Knowledge (software skill)

In relation to this matter, majority in the industry of advanced economic countries like the United States prefer employees with deep conceptual knowledge of BIM instead of those with minimum procedural knowledge of the software. HEIs in the US as well as in the UK have started to look into the demands from the industry in this matter. According to a survey carried out by Taiebat and Ku (2010a) on 42 AEC firms across the US, 50% of the firms prefer graduates with deep conceptual knowledge of BIM when hiring new employees with BIM skills, while only 12% prefers graduates with BIM software skills alone and 38% prefer both. In the following year, Ku and Taiebat (2011) conducted another survey with the same objective, but this time on contractors across the US. The survey found that nearly half (49%) of the firms prefer graduates with deep conceptual knowledge of BIM, while 11% prefer graduates with BIM software skills alone, and 40% prefer both, which makes the two surveys consistent with each other. When BIM was introduced into the AEC tertiary education by several HEIs in the US circa 2003-2006, it was mostly taught as a single module, very much similar to the teaching approach adopted for CAD (Ibrahim, 2007). However, majority in the academia later began to realise that BIM was different to CAD and that it may need its own method and approach that is unique to its own system that projects a shift in thinking and culture (Denzer and Hedges, 2008, AIA, 2014). From 2007 onwards, more HEIs in the US have began to develop its BIM curriculum based on the need to equip students with deeper conceptual knowledge of the technology rather than just proficient software skills (Barison and Santos, 2012, Ozcan-Deniz, 2016), with the aim of answering the demands of the industry. This action was later on followed by countries from other parts of the world such as the UK and Australia (AIA, 2014, Kiviniemi, 2014, Morton, 2012). As described by Yori (2011) and Kiviniemi (2014), the use of BIM in professional practice is not limited to design and modelling tool but also as a medium for simulation, operation, and collaboration that needs to be reflected in their education training. Hence, more HEIs began to integrate BIM into their existing curriculum and introduced intra-modules and interdisciplinary collaboration modules with BIM acting as the main working medium for students (Barison and Santos, 2012). The way academia in advanced countries such as the US and the UK respond to the needs of its industry in this matter is an aspect that should be considered by Malaysia.

ix. <u>Integrating BIM into Curriculum</u>

As previously stated, the industry highly demands employees with deep conceptual knowledge of BIM rather than just proficient software skills. In relation to this, some of the AEC tertiary programs have started to look into this matter by developing a curriculum and offering modules that are expected to meet the industry's demand. However, to date there has yet to be any standard formula or formal instructional strategy in teaching BIM at a national level in any country, even in the US (Cheng, 2006, Gu and de Vries, 2012, Crumpton et al., 2008), which is a country with the highest rate of BIM implementation (McGraw-Hill, 2012a).

The academic freedom enjoyed by academia allows them to determine their own teaching and learning objectives for their academic programs which is unique to their own academic philosophies, thus resulting in unique approach to interpretations and practices of subjects including BIM. This may be positive to the development of knowledge as a whole, but it may be negative for a field that has been very much industry oriented such as architecture and construction, especially in developing countries like Malaysia that expects tertiary education to supply technological knowledge and skills to the workforce for their AEC industry (Westphal, 2002). Having this in mind, there are still many HEIs that have not seriously considered the industry's demands when formulating their BIM curriculum. In fact, majority of the HEIs have struggled to implement BIM into their curriculum, let alone to integrate BIM into their curriculum in order to meet the industry's demands (Sacks and Pikas, 2013, Ferrandiz et al., 2016). According to Gu and London (2010) who conducted focus group interviews (FGIs) across Australian cities, the AEC programmes failed to complement the industry's needs as digital tools such as BIM were taught through stand-alone modules, focusing on software skills rather than deep conceptual knowledge.

As has been mentioned, the significant complexity of BIM is different from CAD because it requires new teaching method, which needs more space in the curriculum and different approach altogether (Becerik-Gerber et al., 2011a, Ambrose, 2012). In response to this, academics must review the current curricular approaches and strategise in the effort of developing a new teaching and learning system that employs BIM's intelligent features and collaborative approach central to the students learning experience, which reflects how BIM is used in real-world practice. According to the majority in the architecture education and industry, this can only be done through full integration of BIM into the current academic curriculum (Becerik-Gerber et al., 2011a, Ambrose, 2012, Sharag-Eldin and Nawari, 2010, Forgues et al., 2011b, Macdonald, 2012, Brown and Peña, 2009, Gu and London, 2010). However, Guidera and Mutai (2008) cautioned the academia in its pursuit to develop BIM curriculum that other educational objectives may be compromised if too much time, effort, and concentration are focused on the need to equip students with high levels of competencies on a complex technology like BIM and its broad range requisite software tools.

Therefore, a more holistic and careful approach is needed in strategising the integration of BIM into the curriculum. In order to achieve this, it has been suggested that a curriculum-wide coordination or even a university-wide coordination needs to be done accordingly in order to reconfigure the current courses to integrate BIM into the architecture pedagogy (Berwald, 2008, Woo, 2007, Azhar et al., 2008a). This will provide students with BIM-centred knowledge and skills of architecture that is required by the present industry without having to compromise other educational objectives. A guideline for developing BIM curriculum prototype that takes into consideration on the industry's needs in balance with established best practices of BIM is needed by the Malaysian accrediting body, which in this case is the Malaysian Board of Architects, to help guide the HEIs in Malaysia to effectively implement BIM into their curriculum.

3.5.2 NATIONAL LEVEL BIM SURVEYS COMPARISON

The second step in developing the theoretical framework for this research involves reviewing seven national level BIM surveys that act as a precedent study to assist in the development of research instrument. Considering that Malaysian architecture and architecture education was modelled after the British system which has remained largely the same ever since (Hassanpour et al., 2011); hence, it is in the best interest that the research engaged with UK's National BIM Report developed by the National Building Specification (NBS) of the UK as a primary base line concept with the synthesis of other models to develop the theoretical framework and research instrument for the purpose of data collection. At this point of framework development, the goal was to establish the components and categories of the framework, whereby pattern-matching technique was applied. The selection, culling, and modulation of each section or category was made based on the following criteria:

a) The NBS categorisation of topics that was utilised in the UK, New Zealand, Canada, and Finland.

b) The elements of other models which are deemed necessary but absent from the NBS model.

c) The suitability and appropriateness of the categorisation to be used in the context of BIM adoption and experience.

Table 3.4: Comparisons of National BIM Reports around the world.

Report	The Business Value of BIM - McGraw-Hill	BIM in the Middle East - McGraw-Hill	The Business Value of BIM - McGraw-Hill	The Business Value of BIM - McGraw-Hill	IBC/CCA National BIM Survey	Masterspec BIM Report	NBS BIM Report
Year	2009*	2011	2010	2012	2011	2012	2012
Country	USA	Middle east	Western Europe	Korea	Canada	New Zealand	United Kingdom
Sample size	2,228 respondents (598 architects (27%)) Total firms in US (2009) – 22,989	273 respondents (51 Architects (19%))	948 respondents (404 Architects (43%))	264 respondents (93 Architects (35%))	212 respondents	524 respondents (299 Architects (57%))	1000 respondents (370 Architects (37%))
Survey medium / duration	Internet Online 35 days	Internet Online 4 months	Internet Online 2.5 months	Internet Online 5 weeks	Internet Online N/A	Internet Online 2 months	Internet Online 2 months
Survey Content	Value of BIM – Overview - Perceived ROI, measured ROI, Business Value of BIM Internal business value of BIM - Benefits, Challenges and ways to Improve Business Value Project value of BIM - Value, Factors Affecting Value, Challenges, Opportunities Player value of BIM - Comparison of value, benefits and challenge between parties/roles. Adoption of BIM - Growth, Usage, Importance – Past, current and future - Obstacles & Future Decisions	Employees & discipline info BIM adoption and usage - BIM usage - Usage by company type BIM experience by nos. of projects - By discipline - By company size BIM awareness - Benefits of BIM - Percieved Benefits to non-USERS - BIM Users as Technology Adopters - Non-users as technology adopters Drivers and obstacles - BIM drivers according to all respondents - Reasons for Not Using BIM BIM skills and training - Respondent Training - Type of Training - BIM Users and Non-Users Sustainability - Implementing Sustainability Policies by BIM Users and Non-Users - Implementing Sustainability Policies by company type	BIM adoption - BIM adoption & years of usage - BIM usage - BIM attitudes among non-users - Future Growth - Perceived ROI on BIM investment - Benefits contributing the most value - Importance of BIM in 5 years - Potential Adoption Drivers Overall value of BIM - Perceived ROI by discipline/experience level - Quantifying Results - Current BIM investment priorities - Level of business value Internal business value of BIM - Relative importance of internal benefits - Relative importance of BIM benefits to improving ROI - Ways to improve value of BIM Project Value of BIM - BIM benefits contributing the most value - Perceived value of BIM by phase - Impact of Project Factors on BIM Value - Perceived Value of BIM - Five Years from now - Project Participants Who are Perceived to Experience the Most Value	BIM adoption - Percentage of BIM users - BIM users profile - BIM adoption by user type - BIM proficiency - Years of using BIM - Depth of implementation - Company profile - Perceived obstacles in BIM usage - High impact adoption drivers Overall value of BIM - Perceived ROI by expertise/experience - Percentage of projects on which BIM's ROI is measured - Current BIM investment priorities - Level of business value Internal business value of BIM - Users who perceive BIM benefit as high by BIM proficiency - Users who identify items as highly beneficial & highly influential on ROI improvement Project Value of BIM - Users who perceive BIM benefits as contributing high value to project success - Users who perceive BIM as highly beneficial to project phases - Perceived Value of BIM - Five Years from now Player Value of BIM - Project participants perceived to experience the most value - Top benefits by user type	Employees & discipline info BIM adoption - Percentage of BIM users/ non-users BIM benefits - How BIM benefits - Meeting expectations BIM implementation - BIM planning, implementation manuals & guides CAD Usage - Types of software - Virtual design and construction BIM Usage - BIM in relation to type of activities/usage - Valued outcomes of BIM - Interoperability issues and concerns - BIM model ownership/responsibility/liability by project phase - BIM legal aspects - Types of BIM software - BIM usage - BIM important features BIM experience - Years and level of usage - Projects that used BIM - BIM drivers and challengers - BIM in relation to other team members	CAD Usage - Types of software (main) - Types of software (secondary) - Obtaining CAD objects - Firms' way of using CAD - Linking/Coordinating drawings to specifications Awareness and use of BIM - What is BIM? People's thought of BIM - Management, design, creativity, methods, collaboration. BIM in the future - Predicted use BIM experience - BIM affects: Workflow, practices and procedures, coordination & collaboration - Cost and value Respondents' own thoughts - Understanding of BIM on workflow, practices, procedures, cost & value, speed of delivery, profitability and BIM demands by clients/contractors. Employees & discipline info Current and past project info - Nos. of projects to types of work - Nos. of projects to procurement methods	Employees & discipline info Respondent's involvement in documentation & drawing CAD usage - Used for 2D, 3D or mixed - Types of software (main) - Types of software (secondary) BIM: Awareness and current use - What is BIM? People's thought of BIM - Specifications, design, creativity, methods, collaboration. Uses of CAD models - Organisation's use of CAD BIM in the future - Predicted use Attitudes & Views towards BIM - Speed of delivery, coordination, productivity, visualization, profitability, cost efficiencies, workflow, practices and procedures. - Negative perceptions, uncertainty and views towards BIM adoption. BIM: Expectation & Reality - How it's worked for those using it

Drawing on the issues and concerns raised in Chapter 2 and Chapter 3, it is clearer that the introduction of BIM in the industry and HEIs is not similar to the introduction of CAD. On top of that, moving from CAD to BIM is not about simply replacing a tool with another tool, but rather replacing a tool with a system that is hoped to bring a whole new dimension to the architecture field. With this, the following questions have emerged from the literature review:

i. What are the current trends among the local architectural firms in terms of technological application?

ii. How many firms are aware of BIM and have adopted it? If so, how does BIM affects the design strategies, associated management structures, overall work deliverables, and cultures within these firms?

iii. Are the Higher Education Institutions (HEIs) aware of the technological trends in the industry?

iv. How are the Higher Education Institutions (HEIs) equipping their graduates with the capabilities to make the most out of digital technology in response to the market's needs?

v. How could a framework of recommendations support the integration of BIM within the architecture programmes in Malaysia?

According to the literature discussed in both chapters, the national BIM report models, and the above research questions; hence, the present study suggests that the following criteria and considerations must be taken into consideration. The process involves forming the theoretical framework to guide this research throughout the process of figuring out the best way for the future integration of BIM into the architecture curriculum in response to the needs of the industry. The table below summarises the theoretical framework for this research.

Table 3.5: Theoretical framework for the assessment of BIM in the industry.

PROFESSIONAL PRACTICE / INDUSTRY		
ELEMENTS	**CATEGORY**	**CRITERIA TO EXPLORE**
CURRENT USE OF TECHNOLOGY	Type of technology	The type of software used by the organisation and how they rank from one another.
	User experience	The level of difficulties in using the software.
	Process and experience	The positive and negative impact of the technological application on practice.
THE IDEA OF BIM	Awareness of BIM	The level of awareness towards BIM.
	Adoption of BIM	The choice whether to adopt BIM technology or not.
	User experience	The positive and negative impact of the technological application on the practice.
FUTURE: DRIVERS AND BARRIERS	Drivers of BIM	The elements that encourage the adoption and usage of BIM.
	Barriers to BIM	The elements that discourage or hinder the practice to adopt BIM.
	BIM in the future	Future prospect of BIM.
TRAINING	Current practice	The method used to supply staff with technological skills and proficiency.
	In-house training experience	The experience of being trained in-house.
	Tertiary education as training platform	The prospect and hope of the practice towards tertiary education in relation to equipping the workforce with technological skills.

Table 3.6: Theoretical framework for the assessment of BIM in architecture education.

ACADEMIA / EDUCATION		
ELEMENTS	**CATEGORY**	**CRITERIA TO EXPLORE**
CURRENT TECHNOLOGY TAUGHT	Type of technology	The types of software used by the organisation is using and how they rank from one another.
	User experience	The way these applications are currently taught.
	Process and experience	The positive and negative impact technological application has towards the institutions and their students.
THE IDEA OF BIM	Awareness of BIM	The level of awareness towards BIM.
	Teaching BIM	The method used in teaching BIM.
	Students' experiences	Experience gained by the institutions in teaching students
FUTURE: BARRIERS AND EXPECTATIONS	Drivers of BIM	The elements that encourage the adoption and usage of BIM.
	Barriers to BIM	The elements that discourage or hinder the practice from adopting BIM.
	Non-user expectation of BIM	Future prospect of adopting BIM for current non-user.
CURRICULUM	Conceptual knowledge vs procedural skills	The position that the Higher Education Institutions are taking in forming their BIM syllabus; conceptual knowledge, or procedural skills of software.
	Curriculum to meet demands of the industry	The level of consideration taken in response to the demands of the industry.
RESEARCH	Current BIM research	The amount and size of academic research related to BIM.
	Collaboration BIM research	The amount of joint-research between universities or faculties.

3.6 SUMMARY

As a continuation of the previous chapter, this chapter has further discussed the development and high importance of BIM in the Malaysian AEC industry, which further signifies the trend within the industry relating to the inevitable shift from CAD to BIM. As it is with many technological shifts, the industry is faced with various issues and questions; hence, it is important to properly handle all the problems to avoid any interference in the progress towards adopting BIM as a new technology. From here in, the literature looked upon how HEIs, which are regarded as an established source of supply for workforce; can partake to assist or even lead the industry in its quest to implement new technologies. However, the Malaysian government (through the Malaysian Board of Architects) have yet to develop any guidelines or recognised process to embed BIM into the curriculum of architecture programmes in the country despite acknowledging the importance of BIM and the potential role of academia in assisting the industry to shift to the BIM technology. Even though some Higher Education Institutions (HEIs) may have taken the steps to introduce BIM to its students, there is no guideline or recommendation from the accrediting governing body, or even conclusive research by local establishments that could assist the paradigm shift. This is a concern that needs to be addressed considering the quality of the core modules in the architecture syllabus/curriculum such as design studio, theory, and technical modules that have always been kept at a high level by the accrediting body through strict accreditation process. This is to ensure that the quality of the architecture programme in particular, and the quality of architecture education in general, are up to the standard. This chapter has perused the issues, matters of concern, potentials, and benefits of BIM adoption globally as well as within the background and context of Malaysia, which later helped to identify the research questions that determined the outlines in developing the research framework that is beneficial in guiding the whole process of this research.

CHAPTER 4: RESEARCH METHODOLOGY AND METHODS

4.1 INTRODUCTION

The two previous chapters, namely Chapter 2 and Chapter 3 have provided a detailed review on relevant literature written on the global evolution of BIM as well as how it has been rapidly changing the practice of AEC industry. On top of that, it has also prompted the stakeholders particularly those in the Higher Education Institutions (HEIs) to rise to the occasion in order to fulfil the demands and opportunities brought by it. A set of research questions emerged at the end of the previous chapter, including a theoretical framework that is developed for the purpose of describing the underlying theory behind the industry-academia relationship in regard to BIM development. Subsequently, Chapter 4 aims to review the suitable and appropriate research techniques and approaches that could be adopted in order to explore the research questions that were developed within the theoretical framework as described in the previous chapter.

This chapter aims to further explore the philosophical and methodological concerns related to the applied research techniques. Apart from that, it also aims to increase understanding of the research design and process flow that build up the framework for the overall process of knowledge inquiry in this study. Hence, it is essential to address the fundamental concept and the necessary requirements in defining the nature of this research to help build up the research process framework that is known to be a descriptive research. Moreover, this chapter also plans to describe the relevant factors and aspects that tend to support the notion as to why surveys are considered as a feasible research instrument to help achieve the objective of a descriptive research. In relation to this, a research strategy or design will be deemed useful based on its ability and competency to effectively guide and aid the research process in ensuring that the goals and objectives of the research can be achieved. Hence, this chapter will further discuss how both surveys, namely quantitative and qualitative, are constructed to ask the right questions to the target population. The questionnaire must be effective as a data-collecting instrument and should be in line with the aim and objective of the research. In summary, this chapter is very significant because it describes the development of the research strategies and procedures which can act as the guide for the present research through several phases which include gathering, measuring, and evaluation of data prior to the discussion of the findings.

According to Rajasekar et al. (2006), research methodology can be defined as the art of studying how a research can be carried out scientifically. Naoum (2012) further added that research methodology refers to the way of questioning the research objectives. Meanwhile, Kothari (2004) correspondingly stated that it is also a means to systematically solve research problem. In addition to this, Neuman (2014) emphasises that research methodology must rest on the foundation of philosophical assumptions and principles. Therefore, it is safe to sum up that research methodology refers to the comprehensive strategy that is adopted to scientifically, philosophically, and systematically explore and solve knowledge inquiry.

In relation to the above discussion, a 'nested' methodology approach that was introduced by Kagioglou et al. (1998), (2000) will be adopted for the design and flow of the research process.

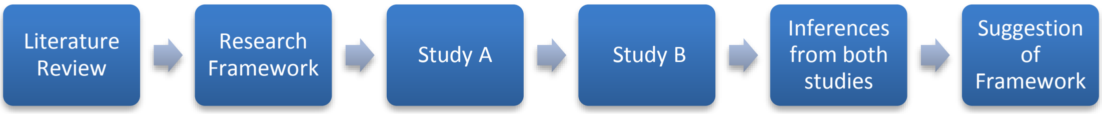


Figure 4.1: General methodology of research

4.1.1 GENERAL METHODOLOGY OF RESEARCH: NESTED APPROACH

Boussabaine (2008) in his book, *Embracing Complexity in the Built Environment* stated that built environment is a very complex multidisciplinary field. Likewise, Prof Peter Barrett who was once the President of the CIB (International Council for Research and Innovation in Building and Construction) acknowledged the complexity of the built environment research domain in his foreword to *'Advanced Research Methods in the Built Environment'*(Knight and Ruddock, 2009). In addition, this notion is shared by many other researchers such as Seaden and Manseau (2001) and Flanagan et al. (2007). Meanwhile, Hensel and Nilsson (2016) went a little further by specifically pointing out that the architecture research itself is complex. On top of that, it tends to get more complex over time mostly due to the rapid development of digital technologies and all the related prospects.

However, the AEC industry has not been treated in much detail in terms of research and studies (Shaw, 2010, Kamar and Hamid, 2012, Dale, 2007) despite its important, huge, and substantial contribution to the economy of most countries in the world (Government, 2013, Betts et al., 2015). Furthermore, this unfavourable situation has been observed to extend into its sub-field known as digital innovation in architectural practice which is the focus of the current research (Becerik-Gerber et al., 2011a). In regards to this, several researchers such as Whyte (2011), Aram et al. (2013), and Gu and London (2010) went further to elaborate on this issue by specifically pointing to the lack of critical analysis, shared research methodology, and broad theoretical framework (Franz, 1994) within the AEC research field. Knight and Ruddock (2009) posit that most researchers in the AEC industry are academically trained in professional areas instead of being involved in traditional postgraduate research, which further implies that research in the AEC industry is still relatively new and considered as a diverse field of study.

In relation to the issues mentioned above, it is not surprising that there are limited number of established works related to the AEC industry despite acknowledging that it is a very active industry. Hence, it makes it more difficult to gather references needed to build up the research foundation. According to Onwuegbuzie and Leech (2005), more often than not, pragmatic researchers tend to adopt research methods that can actually address the underlying research questions of the research rather than employing those with preconceived bias of being the supreme paradigm in research methodology. Hence, this had led the current research to adopt the 'nested' methodology approach introduced by Mike Kagioglou et al. (2000) who is the current Dean of Art, Design and Architecture at the University of Huddersfield.

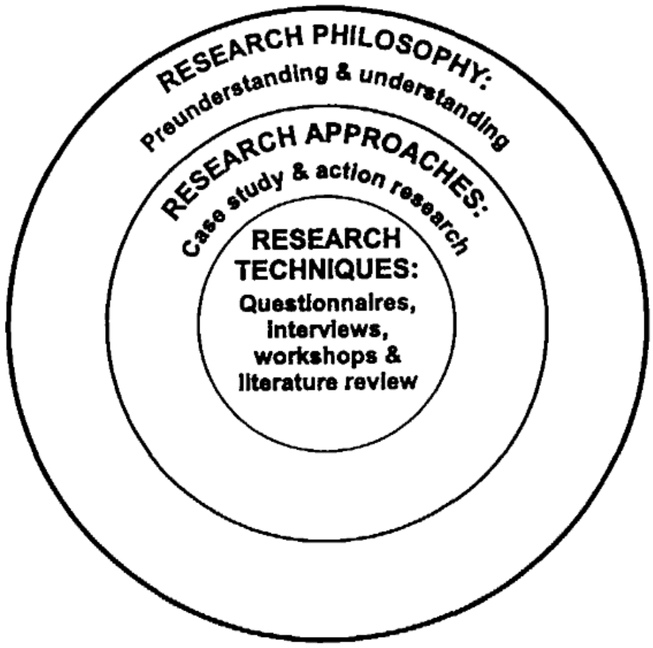


Figure 4.2: Nested Research Model (Kagioglou et al., 2000).

The nested research methodology model was developed with the purpose of providing a contingency-based research methodology that is integrated and comprehensive based on the understanding that it should *"...suit the method to the problem, and not the problem to the method*" (Linstone, 1985) in a coherent and consistent way (Kagioglou et al., 2000). As can be observed in Figure 4.2, the model starts with the outer ring that represents the unifying *research philosophy*, which is shaped by the assumptions in research foundations known as ontological and epistemological. The outer ring then guides and energizes the middle ring which is represented as *research approaches*. *Research approaches* consist of the dominant theory generation and testing methods that leads the research further to the innermost ring known as the *research techniques*. The final phase of the nested model describes how the process of data collection should be carried out and managed. Hence, the function of the nested model is to explicate the research methodology by narrowing down and tying the research philosophy, approaches, and techniques altogether in order to provide an effective progress for the overall research workflow. The following sections will thoroughly describe the elements of the research methodology in accordance to the nested model shown in Figure 4.2.

4.2 RESEARCH PHILOSOPHY

According to Davison (1998), research philosophy acts as a set of beliefs concerning the steps involved in the process of gathering, analysing, and utilising the data of a particular phenomenon. Saunders et al. (2015) simplified the term by associating it to "the development of knowledge and the nature of knowledge". It is worth to note that there is more than one way or approach that could be adopted when seeking for knowledge through systematic or empirical means or in other words doing science. Each of these approaches in doing science; both social science and natural science lie on the philosophical underpinnings or assumptions that justify how a research should be conducted. These assumptions which are known to offer distinctive standpoints towards the overall process of creating knowledge should culminate in the research approaches to uniquely promote knowledge enhancement.

The huge differences found in these assumptions have led to an intense debate or 'paradigm wars' among researchers in the 1990s concerning the superiority of respective 'paradigm' (Dainty, 2008a, Knight and Ruddock, 2009), which will be elaborated later in this chapter. However, most of the recent researchers reckoned that there is no one particular philosophy that is intrinsically better than the other (Podsakoff et al., 2012, Benbasat et al., 1987, Davison, 1998); hence, there is no point to intensively debate or discuss it when conducting a research (Neuman, 2014). Nevertheless, it is undeniable that researchers tend to favour one method over the other when conducting a research (Podsakoff et al., 2012, Neuman, 2014). According to Easterby-Smith et al. (2002), there are three main significances of research philosophy described as follows: (1) help to refine and specify the research design, (2) assist researchers to evaluate the feasibility of their research design by identifying the limitations of particular approaches beforehand, and (3) help researchers to creatively adapt or modify their research methods to other methods beyond the normal practice. Therefore, in light of all the three reasons provided, it is definitely important to describe the philosophical foundations of the present research methodology based on the two main assumptions which are ontology and epistemology.

4.2.1 ONTOLOGICAL CONSIDERATION

Firstly ... nothing exists;

secondly ... even if anything exists, it is incomprehensible by man;

thirdly ... even if anything is comprehensible, it is guaranteed to be inexpressible and incommunicable to one's neighbour.

Gorgias 500 BC, quoted in Aristotle, De Melisso Xenophane Gorgia 980a:19–20

(O'Gorman and MacIntosh, 2015)

According to the statement provided by Gorgias, a pre-Socratic Greek philosopher who was regarded as the "father of sophistry" (Wardy, 2005); hence, it is safe to sum up that *existance* comes before knowledge. However, it is not part of the main concern whether knowledge can be understood or communicated. The upmost priority is to recognize *reality*, or the *nature of reality*. In view of this, it has been widely agreed that the first stage in formulating a research is to articulate the *ontology* which refers to the study of *being* or *reality*, or in simpler words it can be described as 'how we view reality' (O'Gorman and MacIntosh, 2015, Walshaw, 2012). Meanwhile, in the aspect of ontology, there are two positions that can be used to see the world, namely *objectivism* or *subjectivism*. Objectivism or also known as realism tends to imply that science entities exist independently of humans with their thoughts or perceptions on it. On the other hand, subjectivism which is also known as *interpretivism* or *constructivism* indicates that science entities and their meanings are created based on human perceptions and interpretations, that is often subjective and limited.

Table 4.1: Network of basic assumptions characterizing the subjective-objective debate within social science (Morgan and Smircich, 1980)

	Subjectivist Approaches to Social Science ←				→	**Objectivist Approaches to Social Science**
Core ontological assumptions	Reality as a projection of human imagination	Reality as a social construction	Reality as a realm of symbolic discourse	Reality as a contextual field of information	Reality as a concrete process	Reality as a concrete structure
Assumptions About Human Nature	Man as pure spirit, consciousness, being	Man as a social constructor the symbol creator	Man as an actor the symbol user	Man as an information processor	Man as an adaptor	Man as a responder
Basic Episte-mological Stance	To obtain phenomenological insight, revelation	To understand how social reality is created	To understand patterns of symbolic discourse	To map context	To study systems, process, change	To construct a cositivist science
Some Favored Metaphors	transcendental	Language game, accomplishment, text	Theater, culture	Cybernetic	organism	machine
Research Methods	Exploration of pure subjectivity	hermeneutics	Symbolic analysis	Contextual analysis of Gestalten	Historical analysis	Lab experiments, survey

The main objective of this research is to identify the impacts and benefits of BIM on Malaysian AEC industry that acts as an IT-based information processing *system*.

Subsequently, the findings obtained from the current study will be used to suggest an approach to incorporate BIM into the current architecture education syllabus in hope of reflecting the needs of the industry. Another main concern of this study lies in the system itself, whereby the participants must act as a 'responder' that provides feedback about the effect of the system on their establishments. Therefore, in accordance to the '*network of basic assumptions characterizing the subjective-objective debate within social science*' recommended by Morgan and Smircich (1980) (refer to Table 4.1); hence, the present research has decided to lean towards objectivism rather than subjectivism for its ontological position.

4.2.2 EPISTEMOLOGICAL CONSIDERATION

In the case of social research, it is generally acknowledged that the issues on both ontology and epistemology often merge together; hence, it is not possible to discuss one without discussing the other. This is in line with Crotty (1998) who expressed that '*to talk of the construction of meaning is to talk of the construction of meaningful reality*'. Epistemology seems to concern with the process of turning things *believed* into things *known*: doxa to episteme (Davison, 1998) or simply put by Saunders et al. (2015) as '*the development of knowledge'*. It is important to note that epistemology also consists of two major philosophical positions known as *positivism* and *interpretivism*. In relation to this, it is worth noting that the two approaches can also be referred as *deductive* and *inductive*, *realist* and *nominalist*, *objectivism* and *subjectivism, positivism* and *anti-positivism*, or *scientific* and *interpretive* (McMurray, 2009, Easterby-Smith et al., 1991, Neuman, 2014). *Positivism* can be described as the approach of natural sciences that entails the understanding of reality through empirical evidence, but with the emphasis that knowledge inquiry should be performed objectively, while the findings must be free from external social forces. Another approach is *interpretivism* which seems to suggest that reality or knowledge is multiple and relative to several aspects which include human feelings, understanding, interpretations and actions, and it should never be influenced by law-like regularities such as *positivism*.

Table 4.2: There are five principles of positivism (Bryman, 2015)

	Principles	Meaning
1	Principle of *phenomenalism*	Knowledge can only be established if it can be confirmed by the senses.
2	Principle of *deductivism*	Theory is used to develop hypotheses that can be tested, verified and validated.
3	Principle of *inductivism* (also known as *Radical Positivism*)	Only facts that are based on empirical observations and verified can be accepted as knowledge.
4	Be objective	Knowledge inquiry must be carried out in an objective manner and value free.
5	Difference between scientific and normative statement	Science should be differentiated from common sense, while researcher should not be biased by their common sense.

In relation to the *five principles to positivism* recommended by Bryman (2015) (refer to Table 4.2) and the *network of basic assumptions* by Morgan and Smircich (1980) (refer to Table 4.1), it is safe to say that the present research tends to lean heavily towards *positivism*. As has been mentioned, the main concern of this research is the BIM system itself rather than the user. It is widely aware that the outcome of this research is to be used for human, but the attributes identified in the early stages of the research are largely based on the effects of BIM system on the AEC industry. With this consideration, it is important for the current research to be objective and value free without including any inputs that are based on the emotions and feelings of the participants. This notion correlates with Morgan and Smircich (1980) *basic epistemological stance* which states that a research tends to lean towards *positivism* (objectivist) when the focus of the research is to study the system and process. This is consistent to his *assumptions about human nature*, whereby human in a research should only act as a responder rather than social constructor. According to Bryman (2015), one of the principles of *positivism* is *deductivism*, which is an approach that requires a theory to be adopted in order to develop hypotheses that can be tested and verified. Hence, this approach has been chosen for the purpose of this research which will be further elaborated in the next sub-chapter.

4.3 RESEARCH APPROACH

According to the *nested model* research methodology by Kagioglou et al. (2000), the second phase that comes after *research philosophy* is the *research approach*. Creswell (2013b) stated that apart from research philosophy, there are two other framework elements that build the research approach, namely *Strategies of Inquiry* and *Research Methods*.

4.3.1 STRATEGY OF ENQUIRY

Strategies of inquiry is also known as *approaches to inquiry* (Creswell, 2013a) and *research methodologies* (Donna, 1998), and these are the types of models that are usually adopted for research approach to guide in the outlining of the process flow of a research design which include *qualitative, quantitative*, and *mixed methods*

(Creswell, 2013b). However, it is important for the type of model (or models) to be capable of reasoning out the theory of the research to enable it to be adopted for any research approach. Silverman (2013) further stated that ‘any scientific finding is usually to be assessed in relation to the theoretical perspective from which it derives and to which it may contribute’. Therefore, it is necessary to understand how the objectives, theory, and philosophical assumptions of this research are able to shape the strategies of inquiry.

4.3.1.1 DEDUCTIVE VS INDUCTIVE THEORY (direction of theorizing)

The word *theory* has become one of the most used words in the research world; hence, it is hard to find any established research study that does not mention the word *theory*. On top of that, the word *theory* has more than one definition. In fact, Abend (2008) had managed to outline seven meanings of the word *theory* in research, albeit its general definition that seems to explain or interpret knowledge about science (or social science) in an organized and systematic way (Neuman, 2014). Nevertheless, the better concern revolves around how the theory works in research or in other words, understanding the link between theory and research. However, it is not easy to elaborate on the link between theory and research because there are several views that come with this, but the one that seems conspicuous is the direction or approach that is chosen in formulating the theory of their research. There are two directions or approaches in *theorizing* a research, namely *deductive* and *inductive*.

Figure 4.3: The process of deduction and induction

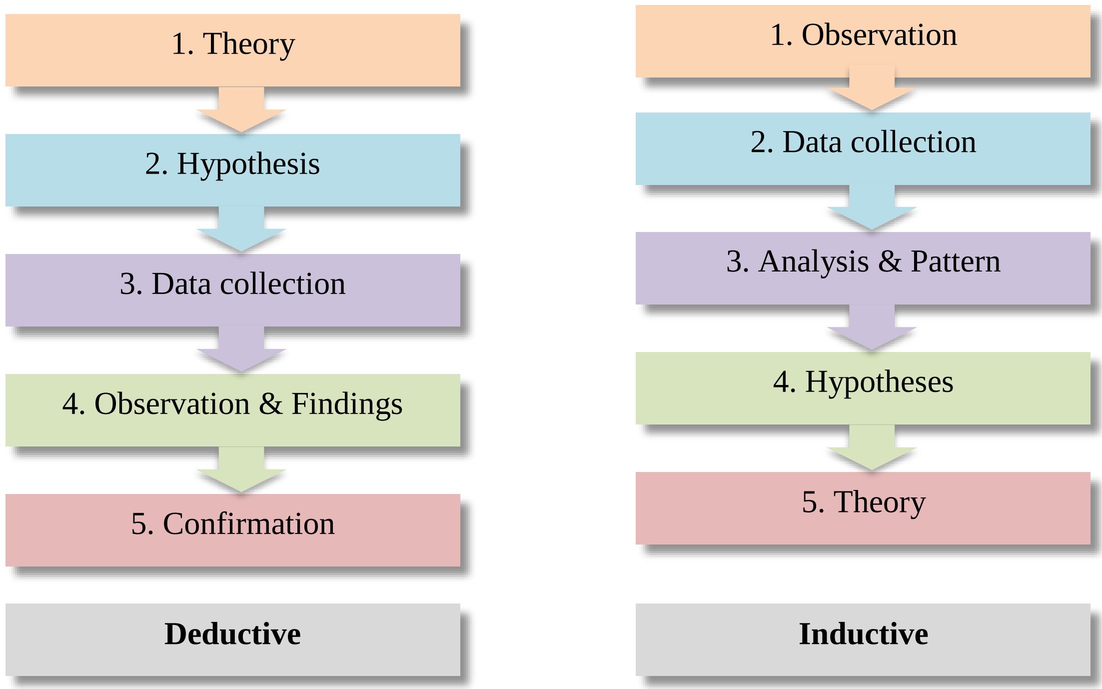


Table 4.3: Major differences between deductive and inductive approaches to research (Saunders et al., 2015)

Deduction emphasises	Induction emphasises
i) scientific principles ii) moving from theory to data iii) the need to explain causal relationships between variables iv) the collection of quantitative data v) the application of controls to ensure the validity of data vi) the operationalisation of concepts to ensure clarity of definition vii) a highly structured approach viii) researcher is independent of what is being researched ix) the need to select samples of sufficient size in order to generalise conclusions	i) gaining an understanding of the meanings humans attach to events ii) a close understanding of the research context iii) the collection of qualitative data iv) a more flexible structure to permit changes of research concerns based on the research progresses v) a realisation that the researcher is part of the research process vi) less concern with the need of generalisation

It is important to note that theory is normally addressed at the start of a research project in a *deductive* approach to research. In relation to this, hypothesis is also formulated prior to the testing of theoretical reflections. Moreover, theoretical ideas actually drive data processing (Bryman, 2015). On the contrary, an *inductive* approach entails that the research project has to be designed in order to produce a theory as an outcome product after the research is complete. It is worth to note that this approach is more open-ended and the theoretical ideas normally emerge out of the processed data (Bryman, 2015). There are many differences between deductive and inductive research due to the different process flow involved in the two approaches based on the suggestion provided by Saunders et al. (2015) in Table 4.3. However, although the differences between the two approaches seem to be rigid, most research choose to be flexible by deciding to combine both approaches within the same piece of research but at different points (Neuman, 2014, Saunders et al., 2015, Ali and Birley, 1999, Greco et al., 2001). Following this, Anderson et al. (2015) suggest that it is best to look into the emphasis of the research and the nature of the research topic in deciding which of the two approaches, or the combined, as the most suitable approach to be adopted for a particular research.

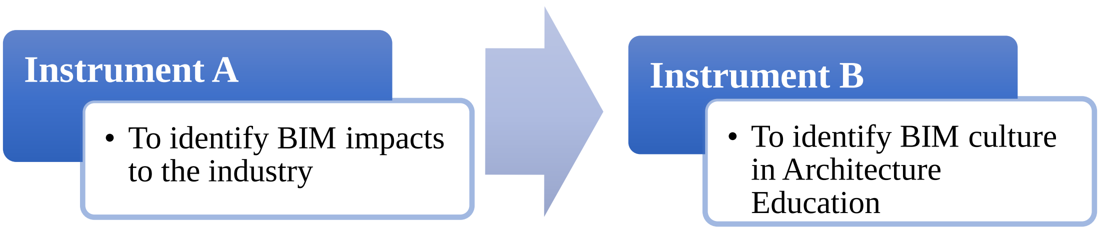


Figure 4.4: The objectives for the instruments used for primary data collection for this research.

In the context of this research, two instruments were used in order to test two sets of samples from different contexts of research. Instrument A was used to identify the impacts of BIM on the industry, while Instrument B was used to identify the impacts of BIM impacts on Malaysia's architecture education. Generally, the available amount of established literature play a big role in starting a research. According to Anderson et al. (2015), a limited number of established literature tends to signify that the field has only received very little attention or have yet to be established, which further implies that inductive approach as a more suitable option. However, there is more than enough established literature related to the impacts of BIM on the industry. For example, the national level BIM reports can easily be found globally which is very helpful in defining the theoretical framework and hypotheses that act as the foundation of this study, which then further takes this research towards a deductive route. However, it is different when it comes to identifying the BIM impacts on Malaysia's architecture education. There are relatively limited number of established literature including the absence of national level report on BIM in tertiary education has left the academic world without any strong guidance, which then provide HEIs with a considerable freedom to shape its own path towards the cause of BIM. On top of that, the lack of established directions related to implementation of BIM in education has provided more room for explorations and experimentations; hence, it makes it more difficult to form a rigid and structured instrument for the purpose of data collection. An instrument with a certain level of openness is needed to allow feedback and opinions that may go beyond the assumptions and hypothesis of the research.

4.3.1.2 RESEARCH METHOD: THE QUALITATIVE QUANTITATIVE CONTINUUM

Table 4.4: Principal Research Paradigm

Ontology	**Objectivism**	**Subjectivism**
	'Reality' is real and apprehensible	'Reality' is subjective to human perceptions and interpretations
Research Problem	What	How and Why
Epistemology	Positivism	Interpretivism
	Knowledge inquiry should be done *objectively* and free from external social forces	Knowledge is multiple and relative to human feelings
Scientific method/ Direction of theorizing	Deductive	Inductive
Research objectives/focus	Description, explanation, and prediction	Understanding, exploration, and interpretation (Carson et al., 2001)
Research Methods/Strategies	Quantitative	Qualitative
Research Design	Specifically determined Structured	*In fieri* Flexible
Scale	Large and wide scale population Suitable for wide scale population survey Extensive	Smaller scale population collected at their respective research sites Intensive
Data Collection Strategies/Design	Survey Experiment Structured interview	Phenomenology Ethnographies Grounded theory

		Case study Narrative research
Data type	Statistical, numerical data generated to represent the social environment	Words, contextual, based on participants' viewpoints
Data analysis	Identify statistical relationships	Search for patterns, themes, and holistic features

Sources: Adapted from (Creswell, 2013b, Bryman, 2015, Neuman, 2014, Bauer et al., 2000, Johnson and Christensen, 2014, Harré, 1979, Chen, 2015, Carvalho and White, 1997, Ben-Eliyahu, 2014, Goldtborpe, 1996, Manchester City Council, Carson et al., 2001, Creswell and Clark, 2011).

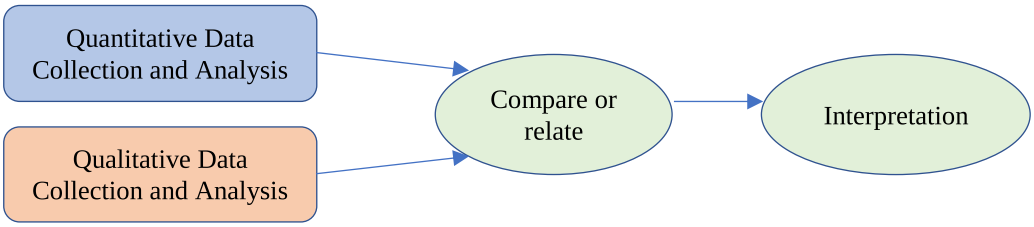
In the context of strategies of inquiry of a research, the step that follows the direction of theorizing would be identifying the types of models for the research approach which is commonly known as the research strategies (Bryman, 2015) or research methods (Donna, 1998). The two most prominent research methods that have been widely employed in knowledge inquiry are the qualitative and quantitative approach. In a simple manner, research that applies the quantitative approach tend to emphasise the quantifications in collecting data, while research that employs the qualitative approach usually focuses on words or pictures in the process of data collection. However, it is not easy to conclude which of the two is better despite their distinct characteristic. In fact, a lot of debate and argument have taken place in determining the superiority of the two approaches from one another since the 1970s (Stanovich, 1990, Oakley, 1999). In the case of this research, the research topic and field are the elements that help in determining the best and suitable approach. As has been previously mentioned, the topic of BIM implementation in the AEC industry is related to two fields, namely the information systems and the AEC industry.

In the context of the AEC industry particularly in the management domain, the merits and demerits of research methodologies involving the two methods have been largely debated in the 1980s and 1990s. Most of the debate was in response to the 'great debate' that took place among researchers worldwide on the varying research philosophies, which was popularly termed as the 'paradigm wars' (Dainty, 2008a) (Knight and Ruddock, 2009, Bryman, 2008, Edum-Fotwe et al., 1996, Raftery et al., 1997, Scott and Harris, 1998, Runeson, 1997, Dainty, 2008a). This philosophical argument was led by papers published by the Journal of Construction Management and Economics, particularly from Seymour and Rooke (1995) and Seymour et al. (1997) who suggested that it is necessary for the industry to open up to alternative research approaches. Following it, various reviews and analysis were carried out to understand the trends of philosophical and methodological positions adopted within the industry's research domain. However, it seems intriguing that all the findings from a wide number of research that has been carried out over the years (Dainty, 2008b, Dainty, 2008a, Toor and Ofori, 2008, Panas and Pantouvakis, 2010, Zou et al., 2014) showed that majority of the research was performed using the positivism-quantitative approach. The preference of quantitative approach in majority of the research work in field of the AEC industry tends to reflect that the industry has been more inclined towards objectified and positivist research philosophy. Moreover, the preferred choice of research philosophy and methodology in the field of information systems seems to be similar to AEC industry. According to reviews and analysis done by Weill and Olson (1989), Orlikowski and Baroudi (1991), and Alavi and Carlson (1992) on academic papers in core journals written since the 1960s, it can be summarized that a clear majority have adopted the positivism-quantitative approach.

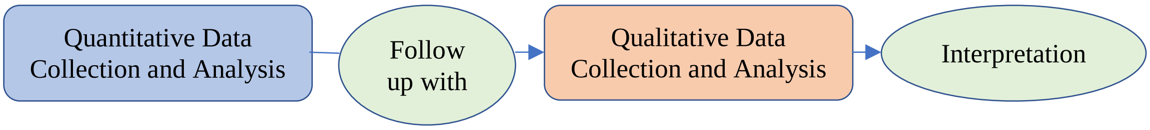
It is necessary to know why most researchers in the AEC industry and information systems have adopted the positivism-quantitative approach into their research work. According to Harty and Leiringer (2007), most researchers in the AEC industry seem to posit that knowledge discoveries should be factual and free from subjective perceptions and interpretations, which is a clear trait of positivism. Meanwhile, Chan and Littlemore (2009) added that researchers perceived that the industry demands for impartiality in findings. On top of that, Runeson (1997) went further by stating that the recognition of positivism in science is a deciding factor, which implies that any other approach would be 'anti-scientific' and has yet to prove itself with productive output, theories, or progress. Some of the factors that need to be taken into account in the adoption of positivism are also shared by researchers in the information systems industry. Findings by Weill and Olson (1989) and Orlikowski and Baroudi (1991) showed that most researchers believed that positivism-quantitative techniques of large-scale sample surveys and laboratory experiments are measurable, objective, and external to outside forces; hence, it is found to be the most suitable method for their research field. The view of Benbasat and Zmud (1999) seems to be consistent with the view of Runeson (1997) which states that in the past, the pursuit of rigor over relevance which in this case is positivism was considered as a standard requirement by most granting agencies, universities, and government. Hence, this further proves that positivism-quantitative was the most dominant and recognized approach.

However, the ever dominant standing of the positivism-quantitative approach took a slight turn within the last 30 years with the emergence of an approach that takes the middle path between the quantitative and qualitative strategy, which is known as the mixed method approach (Bryman, 2015, Gartell and Gartrell, 1996, Gartrell and Gartrell, 2002). As has been previously mentioned, the mixed method approach emerged during the paradigm wars not just as a means to find a middle path for the two opposing approaches, but also due to the fact that an increasing number of researchers have realized that social science is not entirely the same as natural science. This is especially true for the AEC industry considering that many researchers have concluded that the industry can neither be pure natural science nor absolute social science, but somewhere at the intersection of both worlds; hence, the reason for a middle path and a more balanced approach (Love et al., 2002, Fellows and Liu, 2009, Dainty, 2007, Dainty, 2008a). In relation to this, many researchers such as Galtung (1967), Crotty (1998), Ashworth (2000), Wakkee et al. (2007), Holloway and Wheeler (2013) and Bryman (2015) were of view that research methods and designs may not be entirely deterministic to their underlying philosophical position. The selection of research methods and techniques have often been associated with certain particular philosophical positions; however, it is equally crucial for researchers to also consider other factors that can influence the undertaking of the research work, such as practicalities of the research, availability of resources, and other contextual influences. The numbers of research articles based on mixed methods research have consistently increased despite the continuous debate on the compatibility of methods integration until today. In fact, the increase was threefold over the period of 1994-2003 (Bryman, 2008), which signifies the growing recognition of the approach among the researchers of today.

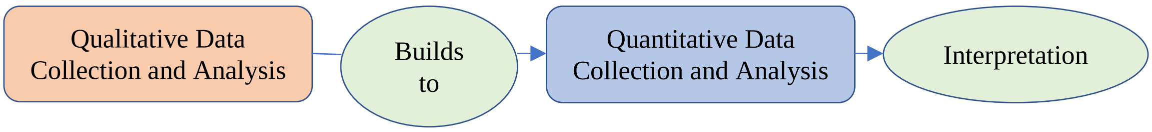
4.3.1.3 RESEARCH DESIGN



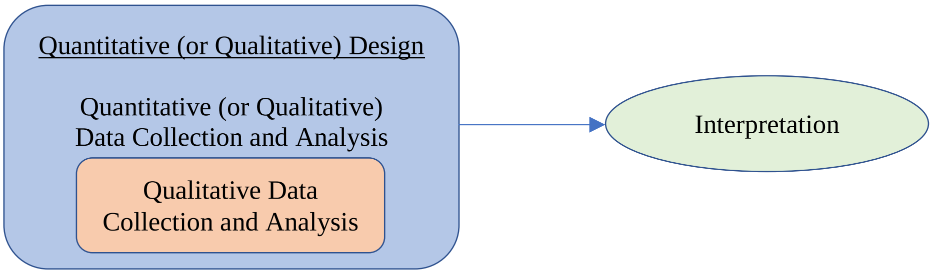
1) The convergent parallel design



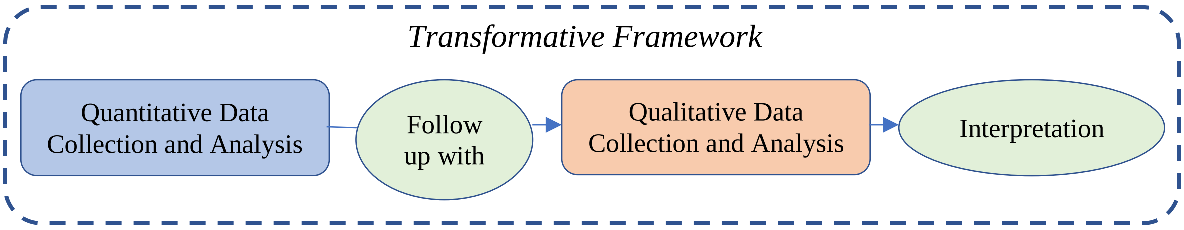
2) The explanatory sequential design



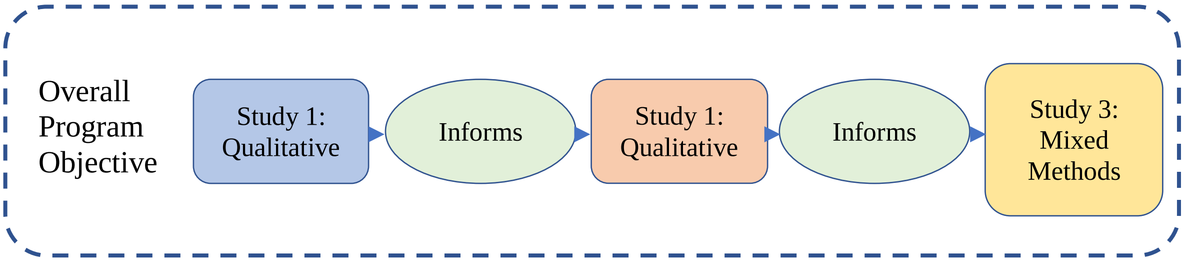
3) The exploratory sequential design



4) The embedded design



5) The transformative design



6) The multiphase design

Figure 4.5: Prototypical versions of the six major Mixed Methods Research Designs (Creswell and Clark, 2011)

According to Creswell and Clark (2011), there are 6 major mixed methods research designs (refer to Figure 4.5). In weighing out what might be the most suited method for this research, the attributes of this relatively new mixed method seems more likely to suit the contextual setting of this research. Although this research on the overall scale may lean towards a more objective and positivist stand from the ontological and epistemological point of view, the lack of literature evidence in Malaysia particularly in the context of architecture education, has forced one of the two instruments for this research to involve inductive reasoning. As a result, the research strategy requires the adoption of both quantitative and qualitative methods, specifically with Instrument A being quantitative and Instrument B being mixed quantitative-qualitative. The present research adopted a very well established mix-method model termed by Creswell and Clark (2011) as the *convergent parallel design* model considering that it requires two different methodologies to be used in obtaining data from two different set of samples simultaneously.

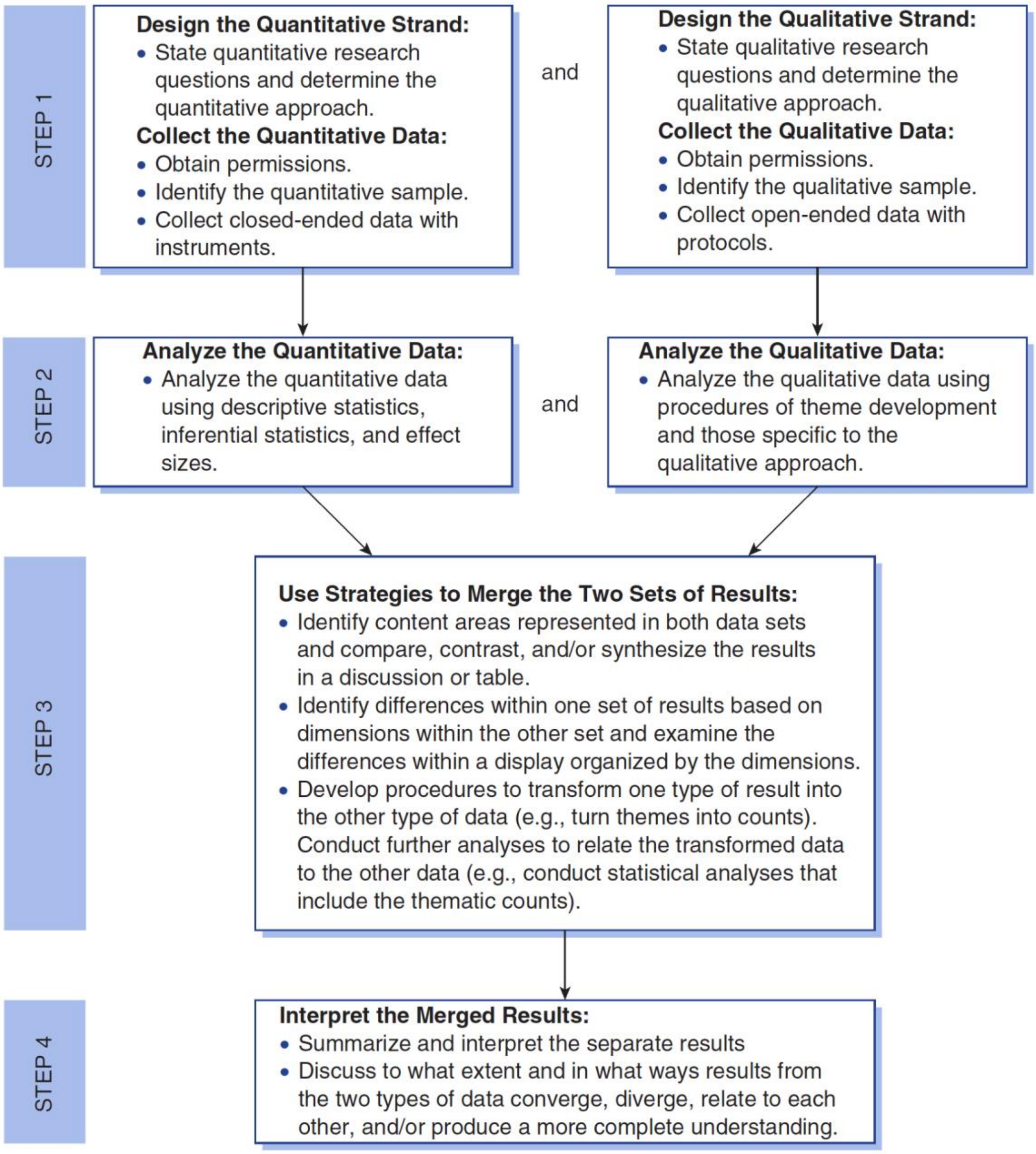


Figure 4.6: Flowchart of the Basic Procedures in Implementing a Convergent Design (Creswell and Clark, 2011)

According to Creswell and Clark (2011), the convergent parallel design treats both techniques equally, analyses the data sets independently, and then merges the two sets of results before finally producing a conclusive interpretation of the results. The main purpose of this design is to acquire different but complimentary data on the same subject as a means of having a comprehensive understanding on the subject matter. Other strengths of this method include the ability to produce intuitive sense, be efficient considering that both data are collected roughly at the same time, and allow both datasets to be analysed separately and independently using conventional techniques before merging the results together. However, Creswell and Clark (2011) have also warned the challenges that might occur when applying this method which include the difficulties in merging the two separate data sets with different sample sizes, obtaining meaningful results between two sets of very different data, and the risk of not knowing what to do when the results oppose each other.

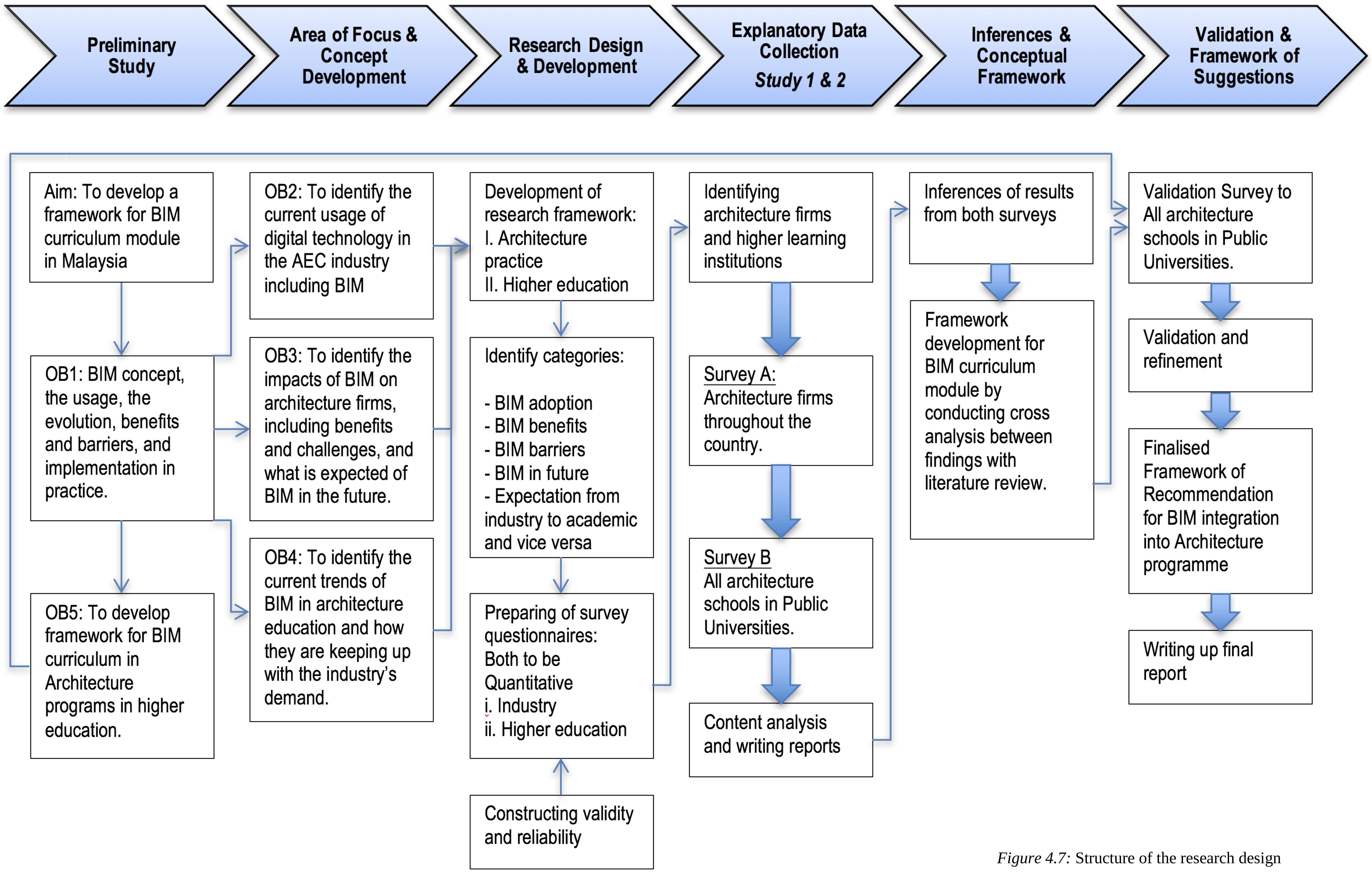


Figure 4.7: Structure of the research design

4.4 RESEARCH TECHNIQUE

Research technique is described as the techniques used to obtain information or data for a research. Prior to choosing the technique, it is imperative to know the type of data needed to allow the research to develop and yield conclusive results. According to Fulcher and Scott (2011) and Eriksson and Kovalainen (2015), there are two types of data sources, namely primary and secondary. Primary sourced data are fresh data collected by the researchers themselves specifically for the purpose they have in mind and these often happened in the form of interviews, questionnaires, experiments and observation (Saunders et al., 2015). On the other hand, secondary sourced data are data that were collected by someone else prior to and for another purpose other than the current project (Saunders et al., 2015), which include articles, letters, minutes of meetings, books, journals, and government reports on surveys and census. Over the years, various techniques have been identified and continuously studied to obtain different types of data. These techniques have its own advantages and disadvantages; hence, it is important to know the propriety of each techniques before selecting the best technique. The following diagrams and tables summarise the merits and demerits of the two sources before looking into the steps and processes involved in the data collection process:

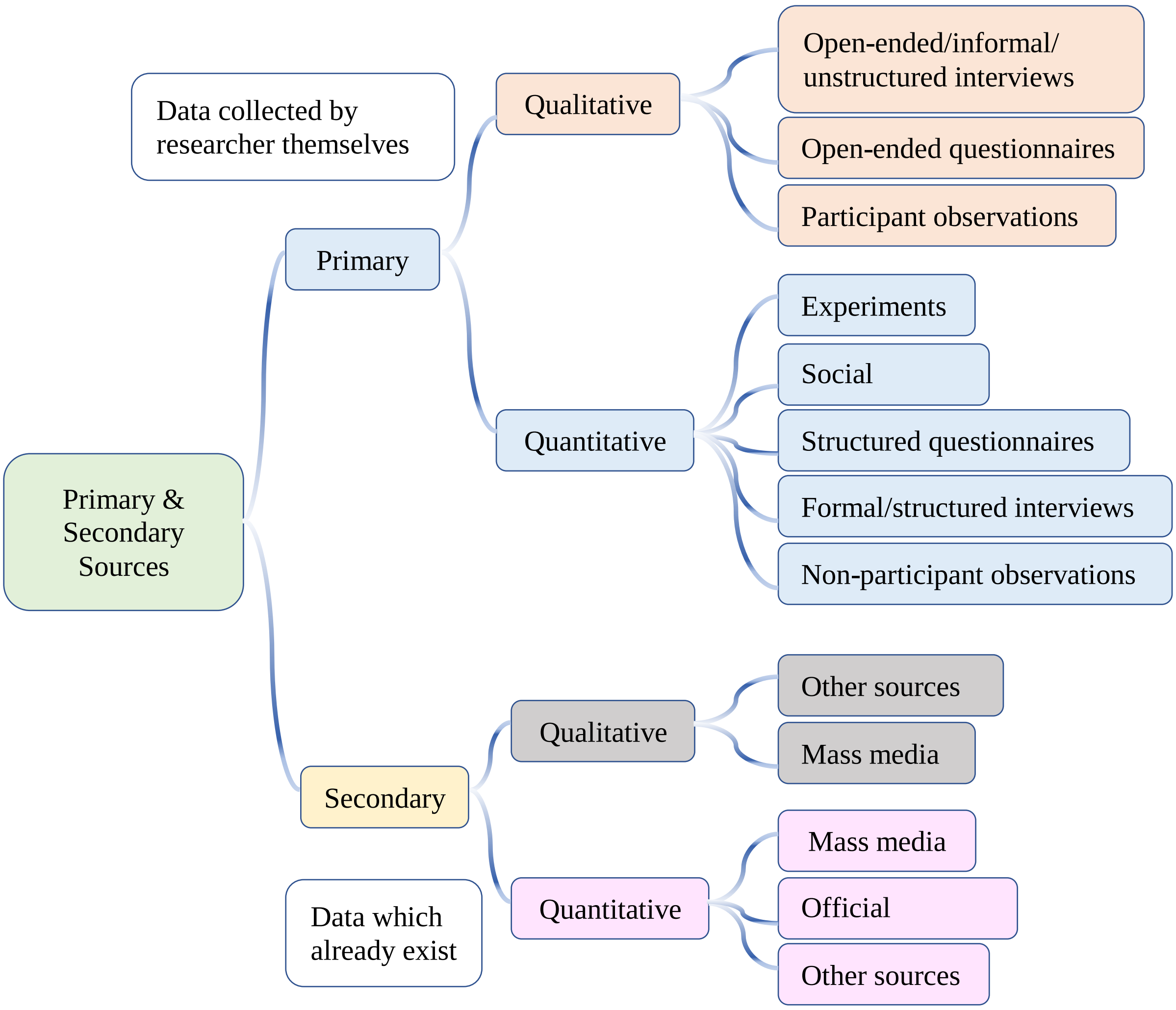


Figure 4.8: Primary and Secondary source (Thompson, 2015)

Table 4.5: The advantages and disadvantages of primary and secondary source (Thompson, 2015, Saunders et al., 2015, Bryman, 2015)

Primary sourced data		Secondary sourced data	
Closed-ended questionnaires	Advantages: • Easy for participants to answer because the questions are straightforward • Quick to complete • Easy to analyse • Allow easy comparison to be made with other sets of data • Easy to repeat Disadvantages: • Not possible to provide further explanations of the question to participants • Cannot follow-up with extra questions to gain richer data • Participants might not agree with any of the available answers • Only generates quantitative data	Qualitative sources: Newspapers Articles Books Journals Novels TV programmes Diaries Historical documents Literatures etc.	Advantages: • Can provide rich data • Assist in understanding how people review certain matters Disadvantages: • Authenticity – data could be forged • Lack of credibility – could be biased or untrue • Representative – unsure who the research represents or who participated in it • Analysis – the research might have not been interpreted or analysed correctly
Open-ended questionnaires (interviews)	Advantages: • Participants are not limited by set of answers, which allows them to express what they really mean and explain why. • The interviewer can follow up with more questions to gain richer data. • Data is generated from a discussion; therefore, it can be detailed and more in-depth. • Can generate different points of view in different interviews to provide better discussion points for the report. Disadvantages: • Different opinions might confuse the researcher • Data could be interpreted differently to what the participant meant.	Quantitative sources: User rates reports, crime rate reports, implementation rates, and awareness rates.	Advantages: • Provide important information • Provide reliable facts with proofs • Cheap, free to use and analyse • Concluded from large samples • Can cover different time span, providing past data • Allow user to compare various groups and professions Disadvantages: • Statistics could be biased • Could be relying on false data • Might only cover the concerns of the researcher
Structured interviews	Advantages: • Questions can be explained to overcome knowledge problems • Known to be very reliable data as all participants are choosing from the same set of answers Disadvantages • Interviewer cannot probe and ask further questions • This data is usually used for quantitative reports and more difficult to convert to qualitative data • Data is not as rich in comparison to the open-ended questionnaires		

	• Time consuming compared to the other methods that can provide similar outcomes • Similar data can usually be generated from previous researches (secondary sources)		
Unstructured interviews	Advantages: • Allows the interviewer to have an open conversation/discussion with the participant to cover a wide subject • Interviewer can ask follow-up questions, which can create better interaction for richer and more valid data • This kind of interview can remove formal behaviours and allow the participant to give more open and honest answers • Questions can be changed to suit the different background of each participant • Participants are not limited by a set of answers; therefore, they can express what they really mean and explain why • Can generate various points of views, which can provide better discussion topics for the report Disadvantages: • Take longer time which makes it difficult to find people who are willing to participate • Questions will probably change in different interviews, which makes the data less reliable. • Difficult to replicate the study • Data can be more difficult to analyse and inflexible to compare		
Postal/Self-completion questionnaires (survey)	Advantages: • Relatively inexpensive, particularly when undertaken through online portals. • Results can be readily obtained. • Participants can respond at a time convenient to them. • Participants are more likely to give personal or embarrassing responses, if they had the privacy of self-completion. • Can produce a large amount of data. • Less chance of researcher bias in comparison to other methods of research. Disadvantages: • Response rate can be low. • Usually only a certain group of people tend to be interested in taking part.		

	• Unclear as to who completed the survey. • Unable to ask follow-up questions or explain the questions.		
Telephone interviews	Advantages: • Save time from travelling long distances. • Suitable if there are no other methods of communication available. Disadvantages: • Less effort is made to choose accurate answers. • Must be arranged for a particular time and date. • It is not viewed as the most suitable method to gain valuable information. • A lot of preparation needs to be done beforehand. • Facial and body language are not visualised, which may lead to misunderstanding between both parties.		
Experiments	Advantages: • More common in natural science research Disadvantages: • Not a common practice for social science research.		
Participants observation	Advantages: • It heightens the researcher's awareness of significant social processes. • It is particularly useful for researchers working within their own organisations. • Provides the opportunity to the experience the emotions of those who are being researched. Disadvantages: • It can be very time consuming. • It can pose difficult ethical dilemmas for the researcher. • There can be role conflict for the researcher (e.g. 'colleague' versus researcher). • The participant observer role is a very demanding one. • Access to organisations may be difficult. • Data recording is often very difficult for the researcher.		
Focus groups	Advantages: N/A Disadvantages: N/A		

Case studies	Advantages: • Very suitable for the construction industry. • Can give a full picture of the task in hand. • Useful to prove literature studies. Disadvantages: • Not many BIM projects available. • Difficult to gain much information on the use of BIM within projects.		
Pilot studies	Advantages: • Very useful to obtain an insight of the task in hand. • Improve understanding. • Enhance research accuracy. • Enhance the supporting evidences. • Very suitable for future research. Disadvantages: • Require a lot of preparation. • Require a lot of time and effort.		

In reference to the above table, the research continued by adopting a number of research techniques that are applied in the three phases of this research. This subchapter discusses each technique and justifies the various phases involved in this research. The research techniques have their own attributes but are correlated to each other as illustrated in Figure 4.8.

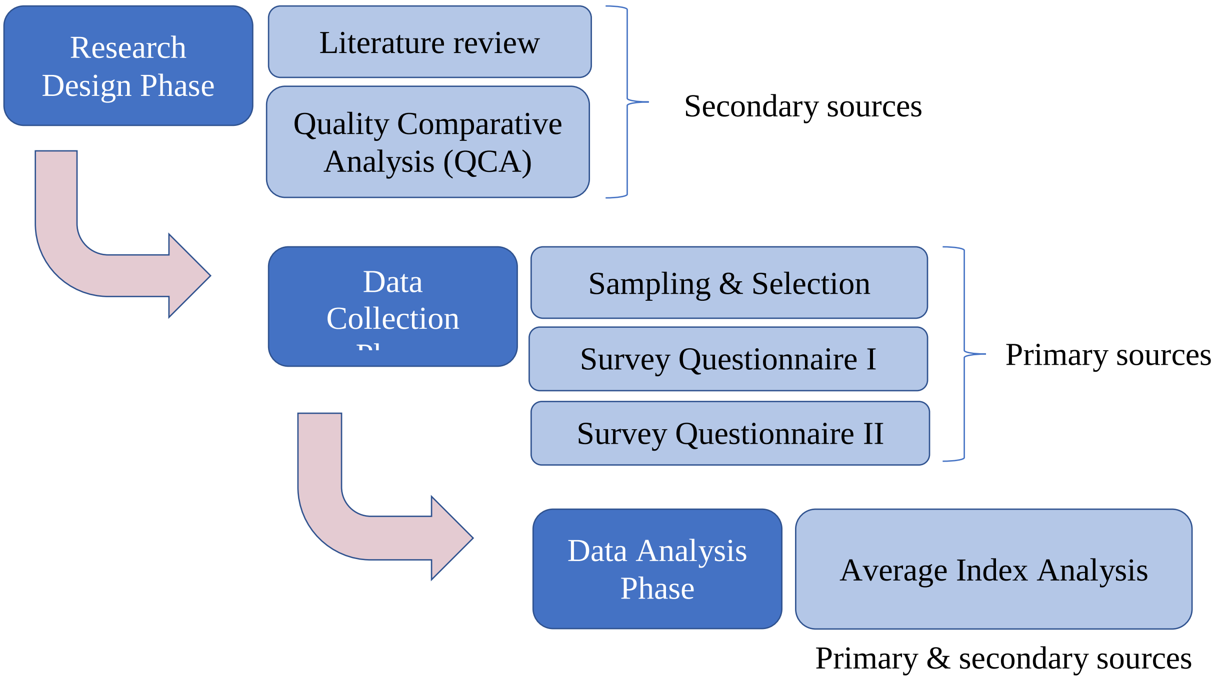


Figure 4.9: Research techniques used for each phases of the research.

4.4.1 RESEARCH DESIGN PHASE

<u>Literature Review</u>

In the initial phase of a research, literature review is the first crucial step after the identification of research topic. Literature review is not carried out by simply reading without any direction or objectives because a well-executed literature review must accomplish several purposes. According to Creswell (2013b) and Marshall and Rossman (2014), literature review does not only discuss the findings of previous studies but also relates the research to the larger ongoing dialogue in the literature, filing in gaps and extending prior studies related to the research topic. However, the review of literature can be time consuming and exhausting considering the abundance amount of literature. The key to achieve a fruitful discussion is to review the key books, articles, and main figures objectively (Bryman, 2015). Hence, with this in mind, the literature review for this research will be carried out based on a positivist/quantitative approach that is consistent to the philosophical nature of this research.

Creswell (2013b) stated that a quantitative research often starts with a considerable amount of literature that introduce problems or issues related to the context of the topic, with the aim of providing a direction for the research questions or hypotheses. In the context of this study, the literature review is discussed in Chapter 2 by introducing the development of a new trend as well as the adoption of BIM technology within the AEC industry globally and locally. Subsequently, this forms the knowledge of the current issues including the challenges related to BIM adoption in the industry, particularly refers to the lack of training, skilled users, and expertise to fully utilise the technology. The section then continues to discuss the notion held by among researchers and industry stakeholders which states that academia have a huge potential to provide the industry with graduates that are equipped with the right knowledge and skills. The key to ensure that this can be fulfilled is by developing a BIM curriculum that answers the demand of the industry, which eventually winds up to the formation of the research questions and hypotheses. The second part of the review was continued in Chapter 3 by emphasising the challenge of integrating BIM into an already crowded curriculum, including how the research gap has affected the adoption of BIM in architecture education. At the end of this research specifically in Chapter 7, the literature reviews are revisited, referred, and applied in order to compare, make sense, justify, and theoretically validate the findings of the current research. This process illustrates the positivist reasoning of the research where the literature is deductively used as a framework for the research questions.

The literature review is achieved by systematically evaluating the existing literatures which is covered by more than 500 articles with the main reference of 'Building Information Modelling', 'BIM', 'construction industry', 'technology application in architecture', 'BIM in Malaysia', 'BIM around the world', 'architecture education', 'CAD in education', 'BIM in education', 'BIM in academia', 'BIM curriculum', 'BIM research', 'research methodology' 'positivist and quantitative research' that were obtained from Elsevier, Science Direct, IGI Global, ASCE Library, Wiley, Emerald Insight, Springer, ProQuest, and others. The literature gathered from the world-wide web have provided the research with a huge range of direct and indirect insights into the topic and background of the study. On top of that, it is also helpful in providing clues and information to further search for literature that is not available on the world-wide web, which include a huge range of published and unpublished articles, books, reports, white papers, standards, statutes, curriculums as well as academic thesis and dissertations. The sources from where literature materials were obtained include the following:

- Publishers
- University libraries in the UK and Malaysia

- Government bodies of Malaysia which include JKR (Works Department), CIDB (Construction Industry Development Board), LAM (Board of Architects), Ministry of Works, and the Department of Statistics.

- Professional bodies (UK and Malaysia) which include the RIBA (Royal Institute of British Architects), AIA (American Institute of Architects), NZIA (New Zealand Institute of Architects), RICS (Royal Institution of Chartered Surveyors), PAM (Malaysian Institutes of Architects), and BuildingSMART.

- Technological software producers/companies.

<u>Qualitative Comparative Analysis</u>

The Qualitative Comparative Analysis (QCA) is described as a data analysis method that was originally developed by Ragin and Rihoux (2004) with the purpose of establishing logical conclusions for data set supports. This method of data analysis adopts techniques that systematically match and contrast the samples or occurrences for the purpose of developing common causal relationships which eliminates all other possibilities (Berg-Schlosser et al., 2009). In the context of this study, this method is applied in Chapter 3 to generate a comparison analysis for the different approaches employed by national and international organisations around the world in conducting survey for BIM adoption in the global AEC industry. Subsequently, the QCA was -adopted to compare various approaches employed by researchers and educationists to survey BIM adoption and experience in the context of academia.

4.4.2 DATA COLLECTION PHASE

Survey questionnaires

The initial stage of this research observed the process of literature review as well as the QCA that were carried out on secondary sourced data in order to obtain enough information to introduce a problem and build a case in the context of the topic. This is believed to lead to the development of research questions as well as the research framework. Following the development of a solid case for knowledge inquiry, it is important to obtain primary sourced data to test the hypothesis developed from the research questions. In this case, the focus is to find a technique to formulate a curriculum module to integrate BIM into architecture education based on the demands of the local industry. According to social science research that has been carried out, survey based research is one of the most established, popular, and widely used technique in gathering primary data (Rovai et al., 2013, Vir, 2015, Bryman, 2015). As can be observed in *Table 4.6*, there are several established survey techniques that can be used to obtain primary data. However, this research has chosen to adopt the *self-completion/self-administered questionnaire* technique of *survey* based on several reasons. Hence, it is worth to know both the advantages and disadvantages of utilising this method which are described in the following table:

Advantages	Disadvantages
Cheaper and easier to administer	Cannot prompt
Quicker to administer	Cannot probe
Absence of interviewer effects	Cannot ask many questions that are not salient to respondents
No interviewer variability	May not know who answers
Convenience for respondents	Cannot collect additional data

Provide a larger geographical coverage for the sample population compared to other means	Difficult to ask a lot of questions
Capable of collecting data from a large number of respondents	Greater risk of missing data
Advanced statistical techniques (software) can be utilized to analyse survey data	Risk of lower response rates

Table 4.6: The advantages and disadvantages of survey research (Bryman, 2015, Bourque and Fielder, 2003, Fottrell and Byass, 2008, Office, 2015, Trochim and Donnelly, 2006).

The above table seems to suggest that it is tangible for the survey technique to have its own advantages and disadvantages towards the research. However, in the case of the current research, one of the main concerns revolve around the need for the information to represent the national architecture industry instead of only representing small group of organisations or people. Therefore, a self-completion questionnaire technique is deemed to be the most suitable method in comparison to other techniques such as interviews, case studies, focus group, and observation (refer to Table 4.6). On top of that, it is believed to be capable of collecting data from a large number of respondents of a large geographical coverage within a limited time frame. Apart from that, this survey technique is also more objective, impartial, and free from external social forces such as the interviewer or surveyor; hence, this suits the philosophical stance of this research which is positivist. Apart from the numerous advantages of adopting the survey technique for the purpose of data collection, these two factors are considered the most important in choosing the most suitable technique.

The following step is to identify the type of questions that will be used to build the questionnaires for the survey. As can be observed in Table 4.6, there are two types of questionnaires: (1) open-ended questionnaire, and (2) closed-ended questionnaire.

Both types of questionnaire have its fair share of advantages and disadvantages. As stated earlier, there are two surveys that will be carried out on two different set of samples with different numbers and background, namely Survey A and Survey B. Survey A is necessary to gather information from as many firms in the Malaysian architecture industry, a feat that covers a substantial amount of population and should be distributed to a wide geographical area. In addition, it is important to note that the positivist philosophical stance of this research also entails for a more direct, objectified, impartial, and quantitative method. Therefore, these two factors require the questionnaire for Survey A to be constructed with closed-ended questions. However, Survey B takes a slightly different turn in its data collecting approach. The present research is known to lean towards being a positivist; hence, the lack of information on BIM within the local context of tertiary education makes it difficult to form a rigid and structured survey questionnaire. This situation has also left HEIs with considerable freedom to explore and shape their own path towards the BIM cause. As a result, the survey questionnaire has to have a certain level of openness to allow feedback and opinions that may go beyond the assumptions and hypothesis of the research. Moreover, this has also prompted the questionnaire for Survey B to be filled with both closed-ended and open-ended questions.

Further to agreeing the type and structure of questions suitable for the questionnaire, the present research continued by exploring the content and style of questionnaire for both surveys. As stated in the previous chapter; the content and style of the questions for both survey questionnaires were constructed based on the QCA performed on various existing surveys discussed in the previous chapter. The QCA process, which involved perusing and analysing existing questionnaires samples gathered from academic, government and industry sources, eventually led the research to largely adopt questionnaires from the NBS (2012) and Masterspec (2012) national survey of the UK and New Zealand. According to Bryman (2015), McColl et al. (2001) and Hyman et al. (2006), the common and legal practice tend to encourage researchers to adopt questions that have been employed by other researchers for their survey questionnaires. Pre-existing questionnaires, particularly those of established studies have definitely been piloted and tested for actual usage. Hyman et al. (2006) stated that using pre-existing questionnaires has been proven to be cost efficient and time efficient. Further to this, Bryman (2015) also added that existing questions allows one to draw comparisons with other research, similar to the QCA performed in Chapter 3 for the purpose of this research. However, as mentioned in Chapter 3, the questionnaires for this study were constructed based on the UK model as the Malaysian architecture education was modelled after the British system and this has remained largely the same ever since (Hassanpour et al., 2011). Therefore, it is in the best interest that the questionnaires for both Survey A and Survey B to be majorly constructed based on the UK's National BIM Survey provided by the NBS.

4.4.3 SAMPLING AND SELECTION METHOD

It is often the case that researchers perform sampling when conducting surveys. This is normally done by selecting a portion of the population as samples, and electing to survey only those sampled units, which are then recognized as representing the whole targeted population. However, as in the case of this research, the targeted population for both surveys is limited to a number which is feasible to be approached; thus, allowing the researcher to distribute the survey to every member of the targeted population rather than just opting for a survey through sampling. However, the techniques used for the sampling and selection method were not discussed and elaborated in this chapter. The sampling and selection method for Survey A is discussed in Chapter 5, whereas Survey B is discussed in Chapter 6.

4.4.4 DATA ANALYSIS PHASE

There are two steps involved in the data analysis phase for both surveys which are described as follows:

1. Data collection and preparation

2. Data description (Descriptive Statistics)

However, the techniques used for the purpose of data analysis phase were not discussed together in this chapter due to the slight difference in the structure and attributes of Survey A and Survey B. The steps involved in the data analysis phase for Survey A is discussed in Chapter 5, whereas Survey B is further elaborated in Chapter 6.

4.4.5 VALIDATION OF FINDINGS

Please refer to Chapter 7 for the validation of findings method used for both Survey A and Survey B.

CHAPTER 5: RESULTS AND KEY FINDINGS - PHASE I

5.1 INTRODUCTION

This chapter describes the questionnaire survey, the planning that was considered prior to undertaking the process, how it was conducted and analysed with more emphasis on technical procedures, and finally followed by the report on findings. The findings from this chapter will later be cross-analysed with the survey in Phase II that involves the Higher Education Institutions (HEIs).

5.2 QUESTIONNAIRE OVERVIEW

A questionnaire survey was developed and issued to all the architectural firms in Malaysia, amassing a total of 535 firms. As stated in previous chapters, the main purpose of carrying out this quantitative survey is to achieve objectives 2, 3, and 4. Objective 2 was to find out the trends on the current use of digital technologies in professional practices while objective 3 was to study the impacts of BIM on professional practice, which include design strategies, project deliverables, associated management structures and cultures within the practice. These will bring the research to the next equally important aspect that needs to be unravelled; which answers the fourth objective; i.e. the expectations of the industry towards HEIs in regards to their involvement and contributions to the BIM development in the country.

At the time of the survey, all architecture firms were registered to the Malaysian Institute of Architects or *Pertubuhan Arkitek Malaysia* (PAM), the professional body for architects in Malaysia, and the Malaysian Board of Architects or *Lembaga Arkitek Malaysia* (LAM), the regulating body for architects in Malaysia. These firms operate throughout the country, including East Malaysia, providing services in multiple phases of the design and construction process. The survey, which was electronically distributed through emails, was carried out from 18th March to 17th June 2013, a total period of three (3) months. From the survey, 140 firms responded, which gave a response rate of 26%. From a demographic standpoint, 61% of the responses came from Kuala Lumpur, Malaysia's capital and the biggest city.

5.3 SAMPLING APPROACH

Surveys are generally conducted to gather information about a population. However, it is in many cases impractical or impossible to survey an entire population due to factors associated with its substantial size, which includes information, cost, time, energy, and control. Therefore, researchers have suggested a mechanism to survey a particular population by selecting a portion of the population as samples, and survey only those sampled units, which is then recognized as representing the whole targeted population.

Fundamentally, survey samplings can be grouped into two (2) broad categories: probability-based sampling and non-probability sampling (Ronald D. Fricker 2012) (Bryman, 2015). A probability-based sample is one in which the respondents are selected using some sort of probabilistic mechanism, and where the probability of which every member of the frame population could have been selected into the sample is known (Ronald D. Fricker 2012). Sampling probabilities do not necessarily have to be equal for each member of the sampling frame. The types of probability sampling include simple random sampling (SRS), stratified random sampling, cluster sampling, and systematic sampling. On the other hand, non-probability samples, which is sometimes known as convenience samples, occur when either the probability of every unit or respondent included in the sample cannot be determined; or is simply left up to each individual to choose to participate in the survey (Ronald D. Fricker 2012).

However, sampling was only suggested due to the consideration that surveying the whole population could be too overwhelming and time consuming. As in the case of this research, the targeted population is limited to architecture firms within the context of Malaysia, such that it is not entirely a huge country and has a population barely reaching 30 million people (CIDB, 2013, C.I.A, 2014). The full list of the local architecture firms in the country, which was obtained from PAM and LAM's website, indicated that the targeted population, which amounts to 535 architecture firms, is a feasible number to be approached. With the ease of today's internet technology, surveys can be easily distributed to the target population through email. The usage of email saves costs in terms of human resources and related expenses, and time; it can be effectively controlled and monitored. Apart from that, it is generally accepted among researchers that a larger sample size or portion of the population will result in more precise outcomes. It was due to these considerations that the researcher decided to distribute the survey to every architecture firm in the country rather than opting for a survey sampling.

5.4 QUESTIONNAIRE DESIGN

As stated in the previous chapters, the survey questionnaire was largely adopted from the NBS (2012) and Masterspec (2012) national survey, proven instruments used for national-level surveys in the UK and New Zealand. This survey questionnaire retained the methods adopted in the aforementioned surveys by also inquiring quantitative information from its respondents. This self-completion questionnaire was developed using the online survey tool, i.e. SurveyMonkey, and had a total of 20 close-ended questions that were allotted into five segments. Segment 1, which inquires demographics information, contains six (6) multiple choice-single answer questions. This is followed by Segment 2 that looks into the current usage of digital technologies; containing two (2) multiple choice-single answer questions, one (1) multiple choice-multiple answer question, and one (1) Likert-type scale question. Segment 3 explores the awareness and experience of BIM in practice and contains five (5) multiple choice-single answer questions and two (2) Likert-type scale questions. Segment 4 inquires the respondents' general view towards BIM and has two (2) Likert-type scale questions, whereas Segment 5 scrutinizes the industry's perception towards the role of academia, which has just one (1) Likert-type scale question.

However, some of the details of the contents were improvised to suit the condition and situation in Malaysia, with additional items pertaining to the industry-academia relationship being added into the instrument in order to meet objective number four of the research. In an effort to improvise the questionnaire, the researcher also referred to the guidelines and suggestions provided by Creswell (2013b), Neuman (2014), Bryman (2015), and Saunders et al. (2015) hence ensuring that the finished questionnaire is sufficiently brief, reads well, and contains no bias in its design. The modifications to the contents of the survey were done based on extensive literature review of books, research papers and industries' best-practice reports, as summarized in the following tables.

Segment 1: Demographics

No.	Demographics	References
1	Basic data of employer/employee	Masterspec (2012) NBS (2012) IBC and NBS (2013) Phillips et al. (2013) Bryman (2015) McGraw-Hill (2009)

Segment 2: Applied Computer Technology

No.	Applied Computer Technology	References
2	Usage of digital technologies at establishment.	Masterspec (2012) NBS (2012) IBC and NBS (2013) New Straits Times (2007b) New Straits Times (2007a) Corso and Paolucci (2001) Davenport (2013) Dibrell et al. (2008) Love and Irani (2004) Boland Jr et al. (2007) Latiffi et al. (2013) New Straits Times (2007a) New Straits Times (2007b) Sundaraj (2006) Mohd-Nor et al. (2009) Howell and Batcheler (2005)

Segment 3: BIM in Practice

No.	BIM in Practice	References
3	Awareness and BIM experience	Masterspec (2012) NBS (2012) IBC and NBS (2013) McGraw-Hill (2007) McGraw-Hill (2009) McGraw-Hill (2010) McGraw-Hill (2011) McGraw-Hill (2012a) McGraw-Hill (2012b) Taiebat and Ku (2010a) Taiebat et al. (2010) Becerik-Gerber and Rice (2010) Becerik-Gerber and Kensek (2009) Suermann and Issa (2007) Suermann and Issa (2009) Azhar and Cochran (2009) Azhar (2011) Latiffi et al. (2013)

Segment 4: General View Towards BIM

No.	General View Towards BIM	References
4	BIM in the future: drivers and barriers	Masterspec (2012) NBS (2012) IBC and NBS (2013) McGraw-Hill (2007) McGraw-Hill (2009)

		McGraw-Hill (2010) McGraw-Hill (2011) McGraw-Hill (2012a) McGraw-Hill (2012b) Taiebat and Ku (2010a) Taiebat et al. (2010) Becerik-Gerber and Rice (2010) Becerik-Gerber and Kensek (2009) Suermann and Issa (2007) Suermann and Issa (2009) Azhar and Cochran (2009) Azhar (2011) Latiffi et al. (2013)

Segment 5: Role of Academia

No.	Role of Academia	References
5	Skills and training	Horne et al. (2005) Kymmell (2006) Scheer (2006) Cheng (2006) Berwald (2008) Ivarsson (2010) Burke (2012) Cory and Schmelter-Morrett (2012) Crumpton et al. (2008) Forgues et al. (2011a) Hietanen and Drogemuller (2008) Becerik-Gerber et al. (2011a) Becerik-Gerber and Kensek (2009) Barison and Santos (2012) Barison and Santos (2010b) Brown and Peña (2009), Cory and Schmelter-Morrett (2012) Gordon et al. (2009) Morton (2012) Pavelko (2010) Taylor et al. (2008)

Table 5.1: Survey A questionnaires segments

5.5 CONSIDERATIONS

As part of the process to develop and refine the questionnaire into a sufficient survey instrument, the questionnaire was tested and improved through a series of discussions with a number of PhD students from the University of Strathclyde and other professional colleagues in Universiti Kebangsaan Malaysia, and also by studying the surveys previously carried out by the researcher during his time as a lecturer before commencing PhD studies. Even though these studies and surveys were done much earlier outside the terms of this PhD thesis, the topic of study is the same and this thesis is a continuation of that research but in greater depth and scale. Therefore, the previous surveys carried out by the researcher were taken to serve as a partial pilot study to improvise the questionnaire. Even though the questionnaires from these previous studies were not the same, they do share some similarities in certain aspects; namely the structure, types of questions and answers, mode of delivery, and analysis of data. As a result, some amendments and modifications were progressively made to the questionnaire, accordingly. These include the ordering of questions, the type and scale of proposed answers, choices of phrases and wordings, and the groupings of questions.

5.6 DATA ANALYSIS

The data analysis for this survey has been described in detail in Chapter 3. Basically, there were two steps involved in the data analysis phase for this survey. These are as followings:

5.6.1 DATA COLLECTION AND PREPARATION

As the survey questionnaires were distributed through email via SurveyMonkey, an online development software, all collected response data were compiled in the cloud-based database provided by the online software. This database contains all information records including the dates and time of the distribution and reception of data, Internet Protocol (IP) addresses from where each response was collected, and the percentage of completion for every response of the questionnaire, which allowed the advantage of tracing any discrepancies that could happen in the process.

5.6.2 DESCRIPTIVE STATISTICS

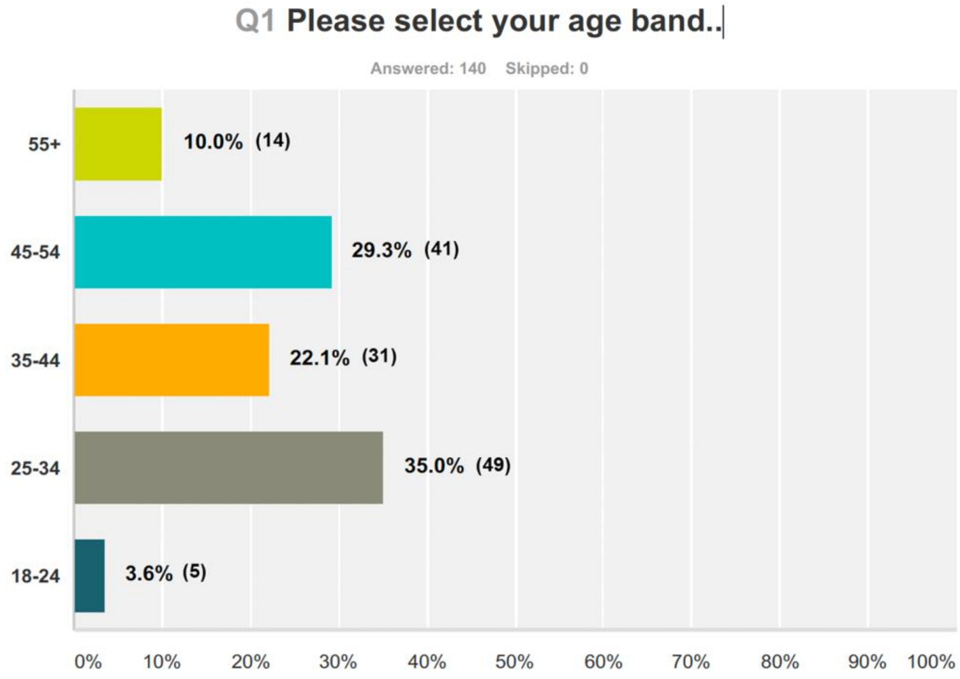
The first phase of this research took on a deductive route, which made the research objective and structured, and consequently resulting in the quantitative approach for its data inquiry. Since the survey questionnaire was the main instrument for the first phase of this research, the collected data from the survey were then described using descriptive statistics. For every question and sub-question, the researcher intended to provide descriptive elaboration with graphic analysis and calculations in the attempt to present the data in a more manageable form and reach deductions that exceed the immediate data alone. To help describe the statistics of the large numerical data in a sensible way, three basic statistical measures were used: distribution, central tendency, and dispersion (Neuman, 2014, Bryman, 2015).

5.7 QUESTIONNAIRE RESULTS

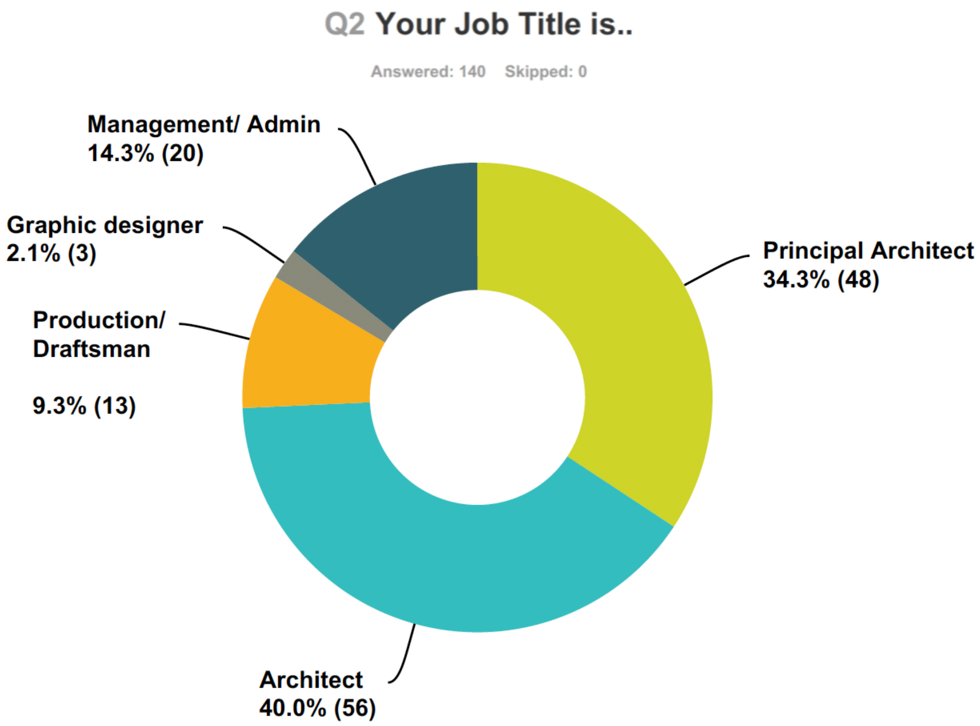
The results obtained from the questionnaire surveys were divided into five (5) segments: demographics, applied computer technology, BIM in practice, general view towards BIM, and HEIs leading the BIM cause. The results are shown as a combination of frequency histograms, percentages, charts, and some responses also include bullet point summaries of comments made by the respondents.

5.7.1 SEGMENT 1 - DEMOGRAPHICS

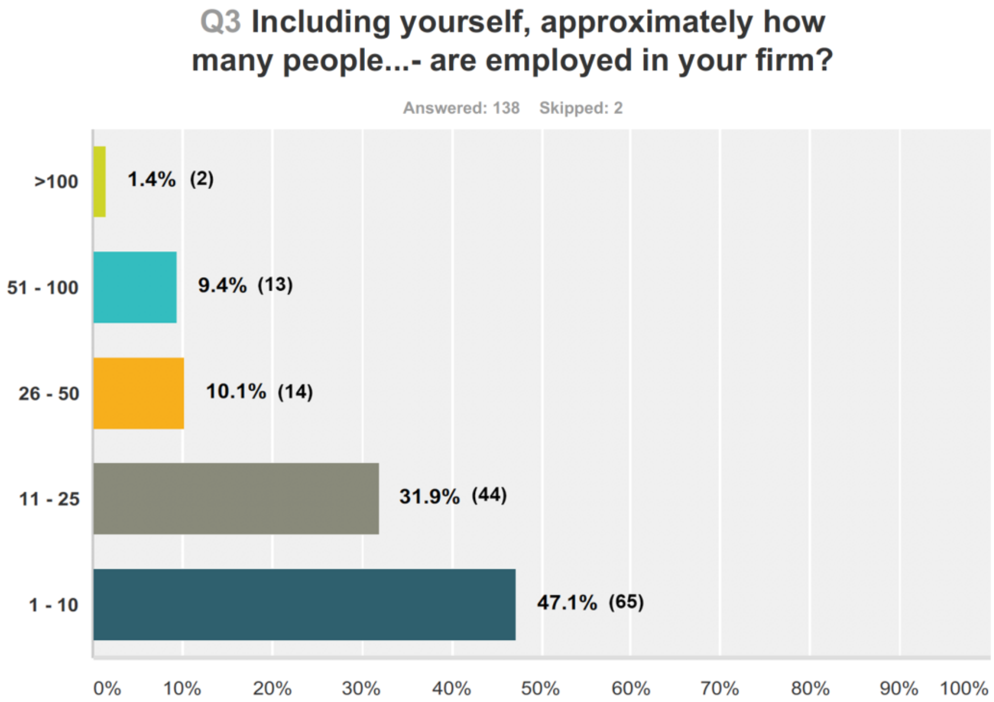
Basic data of employer/employee



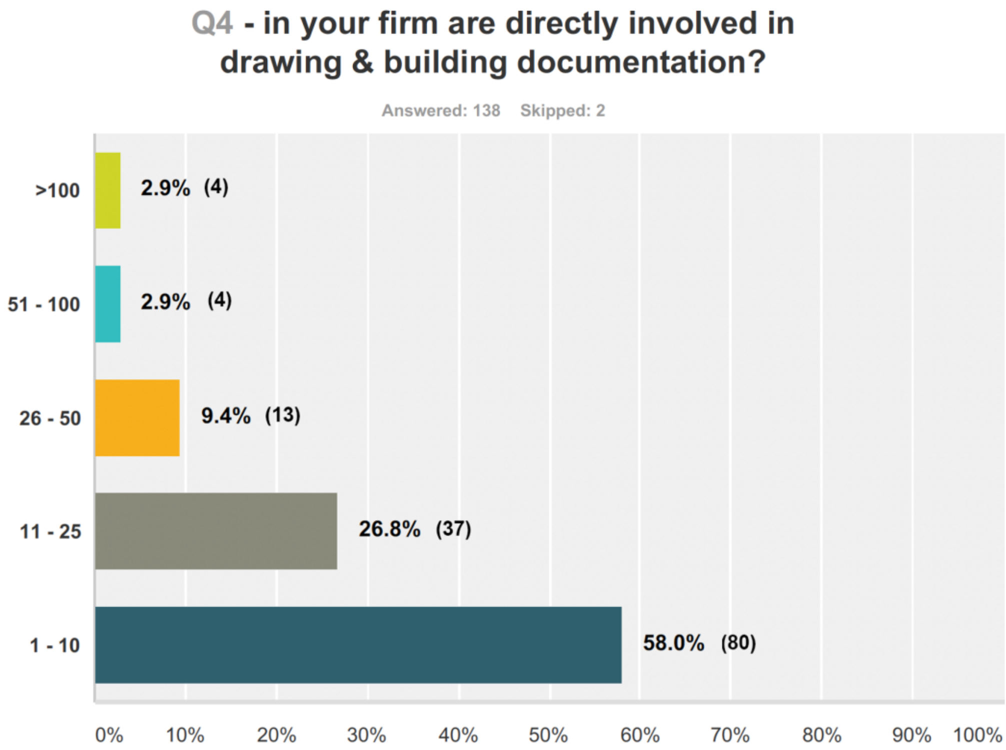
Age (Q1). The first question identifies the respondents' age. Ages in the survey were grouped by variables of 10 years. Out of the 140 respondents, most were within the 25-34 age band with 49 respondents, representing 35% of the overall sample. The age band of 45-54 has 41 respondents, which is the second highest, followed by 31 respondents who were within the age between 35-44. There were 14 respondents who were above 54 years old, representing only 10% of the respondents. Only 3.5% of the sample were aged between 18-24. Based on the age band, there seems to be a balance between the younger generation and the senior generation in the mixture. A correlation analysis could be made later to see whether the adage associating younger generation to technology awareness is true or false.



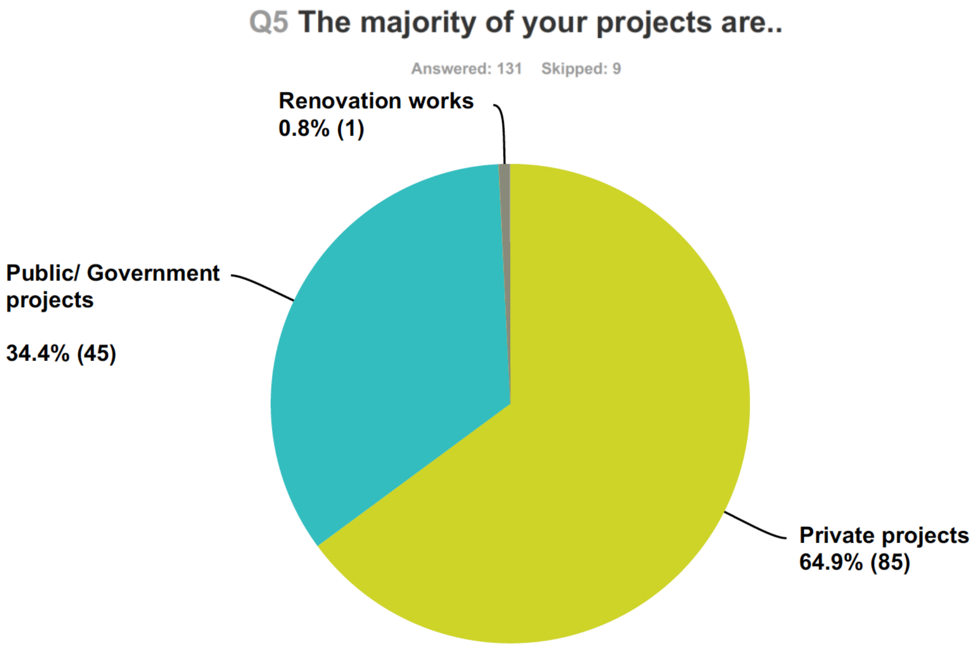
Job (Q2). The next question queries on the respondents' job title. There are five (5) typical positions in an architecture office, with the Principal Architect helming at the top and the Draftsmen relatively on the lower hierarchy. However, this does not affect the ability to respond to this survey as a low hierarchy draftsman or graphic designer could be more involved with the daily use of digital media in the office as compared to the Principal Architect who spends most of his or her time outside the office lobbying for future projects. Architects are apparently the largest position group who took up the survey on behalf of the firms, representing 40% (N= 56) of the sample. This is followed closely by Principal Architects that sums up to 34% (N= 48). 14% (N= 20) of the sample were office managers or administrators, while draftsmen make up only 9% (N= 13). The remaining three respondents, comprising the 2% of the sample were graphic designers.



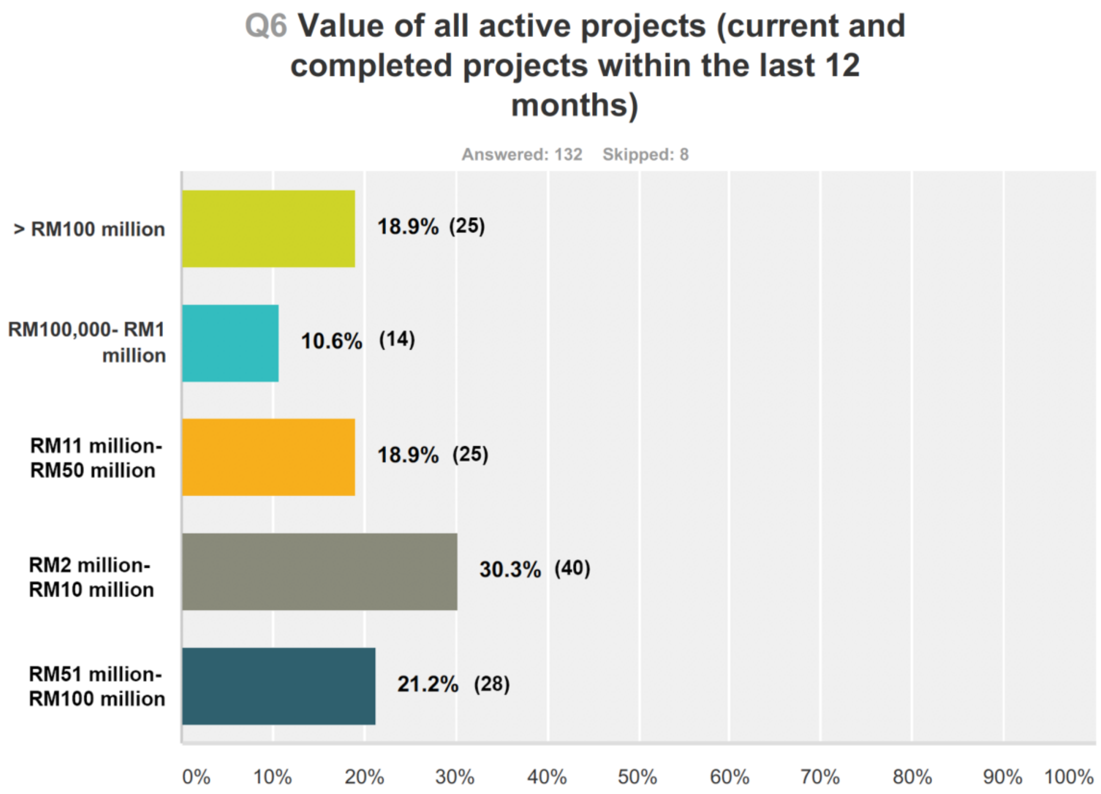
Employee (Q3). The feedback to this question were quite surprising as smaller firms with smaller man power responded more to the survey as compared to bigger firms who by contrast, would have more people who could have opted to respond to the survey. This could be the case where smaller firms may have more free time due to having less active projects, therefore enabling more of them to respond to this survey. On one hand, it could also be said that with the economic crisis and job cuts happening on a large scale, firms have relatively become smaller in sizes and there are now less large firms as compared to pre-economic crisis times. Firms with not more than 10 employees make up the majority at 47% (N= 65) of the sample, followed by firms with 11-25 employees at 32% (N= 44), and firms with 26-50 employees at 10% (N= 14). Bigger firms with 51 to 100 employees make up only 9% (N= 13) of the sample. Firms with more than 100 employees made up the lowest response rate at only 1.4% (N= 2). With this, it shows that the response rate decreases from smaller firms to bigger firms.



Drawing and Documentation (Q4). This question is very much related to Q3 as it relates to the firm's human resource. However, some of the responses to this question seems to be quite surprising as two firms with less than 100 employees apparently have more than 100 people working on drawing and documentation. Q3 reported that only 1.4% (N= 2) of the sample have more than 100 employees, whereas Q4 reports that 2.9% (N= 4) from the sample has more than 100 people directly involved with drawing and documentation. This suggests that some of the firms may have temporarily hired freelancers into their firms for specific projects or even outsourced their work to freelancers. It is also a common practice in some parts of the world such that firms tend to outsource their staff to other firms temporarily, especially when their project related works are low or limited (Idoro, 2011) (Salleh et al., 2013) (Shrestha et al., 2011).



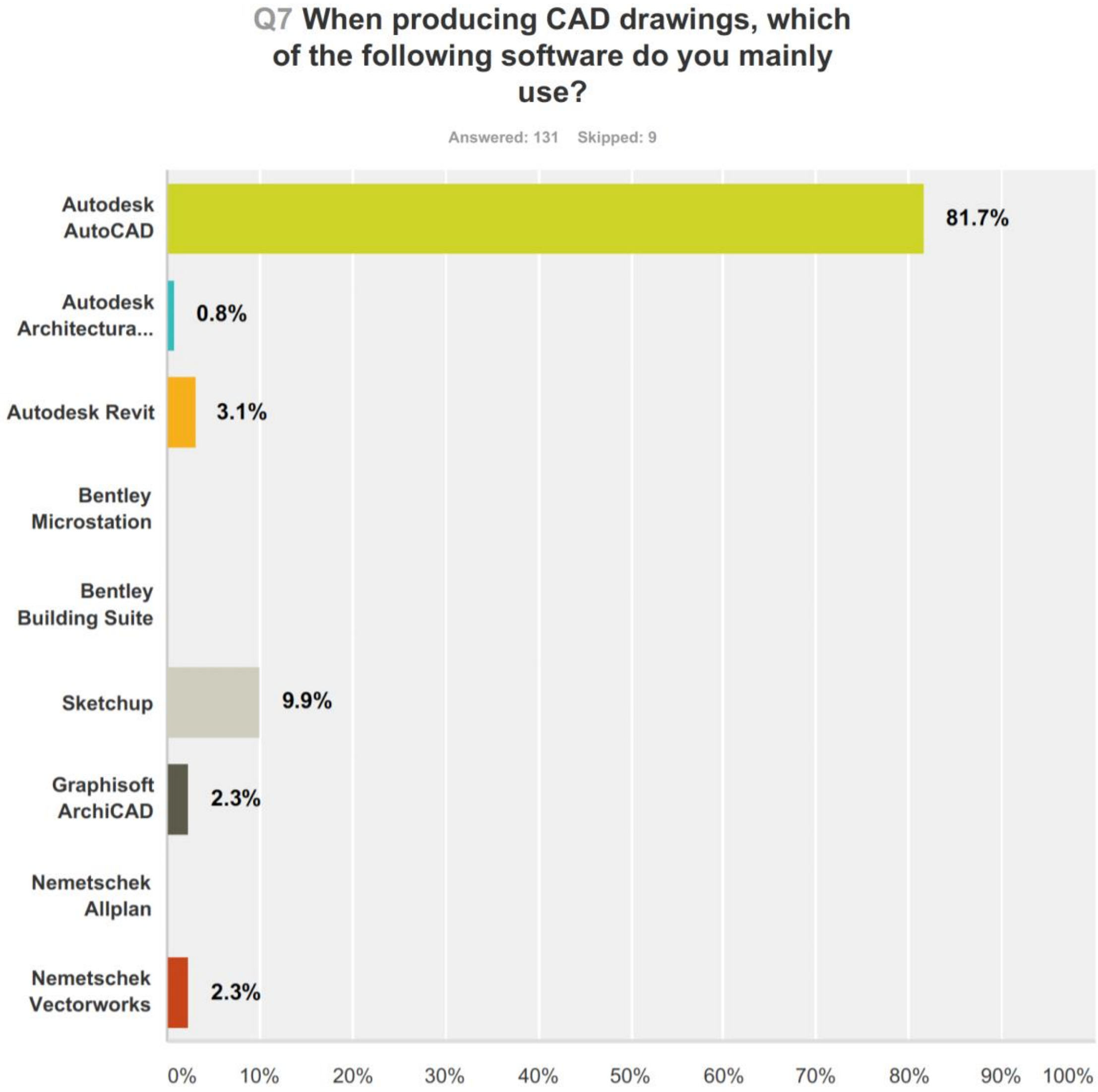
Project types (Q5). 65% (N= 85) of the respondents reported that the majority of their projects come from the private sector, whereas 34% (N= 45) reported having public or government funded projects as their main source of projects. It is noticeable that only one respondent is concentrating on renovation projects, while none are focusing on conservation works. This somewhat shows that a relatively young and developing country like Malaysia focuses more on new projects, unlike in European and North American countries; most of the buildings in the urban areas are less than 100 years old and considered not old enough to carry substantial heritage values to be renovated for conservation.



Project Value (Q6). The economic crisis of North America and Europe since 2008 has impacted not only those two parts of the world but the world over, including South East Asia. As a result, very few architecture firms nowadays are getting projects worth in excess of RM100 million (£23 million). The majority of respondents, which represent 30% of the sample, currently run projects worth between RM2-RM10 million. Respondents above that category are equally distributed with each of the other three categories, having 25-28 respondents or roughly 20% of the sample. This includes firms with active projects that cost more than RM100 million (£23 million). Even though small firms make up nearly 60% of the respondents, the size and value of projects can be seen as being more equally distributed among the respondents.

5.7.2 SEGMENT 2 – APPLIED COMPUTER TECHNOLOGY

Usage of digital technologies at establishment.



Answer Choices	Responses	
Autodesk AutoCAD (1)	81.7%	107
Autodesk Architectural Desktop (2)	0.8%	1
Autodesk Revit (3)	3.1%	4
Bentley Microstation (4)	0.0%	0
Bentley Building Suite (5)	0.0%	0
Sketchup (6)	9.9%	13
Graphisoft ArchiCAD (7)	2.3%	3
Nemetschek Allplan (8)	0.0%	0
Nemetschek Vectorworks (9)	2.3%	3
Total		131

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
1.00	9.00	1.00	1.89	2.03

Main software (Q7). This question, as well as the next question, are amongst the most important questions in the survey as the finding shall answer the second objective of the research. The figure above shows the types of software applications that the architecture firms mainly use to produce CAD drawings. CAD drawings by definition means drawings used for construction and documentation purposes, which are made up mainly of 2D drawings. Based on the response, *AutoCAD* by *Autodesk* has the highest respondents with a total of 107, representing 82% of the sample. Next, in second place is Sketchup with 13 respondents, making up 10% of the sample.

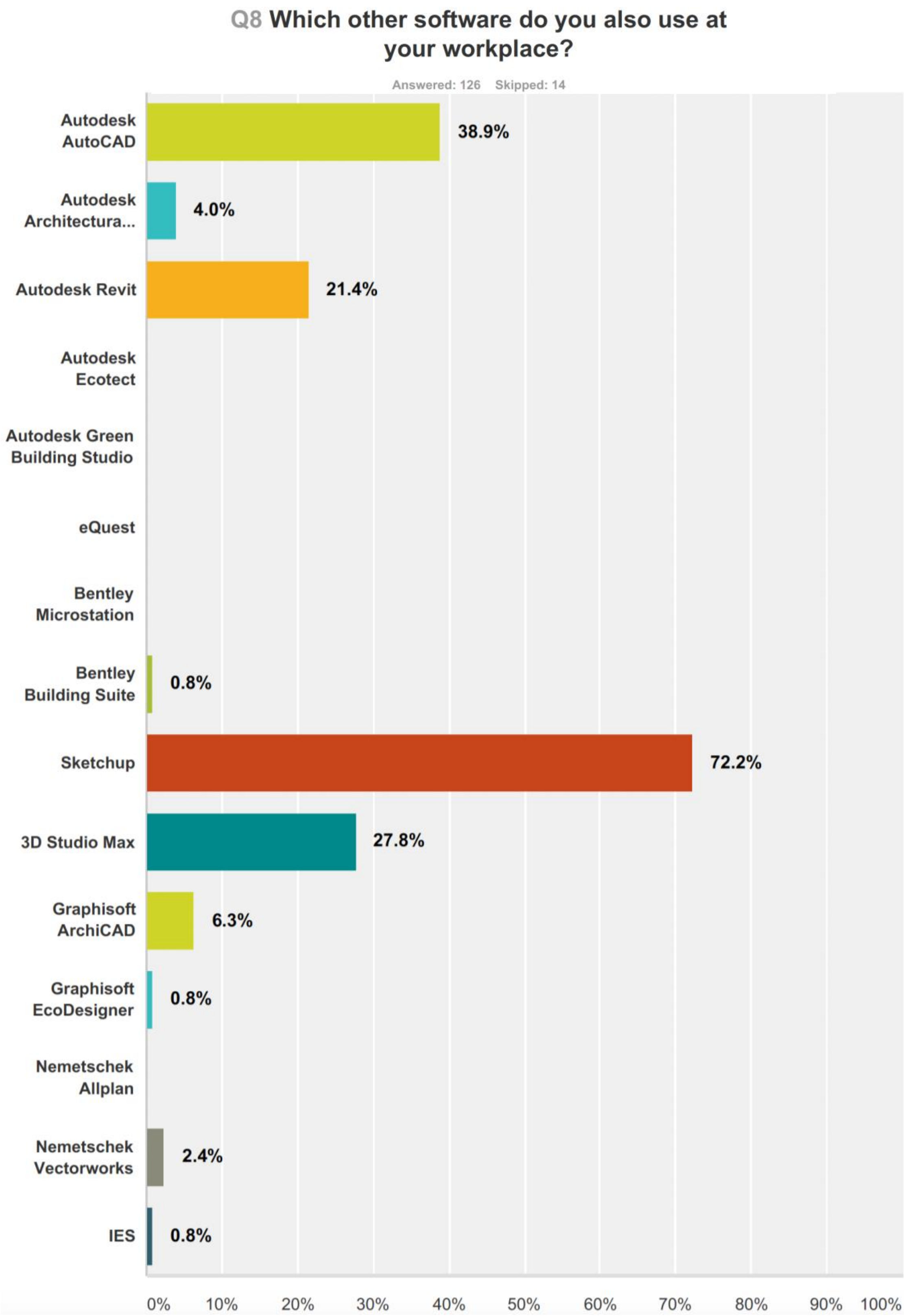
The huge difference between the number of *AutoCAD* users, which sits at first place, and its closest rival shows that AutoCAD is indeed dominating the current CAD market hence setting the standard for the industry's 2D software. There may be a number of reasons as to why this happens as *AutoCAD*, a software traditionally used for the production of 2D drawings, was one of the first 2D drafting applications introduced in the country. Therefore, being among the pioneering software, coupled with tremendous marketing effort during its introduction, the *AutoCAD* name has been synonymous to architects and draftsmen when it comes to 2D drafting (Harrington David, 2001).

Apart from that, the transfer of drawing files from one consultant to the other in a construction project in the early years demanded for all project team members to use the same software application. This was due to the fact that most software applications stand on its own platform during the time and did not share the same format, making it incompatible to open and edit drawing files across different applications. Essentially, AutoCAD, which was one of the earliest 2D drafting application to be introduced in the country, incidentally set a rule that any new office that intends to implement computer drafting has to have AutoCAD to be able to read AutoCAD drawings that come from other senior or leading firms. Although this is no longer a problem as most software applications for today are able to read files from other applications, but by the time this happened, AutoCAD had already been bought and commercially used by most architect firms in the country.

Another revelation made by this question was on the usage of Building Information Modelling (BIM). Software that uses BIM platform such as *Autodesk Revit* and *Graphisoft ArchiCAD* enables 2D drawings to be extracted directly from the main master model, thus making 2D software such as *AutoCAD* and *Microstation* redundant and irrelevant to architecture firms that adopt BIM. Based on this result, it is clear that 92% of the respondents may not have yet adopted BIM, or at least have not made BIM their main platform for project deliverables.

Other software used as main software for producing CAD drawings:

- ZW CAD by ZWSOFT (4 users)
- GD CAD by GD CAD Services Ltd
- ProgeCAD by ProgeSOFT (3 users)
- Sketchup by Google



Q8 Which other software do you also use at your workplace?
Answered: 126 Skipped: 14
Autodesk AutoCAD
38.9%
Autodesk Architectura...
4.0%
Autodesk Revit
21.4%
Autodesk Ecotect
Autodesk Green Building Studio
eQuest
Bentley Microstation
Bentley Building Suite
0.8%
Sketchup
72.2%
3D Studio Max
27.8%
Graphisoft ArchiCAD
6.3%
Graphisoft EcoDesigner
0.8%
Nemetschek Allplan
Nemetschek Vectorworks
2.4%
IES
0.8%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Answer Choices	Responses	
Autodesk AutoCAD (1)	38.9%	49
Autodesk Architectural Desktop (2)	4.0%	5
Autodesk Revit (3)	21.4%	27
Autodesk Ecotect (4)	0.0%	0
Autodesk Green Building Studio (5)	0.0%	0
eQuest (6)	0.0%	0
Bentley Microstation (7)	0.0%	0
Bentley Building Suite (8)	0.8%	1
Sketchup (9)	72.2%	91
3D Studio Max (10)	27.8%	35
Graphisoft ArchiCAD (11)	6.3%	8
Graphisoft EcoDesigner (12)	0.8%	1
Nemetschek Allplan (13)	0.0%	0
Nemetschek Vectorworks (14)	2.4%	3
IES (15)	0.8%	1
Total Respondents: 126		

Comments (10)

Basic Statistics

Minimum	Maximum	Median	Mean	Standard Deviation
1.00	15.00	9.00	6.67	3.89

Secondary software (Q8). An architecture firm can choose to use more than one type of digital media for its project deliverables. This may be encountered for firms that have different employees with diverse set of preferences for specific ability of a software, even though they might work on the same project. It may also happen that the different types of outputs an architecture firm produces, such as 2D drawings, 3D drawings, montage images, virtual reality, simulations, video presentation and so on, may result in the use of different software applications that offers different capabilities. An architecture firm that is considering replacing their main digital application with newer technology might also want to start adopting its new technology as a secondary or supporting application before upgrading it as their main digital application once they fully master it.

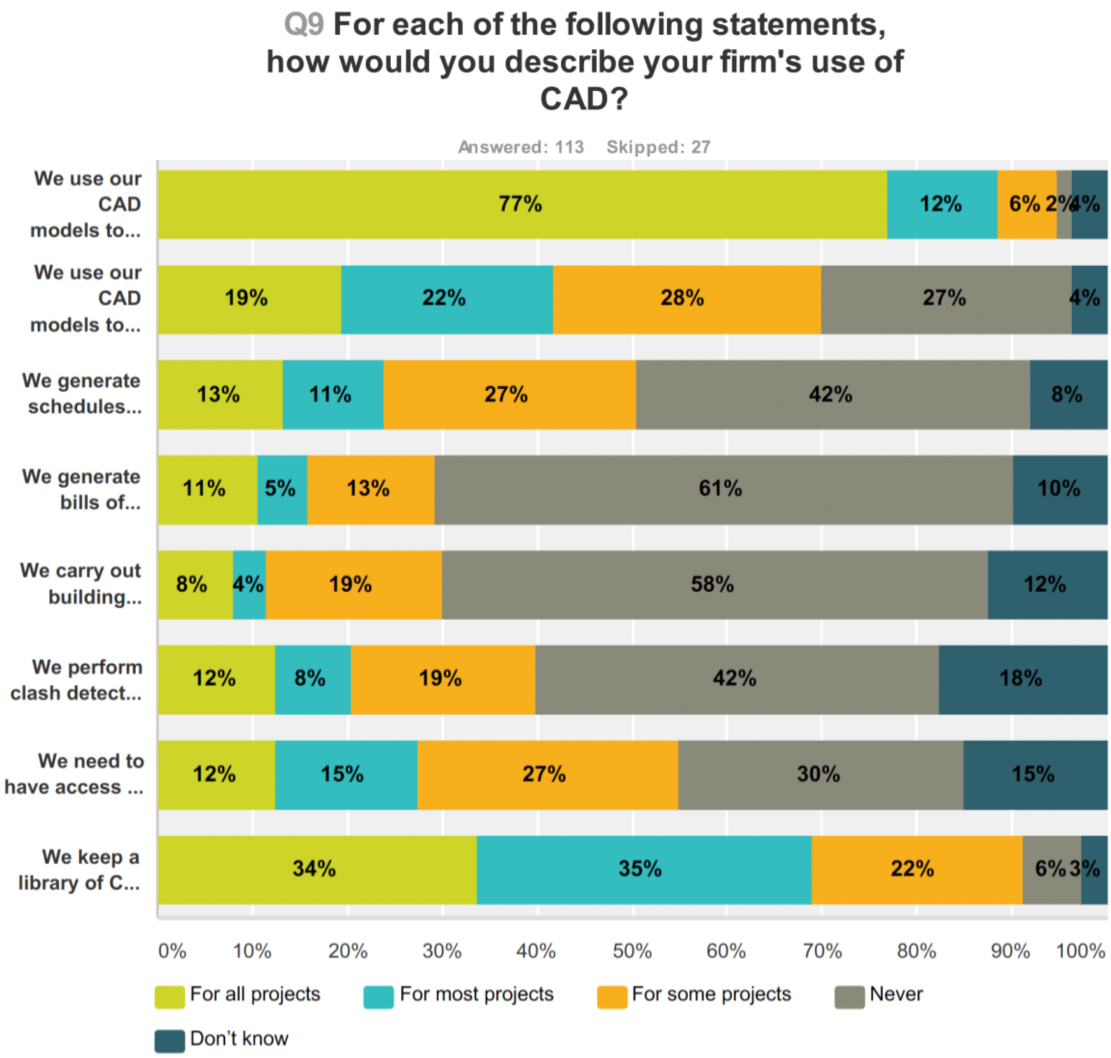
Based on the result, SketchUp by *Trimble Navigation Ltd*., which is a 3D software application, found itself as the most popular secondary or supporting software in the Malaysian market. Although the software is considered relatively new as its first release in the country was in the late 2000, its popularity rose sharply over the years as many consider its *Push/Pull* Technology (U.S patented 2003) has made it probably the easiest 3D software available on the market. However, as the application is meant for conceptual 3D modelling, as its name suggests, SketchUp's popularity would most probably remain stagnant due to its inability to provide high-end 3D renderings. This is where 3D modelling and rendering software such as *Autodesk's* 3D Studio Max and Cinema4D by *Maxxon* comes in. Most SketchUp users ended up having their 3D models rendered in these applications owing to their high-end rendering ability.

These findings also give an insight on Building Information Modelling, where 31% of the sample reported on adopting BIM technology. Among the BIM software, Revit by Autodesk seems to be the most popular with 27 respondents using it, followed by ArchiCAD from Graphisoft, Vectorworks and Allplan, both by Nemetschek. Environmental software like IES, EcoDesigner, Ecotect, Green Building Studio, and eQuest, offer building energy performance simulations, but still have a long way to go from becoming mainstream as only two respondents were reported using it.

Other software used as secondary software for producing CAD drawings:

- ZW CAD by ZWSOFT
- Photoshop by Adobe
- ProgeCAD by ProgeSOFT
- Artlantis by Graphisoft

- Lumion by Act-3D (3 users)
- IntelliCAD by CMS

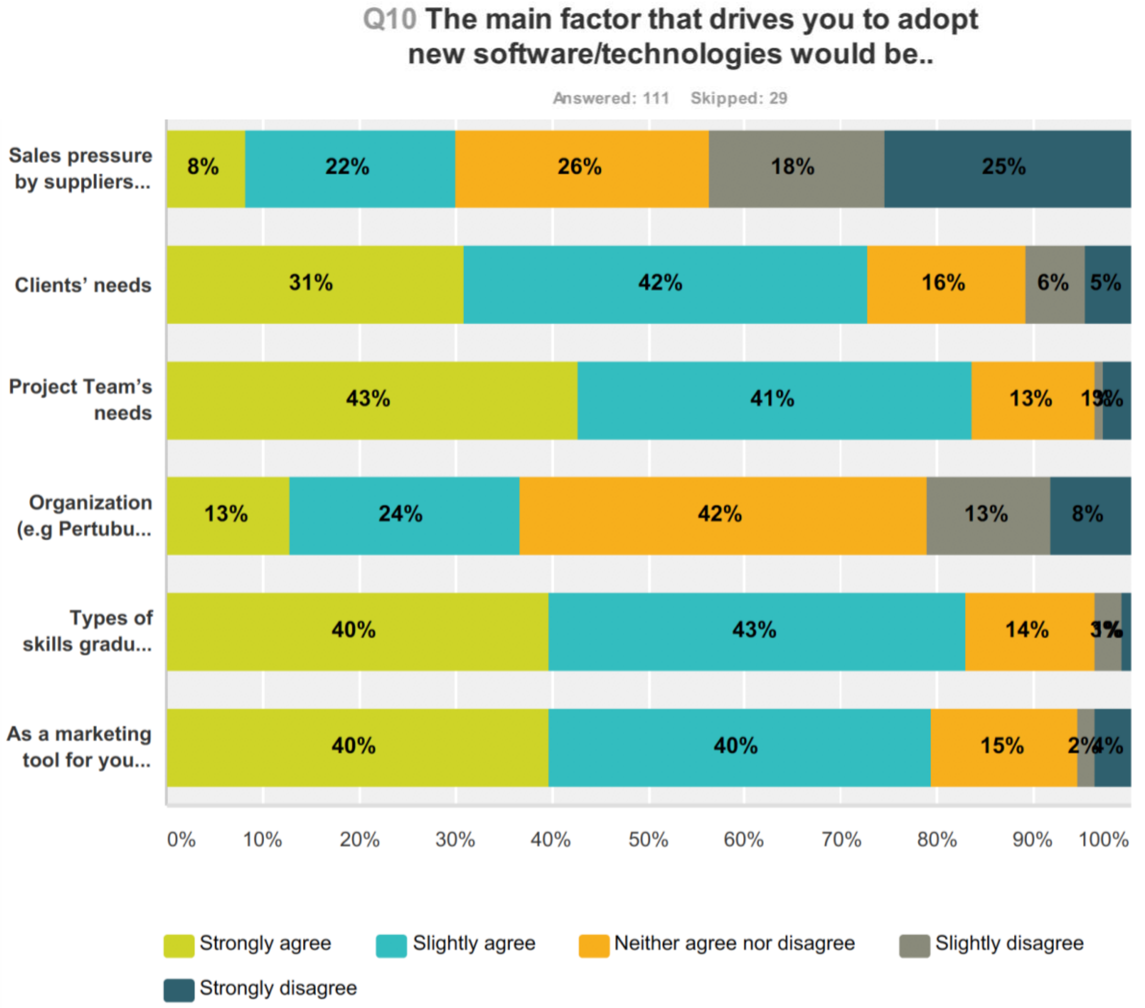


	For all projects (1)	For most projects (2)	For some projects (3)	Never (4)	Don't know (5)	Total	Weighted Average
We use our CAD models to produce 2D drawings	77% 87	12% 13	6% 7	2% 2	4% 4	113	4.57
We use our CAD models to produce 3D visualisations	19% 22	22% 25	28% 32	27% 30	4% 4	113	3.27
We generate schedules directly from our CAD models	13% 15	11% 12	27% 30	42% 47	8% 9	113	2.80
We generate bills of quantity directly from our CAD models	11% 12	5% 6	13% 15	61% 69	10% 11	113	2.46
We carry out building performance analysis on our CAD models	8% 9	4% 4	19% 21	58% 65	12% 14	113	2.37
We perform clash detection by collaborating with others through the use of CAD models	12% 14	8% 9	19% 22	42% 48	18% 20	113	2.55
We need to have access to a wide range of generic CAD objects, not just manufacturer's objects	12% 14	15% 17	27% 31	30% 34	15% 17	113	2.80
We keep a library of CAD objects we create for reuse	34% 38	35% 40	22% 25	6% 7	3% 3	113	3.91

Basic Statistics	Minimum	Maximum	Median	Mean	Standard Deviation
We use our CAD models to produce 2D drawings	1.00	5.00	1.00	1.43	0.95
We use our CAD models to produce 3D visualisations	1.00	5.00	3.00	2.73	1.15
We generate schedules directly from our CAD models	1.00	5.00	3.00	3.20	1.15
We generate bills of quantity directly from our CAD models	1.00	5.00	4.00	3.54	1.09
We carry out building performance analysis on our CAD models	1.00	5.00	4.00	3.63	1.01
We perform clash detection by collaborating with others through the use of CAD models	1.00	5.00	4.00	3.45	1.23
We need to have access to a wide range of generic CAD objects, not just manufacturer's objects	1.00	5.00	3.00	3.20	1.23
We keep a library of CAD objects we create for reuse	1.00	5.00	2.00	2.09	1.02

Use of CAD (Q9). The above figure shows how digital media is used by architecture firms in their project deliverables. The first point confirms that the majority of respondents used CAD software to produce all or most of their 2D drawings, which made up 89% (N=100) of the sample. However, only 41% (N= 47) used the same CAD application for major 3D purposes. Most of the respondents did not use CAD application to generate schedules and bills of quantity, or to carry out building performance analysis.

When looking upon item Q9iii-Q9vi; which include generating schedules, generating bills of quantity, carrying out building performance analysis, performing clash detection; we can see that most of these features are not normal traditional CAD features. Instead, it is mostly BIM features, though some traditional CAD software nowadays may be able to offer some add-ons or plugins to offer similar features. The researcher arranged this question in such a way to indirectly counter-check with respondents who directly admitted to using BIM in their job deliverables later on for Q12. It is worth noting that most of the respondents claimed not to be actively using the software capabilities listed on items Q9iii-Q9vi, indicating that the majority are only using traditional CAD software for project deliverables.



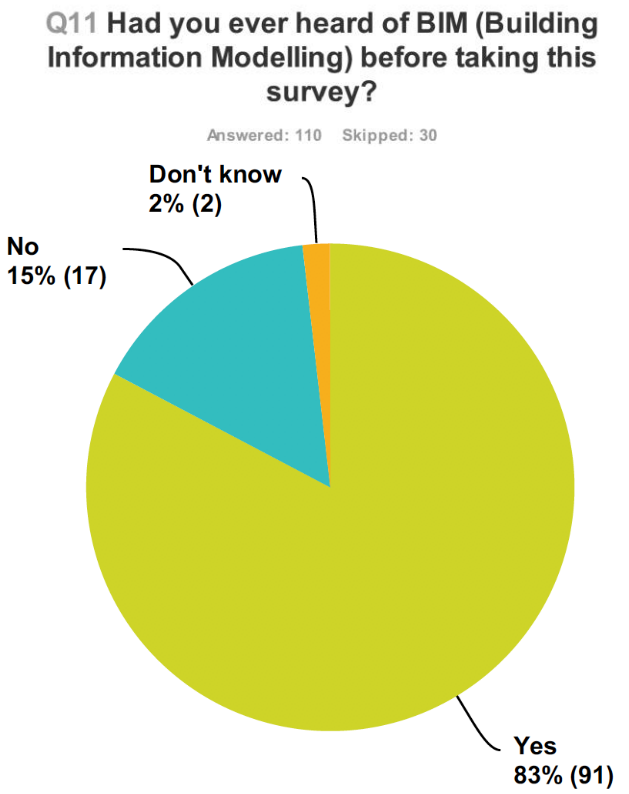
	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
Sales pressure by suppliers and vendors	8% 9	22% 24	26% 29	18% 20	25% 28	110	2.69
Clients' needs	31% 34	42% 46	16% 18	6% 7	5% 5	110	3.88
Project Team's needs	43% 47	41% 45	13% 14	1% 1	3% 3	110	4.20
Organization (e.g Pertubuhan Arkitek Malaysia)	13% 14	24% 26	42% 46	13% 14	8% 9	109	3.20
Types of skills graduate posses	40% 44	43% 48	14% 15	3% 3	1% 1	111	4.18
As a marketing tool for your organization	40% 44	40% 44	15% 17	2% 2	4% 4	111	4.10

Basic Statistics	Minimum	Maximum	Median	Mean	Standard Deviation
Sales pressure by suppliers and vendors	1.00	5.00	3.00	3.31	1.28
Clients' needs	1.00	5.00	2.00	2.12	1.06
Project Team's needs	1.00	5.00	2.00	1.80	0.89
Organization (e.g Pertubuhan Arkitek Malaysia)	1.00	5.00	3.00	2.80	1.08
Types of skills graduate posses	1.00	5.00	2.00	1.82	0.83
As a marketing tool for your organization	1.00	5.00	2.00	1.90	0.97

Drivers for new technology (Q10). From time to time, it is important for business entities to upgrade and update their tools and technology in order for them to keep up with the competitive edge that they should have in competing with other players. However, it is important to know what drives these entities to adopt new technologies so that we know which drivers give the best outcome. Based on the figure, adopting new technologies based on a project team's needs scored the highest rating of 4.2 out of a full rating of 5. This seems to be a very positive practice as it is done on a need-based basis. One point that needs to be looked at with great concern is the fact that 82% of respondents' decision to adopt new technology lies upon the types of skills fresh graduates possess. This means that the direction in which the country's technological path undergoes is directly influenced to a certain extent by HEI. The driver for new technology that received the lowest rating of 2.69 out of 5 is sales pressure by vendors. This is of course a positive sign as commercial marketing might not always be the best reference for a product.

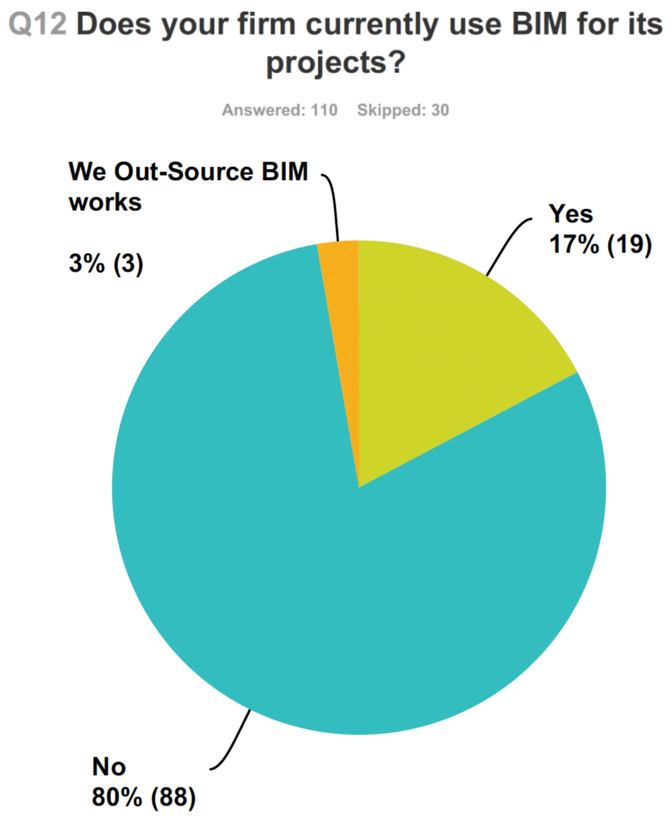
5.7.3 SEGMENT 3 – BIM IN PRACTICE

Awareness and BIM experience



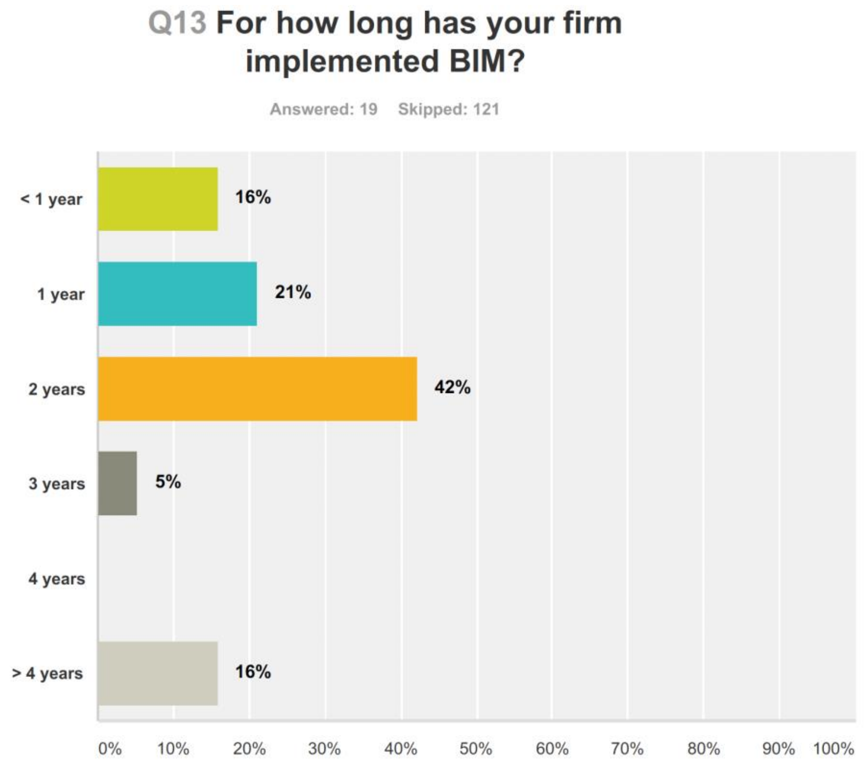
Basic Statistics				
Minimum 1.00	Maximum 3.00	Median 1.00	Mean 1.19	Standard Deviation 0.44

BIM awareness (Q11). By the time the survey reached this question, 30 respondents had ceased to continue completing the survey. However, close to 90% (N= 110) opted to stay on course and continue with the survey through the third segment, which is the most important segment and where the research is centred. The response to this question was overwhelmingly positive, whereby 83% (N= 91) of the sample reported being fully aware of BIM. Compared to UK, the industry's awareness on BIM in Malaysia still has a long way to catch up, as the industry's awareness on BIM in the UK was at 93% (NBS, 2013).



Basic Statistics				
Minimum	Maximum	Median	Mean	Standard Deviation
1.00	3.00	2.00	1.85	0.42

BIM adoption (Q12). This question can be considered as one of the most crucial questions in the survey as it will tell where the country stands in terms of BIM usage. The response to this question is consequential and a concern that needs to be looked into and acted upon carefully and effectively. Based on the above figure, while 83% (N= 91) of the sample reported on being aware of BIM, only 20% (N= 22) are actually adopting it in their project deliverables. Needless to say, that 14% (N= 3) from those who use BIM, opted to outsource its BIM works rather than adopting the technology in-house. This figure is of concern if one would compare it to other parts of the world such as the US and Europe that have nearly 70% and 34% of its players using BIM, respectively (McGraw-Hill, 2012a, McGraw-Hill, 2010). The UK's BIM adoption rate at approximately the same time was at 39% (NBS, 2013). It is still obscure as to why so many people chose not to use it while acknowledging the technology and its qualities. This conundrum will be much clearer as we get a deeper insight on the respondents' experience and understanding of BIM through their coming responses. It is also worth to note that in correlation to Q9, approximately 17%-21% acknowledged to using their 'CAD' tools to generate schedules and bills of quantity, execute building performance analysis, and perform clash detection; these are actually BIM capabilities that are not found in conventional CAD tools. The numbers of BIM users correspond to this, ultimately specifying that these 'CAD' tools are actually under the capacity of BIM.

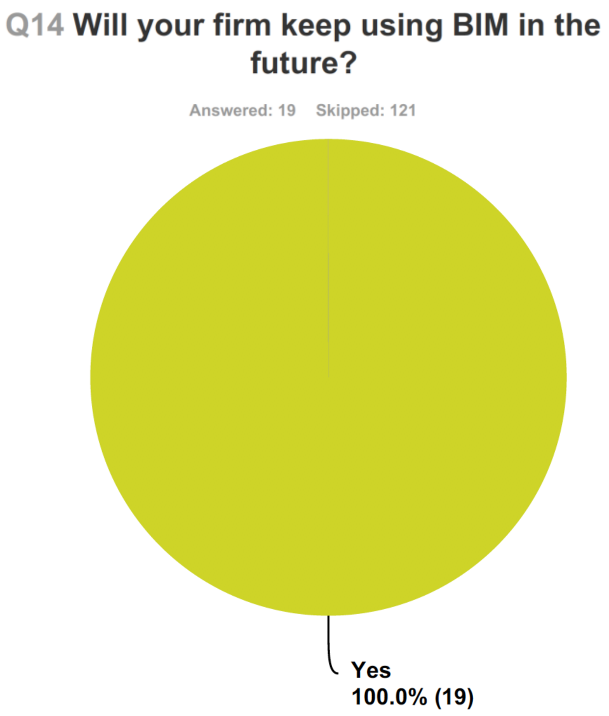


Answer Choices	Responses	
< 1 year (1)	16%	3
1 year (2)	21%	4
2 years (3)	42%	8
3 years (4)	5%	1
4 years (5)	0%	0
> 4 years (6)	16%	3
Total		19

Basic Statistics

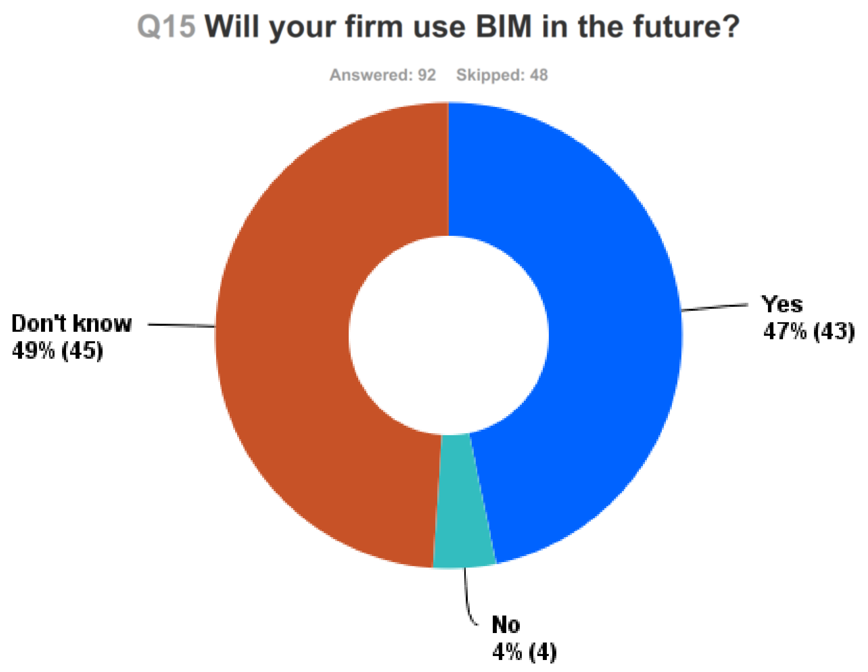
Minimum	Maximum	Median	Mean	Standard Deviation
1.00	6.00	3.00	3.00	1.52

Years of BIM implementation (Q13). This question was directed to BIM users only, which accounts for 19 out of a total 110 respondents. It intends to attain an understanding on the expertise of BIM users developed through years of experience using the technology. The feedback shows us that BIM is still very much new to the architecture industry in Malaysia. Most of the users have been using BIM for not more than two years. This indicates that most BIM users in Malaysia are still at a very early stage of implementation. Only 16% of BIM users have used it for more than four years.



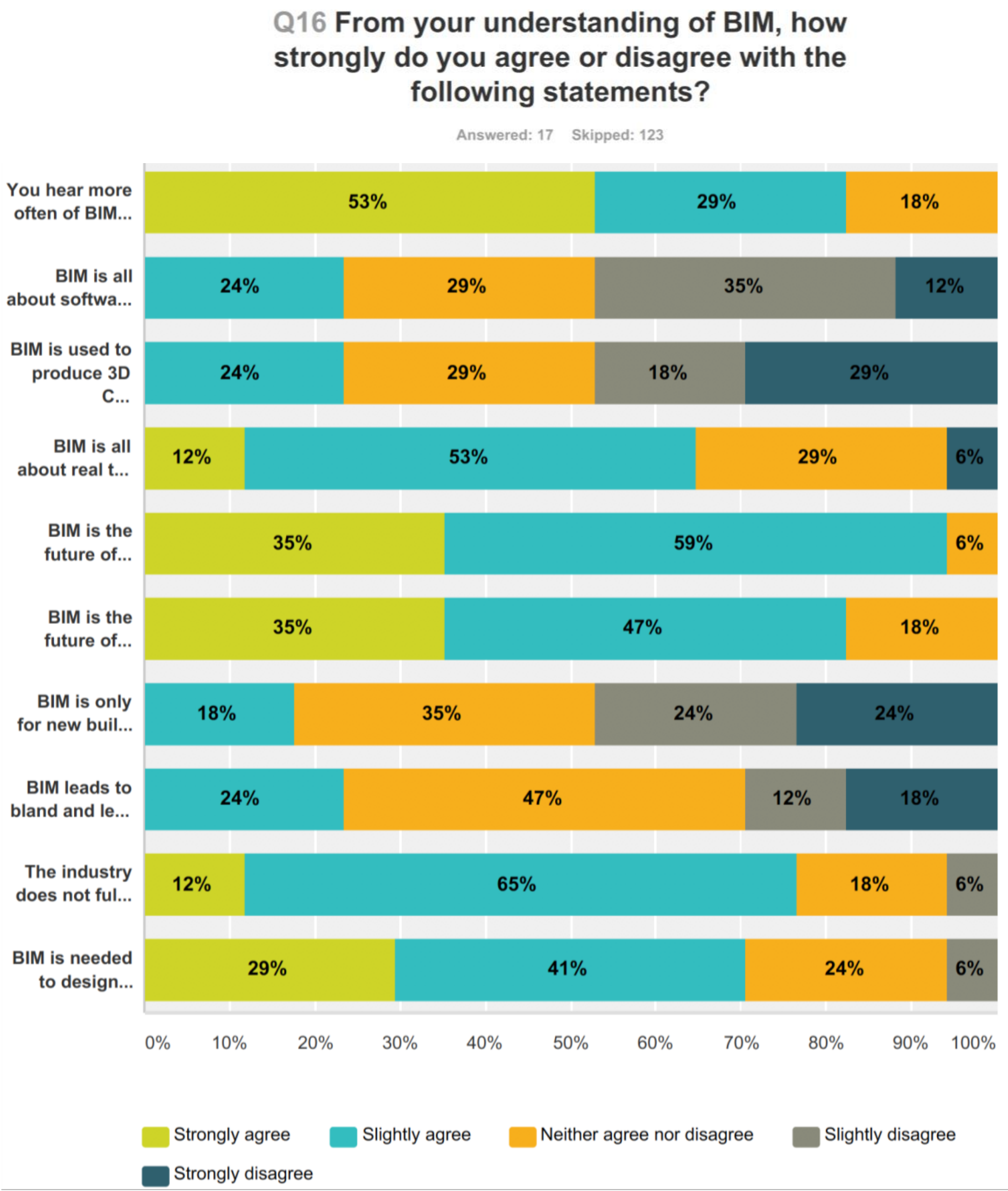
Basic Statistics				
Minimum	Maximum	Median	Mean	Standard Deviation
1.00	1.00	1.00	1.00	0.00

BIM in the future (Q14). This question was directed to BIM users as well. We needed to know whether the BIM users will continue using the technology or revert back to CAD or other technologies. All 100% (N=19) respondents had indicated that they would keep on using BIM in the future for their project deliverables.



Basic Statistics				
Minimum 1.00	Maximum 3.00	Median 2.00	Mean 2.02	Standard Deviation 0.98

BIM for non-user (Q15). This question reverts back to non-BIM users, with 92 respondents, consequently forming the majority of the respondents, in comparison to BIM users. With 83% of respondents having awareness of BIM, it is important to know how many of them are seriously planning to take the crucial step of adopting the new technology. Based on the above figure, nearly half of the non-users indicated that they will eventually adopt the technology in the future. However, the same number of respondents replied that they were still undecided over the implementation of BIM. Though this is not something positive, it still gives hope that there could be a change in the future and that they might adopt the technology as well. This is also due to the fact that only a mere 4% have clearly decided against the usage of BIM in the future.


Q16 From your understanding of BIM, how strongly do you agree or disagree with the following statements?
Answered: 17 Skipped: 123
You hear more often of BIM...
BIM is all about softwa...
BIM is used to produce 3D C...
BIM is all about real t...
BIM is the future of...
BIM is the future of...
BIM is only for new buil...
BIM leads to bland and le...
The industry does not ful...
BIM is needed to design...
53% 29% 18%
24% 29% 35% 12%
24% 29% 18% 29%
12% 53% 29% 6%
35% 59% 6%
35% 47% 18%
18% 35% 24% 24%
24% 47% 12% 18%
12% 65% 18% 6%
29% 41% 24% 6%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Strongly agree
Slightly agree
Neither agree nor disagree
Slightly disagree
Strongly disagree

	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
You hear more often of BIM these days	53% 9	29% 5	18% 3	0% 0	0% 0	17	4.35
BIM is all about software and nothing more	0% 0	24% 4	29% 5	35% 6	12% 2	17	2.65
BIM is used to produce 3D CAD drawings only	0% 0	24% 4	29% 5	18% 3	29% 5	17	2.47
BIM is all about real time collaboration	12% 2	53% 9	29% 5	0% 0	6% 1	17	3.65
BIM is the future of project information	35% 6	59% 10	6% 1	0% 0	0% 0	17	4.29
BIM is the future of project management	35% 6	47% 8	18% 3	0% 0	0% 0	17	4.18
BIM is only for new build, not refurbishment or alteration	0% 0	18% 3	35% 6	24% 4	24% 4	17	2.47
BIM leads to bland and less creative design	0% 0	24% 4	47% 8	12% 2	18% 3	17	2.76
The industry does not fully understand what BIM is yet	12% 2	65% 11	18% 3	6% 1	0% 0	17	3.82
BIM is needed to design sustainable buildings	29% 5	41% 7	24% 4	6% 1	0% 0	17	3.94

Basic Statistics

	Minimum	Maximum	Median	Mean	Standard Deviation
You hear more often of BIM these days	1.00	3.00	1.00	1.65	0.76
BIM is all about software and nothing more	2.00	5.00	3.00	3.35	0.97
BIM is used to produce 3D CAD drawings only	2.00	5.00	3.00	3.53	1.14
BIM is all about real time collaboration	1.00	5.00	2.00	2.35	0.90
BIM is the future of project information	1.00	3.00	2.00	1.71	0.57
BIM is the future of project management	1.00	3.00	2.00	1.82	0.71
BIM is only for new build, not refurbishment or alteration	2.00	5.00	3.00	3.53	1.04
BIM leads to bland and less creative design	2.00	5.00	3.00	3.24	1.00
The industry does not fully understand what BIM is yet	1.00	4.00	2.00	2.18	0.71
BIM is needed to design sustainable buildings	1.00	4.00	2.00	2.06	0.87

Views on BIM (Q16). Even though only 20% from the sample have actually implemented BIM, their experiences are vital in order to ensure that the direction for future strategy would bear fruit and afterwards fulfil the industry's requisites. The first point of this question conforms to Q11, where BIM is becoming a household term nowadays. However, whether this would translate into a fully adopted technology by profession in the near future is yet to be known. Looking at the responses, the users seem to understand what BIM is all about and how it is meant to be utilised. Only a few perceived BIM as just another typical drawing software used for producing 3D images, which is definitely not the case.

The majority agreed that BIM is about real-time collaboration, even though the average rating for this item is just 3.65 out of 5, which is arguably not very strong. This could have happened due to the fact that many users are still beginners and they may have yet to fully utilize BIM on a full-scale collaboration with other team players. The majority also conceded that BIM is the future of project information and project management, where both of these items received a high rating of 4.29 and 4.18 respectively.

Some respondents have expressed that they are unaware of BIM's capability to work on refurbishing or alteration of a building. Since adopting BIM requires a substantial one time investment, it may not be within an architecture firm's immediate decision to do so for primarily refurbishing and alteration works, as these types of labour in Malaysia are usually low-cost and do not generate as much income as a new build. However, nearly half of the sample disagreed that BIM is only for new builds, not refurbishment or alteration.

One detail that seems to be interesting is the sample's perception that BIM leads to bland and less creative design. While many scholars and industry professionals seem to agree that BIM may lead to bland designs, users in Malaysia have mixed opinions towards this. While nearly half of the users are unresolved with regards to this, there is certainly a degree of balance between those who are for this point as those against it. This would subsequently ascertain the next point where a majority of the users (76%) agreed that the industry has yet to fully comprehend what exactly is BIM.

Therefore, it is unsurprising that while the majority of the sample are aware of this new technology, only a small percentage chose to implement it. This is a principal argument as it shows that the lack of knowledge on BIM technology might be the contributing factor towards the hindrance of its full-scale adoption by the industry.

BIM Experience (Q17). This question shall answer the third objective of this research, which intends to look into how BIM has affected architecture deliverables in terms of technical, culture, and business attributes of architecture firms. Based on the following figure of responses, it could be said that respondents have in general, described that BIM has so far given them positive impacts. The following describes the above in detail.

Basic Statistics	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has improved visualisation	1.00	2.00	1.50	1.50	0.50

First of all, 100% (N= 16) respondents agreed that BIM has improved their work in terms of visualization. This is anticipated as many sources have reported that selected parties have started using BIM for visualisation purposes (Becerik-Gerber et al., 2011b) (Sacks and Barak, 2009) (Gonchar, 2006, Kim, 2011). Even though BIM offers many other innovative features, its quality as a visualization tool is unequivocal and should by all means be utilised to its full advantage.

	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has increased coordination of construction documents	1.00	3.00	2.00	1.81	0.73

Increasingly coordinated construction documents happen to be another quality brought about by BIM, with an approval rate of 4.19 out of 5 by the respondents. This demonstrates that those who used BIM in their project deliverables have actually used it to coordinate construction documents within the consultant teams rather than merely for personal purposes such as visualization or clash detections. With this, it is proven that BIM has become the tool for collaboration between key team players.

	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has improved site logistics	1.00	3.00	2.00	2.19	0.73

This is rather similar to improving site logistics, with 63% (N= 10) admitting to the advantage of using BIM for this purpose. This demonstrates that BIM is not only used during the design phase, but also extends to the construction phase. This also implies that contractors and clients have also started to embrace BIM technology; a rarity in traditional construction practices in Malaysia, as coordination of site logistics with BIM necessitates all parties including clients and contractors to adopt the technology.

	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has improved productivity	1.00	3.00	2.00	2.00	0.79

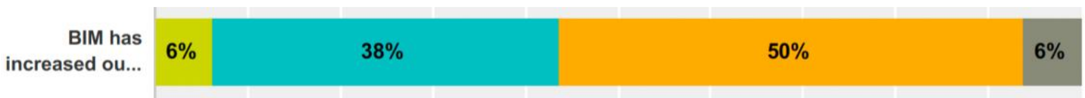
BIM has proved to be able to increase productivity with a 69% (N= 11) approval rate from BIM users. The rest of the users did not disagree to this but have yet to see any clear evidence of increase in productivity. This approval rate is seemingly crucial, as the main reason to adopt any technology whatsoever is its ability to increase productivity (Al-Jabri and Sohail, 2012) (Eadie et al., 2013b) (Azhar, 2011). It should be noted that when users of a new technology approve of its capacity to realistically increase productivity, it is highly probable that non-users will look into the prospect of adopting this new technology as well.

	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has increased speed of delivery	1.00	4.00	2.00	1.94	0.90

In direct relation to increase of productivity, it is expected that there should be an increase in speed of delivery as well. However, a slight increase of approval can be seen when 76% (N= 12) of the respondents agreed that BIM has increased their speed of job deliverables.

	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has brought cost efficiencies	1.00	4.00	2.00	1.94	0.75

The response towards cost efficiencies in using BIM is quite interesting. While a substantial 88% (N= 14) of the respondents have reported that BIM had increased their cost efficiencies, only 25% (N= 4) ‘strongly agree’ while the other 63% (N= 10) ‘slightly agree’ to it. This proves that while it is true that BIM does increase cost efficiencies, it has yet to do so substantially.



	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has increased our profitability & return of investment (ROI)	1.00	4.00	3.00	2.56	0.70

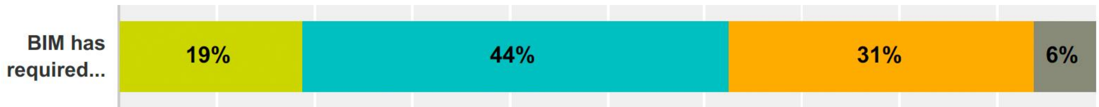
In direct relation to cost efficiencies, not many have experienced appreciable returns of investment (ROI). To clarify, only 6% (N= 1) ‘strongly agree’ that BIM had increased ROI, 38% (N= 6) ‘slightly agree’, while a considerable 50% (N=8) neither agree nor disagree to ROI. This suggests that BIM has yet to show any fortifying evidence that it can indeed produce huge ROI to users in Malaysia, contradicting to the claim by Autodesk (2007) that an ROI of 60% could be achieved within just a year of usage. However, even though it may be strange at first when those who claimed BIM to have increased cost efficiencies may not have made the same claim for ROI, it is not entirely unexpected. Using BIM may straight away offer cost efficiency from daily tasks such as reduced prints, sharing of BIM models, simultaneous working by all team players, utilising clash detection and other simulation tools throughout the design process, and so on in comparison to CAD. However, a return of investment (ROI) on the other hand needs more time to realize as BIM is a long-term investment rather than a short one (Pour Rahimian et al., 2014). It is also worth noting that ROI is not easily calculated as approaches to adoption may differ from one to the other, i.e. immediate switch vs phased-in approach; this affects the effectiveness of ROI calculations formula by Autodesk (2007). Also, researchers posit that ROI is better suited to cost-saving projects than for revenue-generating projects (Brien and Dolenc, 2012).

	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has helped us in producing specifications	1.00	4.00	2.00	2.50	0.94

Another feature in BIM is that users can create specifications earlier on and generate it automatically from the drawings along the project timeline (Eastman et al., 2008, Utiome and Drogemuller, 2013, Chapman, 2011). Considering this, BIM users are anticipated to agree to this question. However, only 57% (N= 9) of BIM users agreed that BIM has helped in producing design specifications. What remains a concern is that the other 44% (N= 7) have described the experience adversely. This raised the question as to what extent do these users actually use BIM and whether it is convenient or not to produce specifications using BIM? What is certain is that only slightly more than half of users use BIM to produce specifications.

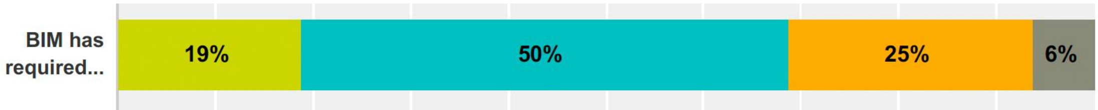
	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has helped us in producing bills of quantities	1.00	4.00	2.50	2.50	0.71

It is within BIM's capability to produce accurate calculations on material and costing that is used to produce bills of quantities (B.Q) (Li, 2013b, Mahdjoubi et al., 2013, Nadeem et al., 2015). However, it is expected that not all architects from the firms use BIM to produce bills of quantities (B.Q). Only 50% (N= 8) of the firms used BIM in producing bills of quantities (B.Q). This is due to the fact that only quantity surveyors (Q.S) produce B.Q in Malaysia's work environment.



	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has required changes in roles and work scope	1.00	4.00	2.00	2.25	0.83

This question is significant in the sense that it affects the traditional practice within the industry. 63% (N= 10) of the firms have claimed that BIM requires changes in roles and work scope. The features of BIM that enables production of drawings, 3D images, simulations of design, bills of quantities, collaboration, and communications have raised the question on whether it is still necessary to have traditional roles such as draftsmen, 3D artists, or traditional project managers as architects can now execute all those tasks by themselves with the BIM platform. Studies by Sebastian (2011), Gu and London (2010), Hannon (2007) and Love et al. (2013) are some of the studies that touched on this issue in general. However, it is notable that even though more than half of the firms have generally agreed that BIM requires changes in roles and work scope, only 19% (N=3) of the firms have 'strongly agreed', indicating that the majority could have probably experienced a change but may not be a significant one.



	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has required changes in our workflow, practices and procedures	1.00	4.00	2.00	2.19	0.81

Corresponding directly to the changes BIM requires for roles and work space, it is expected that BIM will have an effect on existing workflows, practices and procedures as well. With that said, 69% (N=11) of the firms agreed to this notion. This is crucial as changes in roles, workflows, practices and procedures will affect the traditional role of architects and what is required of an architect in the future. Again, the majority responded only 'agree' rather than strongly agree, indicating that they could have probably experienced a change but may not be a significant one.

	Minimum	Maximum	Median	Mean	Standard Deviation
We have a BIM unit/division that handles/supports all BIM matters	2.00	5.00	3.00	2.69	0.77

Another scenario that shows how architect firms are changing as an effect of adopting BIM is that 44% (N= 7) of the architecture firms have established a BIM unit or division to handle and support BIM related matters. However, 50% (N=8) have yet to confirm that they have actually set up a unit or division to oversee matters pertaining to BIM. It is worth noting that starting a new unit or department for new tasks involves more office space, furniture, hardware and software, human resource, and scope of work, resulting in an overall increase in capital. This may not run well with smaller offices with limited resources. Thus, it is possible that 50% (N=8) of the firms did not agree nor disagree because even though they might not have started any BIM unit or division yet, they readily have selected individuals doing it.

	Minimum	Maximum	Median	Mean	Standard Deviation
Clients has increasingly insist on us using BIM	2.00	4.00	3.00	2.75	0.75

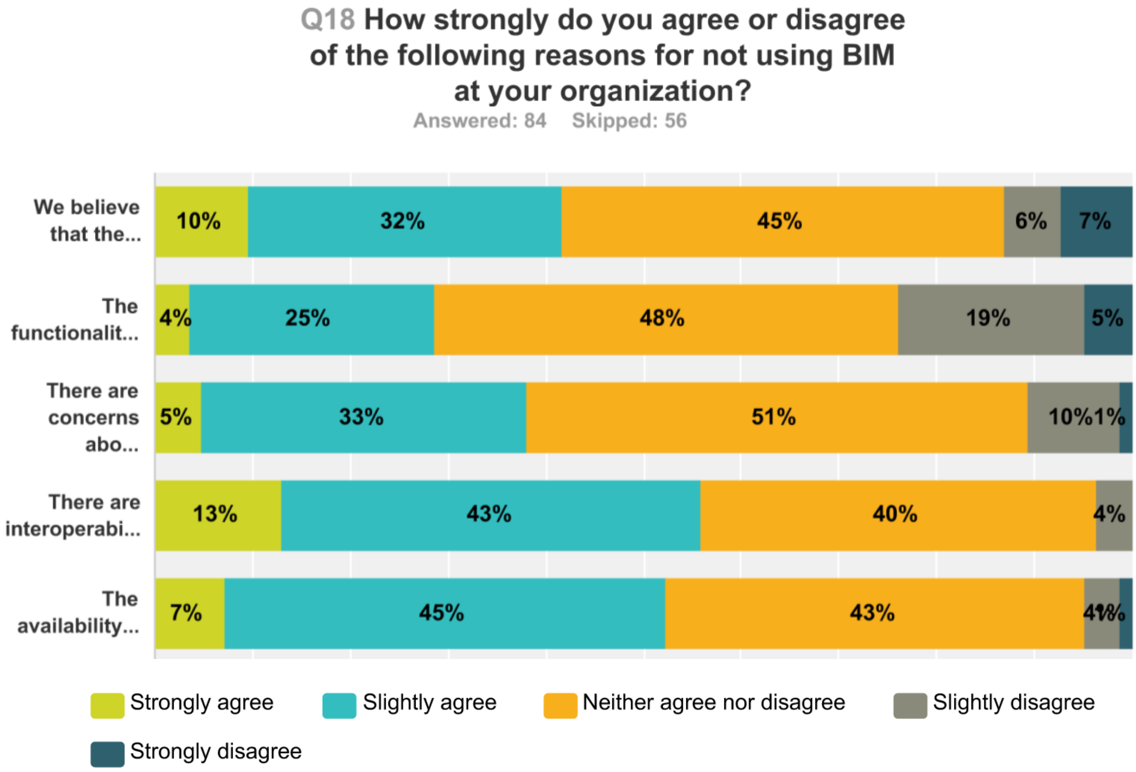
Based on the table above, 44% (N= 7) of the architecture firms that have adopted BIM have claimed that their clients have increasingly insisted them to use BIM. The industry should take note of this as nearly half of the clients for these architecture firms have insisted on BIM implementation despite the perceived high investment (Alabdulqader et al., 2013, Takim et al., 2013, Cheng and Wang, 2010, McGraw-Hill, 2012b) they have to make and the fact that the technology is relatively new which may even lack the support and required expertise. Only 19% (N=3) of the firms have not had their clients increasing; insisting on BIM implementation, while the remaining were uncertain as to their clients' preferences. It is unsurprising that quite a significant portion of clients are still unsure of BIM as determined from a very recent survey done by CIOB (2016b). The survey in UK also found that more than half of the construction clients in the nation is undecided on BIM as they stated to have yet to see any remarkable evidence of its capabilities.

	Minimum	Maximum	Median	Mean	Standard Deviation
We have used BIM successfully	1.00	3.00	2.00	2.25	0.56

It is a positive indication that 69% (N=11) of the architecture firms that have been using BIM were perceived to be using BIM successfully. This trend is in line with the trend in other countries around the world, particularly Canada (60%) (IBC and NBS, 2013), Finland (68%) (Finne et al., 2013), New Zealand (62%) (Masterspec, 2013), and United Kingdom (62%) (NBS, 2014). However, as with the previous question, this notion may not be shared by client-users. Contradictory to CAD, where it does not collaborate or integrate team players on a real-time basis, a collaborative tool like BIM should benefit all its team players equally or at least share a positive perception by all its users; the recent survey done by CIOB (2016b) CIOB (2016a) proved differently.

5.7.4 SEGMENT 4 – GENERAL VIEW TOWARDS BIM

BIM in the future: drivers and barriers

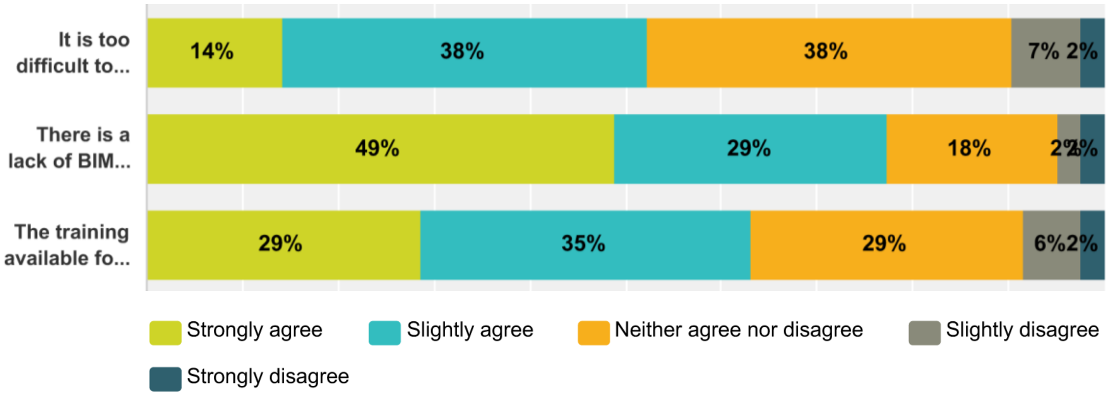


	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
We believe that the approaches/systems we currently use are better	10% 8	32% 27	45% 38	6% 5	7% 6	84	3.31
The functionality of BIM doesn't help much in what we do	4% 3	25% 21	48% 40	19% 16	5% 4	84	3.04
There are concerns about the liability for BIM models	5% 4	33% 28	51% 43	10% 8	1% 1	84	3.31
There are interoperability concerns between BIM and our CAD applications	13% 11	43% 36	40% 34	4% 3	0% 0	84	3.65
The availability of BIM-compatible content/libraries seems to be insufficient	7% 6	45% 38	43% 36	4% 3	1% 1	84	3.54

	Minimum	Maximum	Median	Mean	Standard Deviation
We believe that the approaches/systems we currently use are better	1.00	5.00	3.00	2.69	0.98
The functionality of BIM doesn't help much in what we do	1.00	5.00	3.00	2.96	0.88
There are concerns about the liability for BIM models	1.00	5.00	3.00	2.69	0.76
There are interoperability concerns between BIM and our CAD applications	1.00	4.00	2.00	2.35	0.75
The availability of BIM-compatible content/libraries seems to be insufficient	1.00	5.00	2.00	2.46	0.73

BIM Barriers (Q18). For non-BIM users, which form the majority of the sample, it is important to know the reasons that may have prevented them from adopting the technology. It is to be noted that by this stage of the survey, only 84 out of the 92 non-BIM users remained with the survey while eight non-BIM users had opted out. There are 16 sub-questions in this question that can be further categorized into five groups, namely non-users' perception to the technological dimension of BIM, BIM in relation to human resources, non-users' perception towards BIM in relation to cost and investment, non-users' perception towards legal matters pertaining to BIM, and lastly a little bit on BIM research.

Among the architecture firms that have not used BIM exclusively, 42% (N=35) believed that BIM is not any better than the system or technology that they are currently using, whereas another 45% (N=38) neither agree nor disagree. Even though 42% of non-users of BIM might have claimed that their current system may be better, only 29% (N=24) stated that it was due to functional aspects, while nearly 50% were undecided. Besides that, the concern towards the liability of BIM models can be quite significant for 38% (N=32) of the architecture firms, while most of them (62%, N=52) are not quite sure of that. However, what seems to be more significant to non-users are matters pertaining to interoperability of files and model library. For these, 59% (N=47) perceived that there could be a possibility of an interoperability issue between BIM and the current software that they are using, possibly due to the fact that BIM and CAD are two totally different systems. In addition to this, the requirement by local councils and authorities for *building plan* e-submission to be in DWG (AutoCAD) format (DBKL, 2013, MPKK, 2015) would encouraged firms to retain CAD rather than move to BIM. Even though there are BIM software that can convert BIM propriety and non-propriety file formats such as RVT, IFC, and COBie into DWG format, there could be issues with object enablers and loss of information when exchanging platforms. Apart from that, about half of the non-BIM users (53%, N=44) in Malaysia were concerned about the availability of sufficient BIM-compatible model libraries. As having a sufficient model-library was generally deemed to be vital especially when working with CAD, it is not surprising that users now would expect the same with BIM.



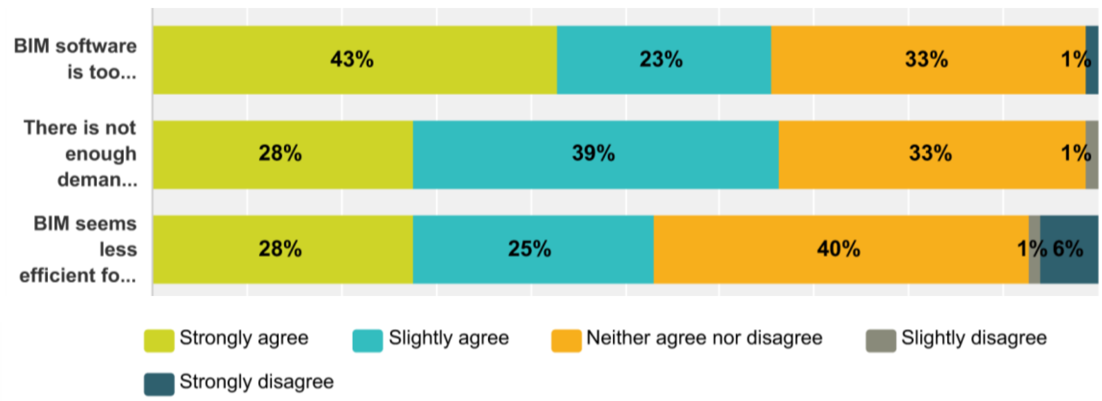
	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
It is too difficult to use BIM software	14% 12	38% 32	38% 32	7% 6	2% 2	84	3.55
There is a lack of BIM skilled staff	49% 41	29% 24	18% 15	2% 2	2% 2	84	4.19
The training available for BIM is insufficient	29% 24	35% 29	29% 24	6% 5	2% 2	84	3.81

	Minimum	Maximum	Median	Mean	Standard Deviation
It is too difficult to use BIM software	1.00	5.00	2.00	2.45	0.91
There is a lack of BIM skilled staff	1.00	5.00	2.00	1.81	0.97
The training available for BIM is insufficient	1.00	5.00	2.00	2.19	0.99

The above sub-questions 6-8 explore BIM in relation to users' skills and training. According to BIM researchers, one of the barriers of adopting BIM is that many users find it difficult to operate BIM as it requires a steep learning curve, particularly at the beginning (Woo, 2007, Tse et al., 2005, Hetherington et al., 2010, Eastman et al., 2008, Sharag-Eldin and Nawari, 2010, Kaner et al., 2008, Weber and Hedges, 2008, Aly, 2014, Cunningham et al., 2015). This is reflected in this survey when 52% (N=44) of non-user architect firms perceived that it was difficult to use BIM. However, there is some light to this as from those who *agree*, only 14% (N=12) claimed to *strongly* *agree* to this notion, indicating that the majority could have perceived that it may be 'slightly difficult' to use BIM rather than 'significantly difficult'.

The responses to the next sub-question is very important as it received the highest percentage of 'agree'. A whopping 78% (N=65) of the architecture firms perceived that there is a lack of BIM skilled staff or expertise to actually run BIM in the office. And from the 78%, 49% 'strongly agreed' to this, signifying that it could be the main reason as to why these firms have not been adopting BIM. What is remarkable is that this was the main obstacle to adopting BIM in other parts of the world as well, which includes New Zealand (Masterspec, 2013), United Kingdom (NBS, 2014) (Eadie et al., 2013a), Ireland (Cunningham et al., 2015), Qatar (Ahmed et al., 2014), Hong Kong (Chan, 2014), India (Kumar and Mukherjee, 2009), Singapore (Teo et al., 2015), as well as among the contractors in the United States (Ku and Taiebat, 2011). A survey done by Liu et al. (2015a) on the AEC industry in Australia and China also revealed that the shortages of skilled personnel is also one of the top barriers to BIM adoption in both countries. The answers for this question as provided by the architecture firms in Malaysia are paramount such that it responds directly to one of the hypothesis of this research and the justification to this notion will be further elaborated later on in this thesis.

Apart from the lack of expertise or skilled staff, the limited availability of training is also a serious impediment to BIM adoption, as claimed by 64% (N=53) of the non-BIM user in architecture firms in Malaysia. In comparison, the lack of comprehensive training on BIM is actually also a hindrance for BIM adoption in countries such as South Korea (McGraw-Hill, 2012b) and China (Consulting, 2014, S.Z.E.D.A, 2013). In fact, there have been many studies around the world that also concurred to the lack of available BIM training as being one of the biggest barriers if not the biggest itself in BIM adoption (Eadie et al., 2014, Enegbuma and Ali, 2011, Enshassi et al., 2016, Becerik-Gerber et al., 2011a, Liu et al., 2015a, Mahdjoubi et al., 2015, Kozlovská et al., 2013, Hosseini et al., Chan, 2014). It is noteworthy that a report by New Straits Times (2007a) have also shown that many Malaysian firms in general do not prioritize digital technology skills development. Both sub-questions 7-8 can be related to each other and the responses to both questions are equally crucial, as now we know that not only is there a real shortage of BIM skilled staff, but there also aren't many resources that can provide adequate training for them to attend, thus aggravating the shortage of skilled BIM staff. The correlation between these two sub-questions brings us back to the research hypothesis which will be further elaborated in the following chapters.



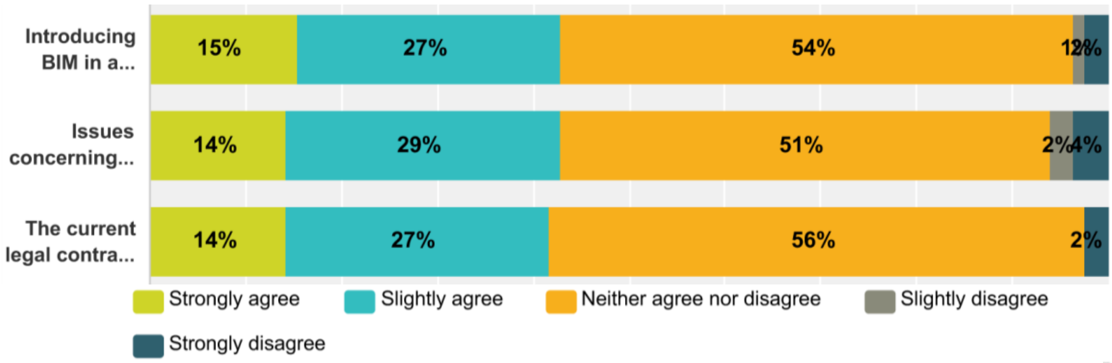
	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
BIM software is too expensive	43% 36	23% 19	33% 28	0% 0	1% 1	84	4.06
There is not enough demand from clients and/or other project members	28% 23	39% 32	33% 27	1% 1	0% 0	83	3.93
BIM seems less efficient for smaller projects	28% 23	25% 21	40% 33	1% 1	6% 5	83	3.67

	Minimum	Maximum	Median	Mean	Standard Deviation
BIM software is too expensive	1.00	5.00	2.00	1.94	0.93
There is not enough demand from clients and/or other project members	1.00	4.00	2.00	2.07	0.80
BIM seems less efficient for smaller projects	1.00	5.00	2.00	2.33	1.08

Subsequently, sub-questions 9-11 validate that cost is a huge concern to users. Despite the efforts by many bodies around the world, both non-government and government organizations, to promote BIM based on their benefits and positive ROIs, the industry has yet to be convinced of it. This seems to be the case in Malaysia where the second biggest hindrance to BIM adoption is the cost of adopting the system. For this, 43% (N=36) of the non-BIM users in architecture firms strongly agreed, while another 23% (N=19) agreed that BIM is too expensive for them. The situation is the same in many other countries for example, it is also perceived as the second biggest impediment to BIM adoption in North America (McGraw-Hill, 2012a), Korea (McGraw-Hill, 2012b), and Germany (Both, 2012); it is actually the biggest barrier to contractors in the United Kingdom (Gledson et al., 2012). Accordingly, many literatures have acknowledged the high cost of BIM software as the major barrier for its adoption, both for start-up and also subsequent costs such as training, and software and hardware updates (Hetherington et al., 2010, Liu et al., 2010, Crotty, 2013, Liu et al., 2015a, Cunningham et al., 2015, Kim et al., 2016). In addition to this, the relatively weak currency of a developing country like Malaysia as opposed to developed countries, where most of BIM software originates, makes the situation even worse. However, what may have influenced such response from the architecture firms in Malaysia is actually the way the industries in Malaysia generally react to any newly introduced technology. According to Sulaiman Mahbob (2015), the chairman of the Malaysian Institute of Economic Research, the industries in Malaysia have often been very reluctant to quickly invest in new technologies. Studies by Mahalingam (2010), who examined into the application of green technology in Malaysia, and Jakobsen (2014), who wrote on the entrepreneurship development in Malaysia, both concluded that the industries' stakeholders in Malaysia are generally very reluctant to invest on new technologies that is deemed to be costly and may have yet to show explicit evidence on ROI.

The lack of demand from clients and other project teams for BIM implementation in their projects is the third major reason for not adopting BIM. With this, 28% (N=23) strongly agree while 39% (N=32) agree, which amounts to 67% (N=55) of the non-BIM user architecture firms in Malaysia to perceive as mentioned above. This correlated to the cost of implementing BIM as previously stated where clients in Malaysia tend to be very reluctant and extra careful in taking up new technologies, including BIM. BIM is a system that needs participation from every individual from every layer in the project including the clients themselves; it also requires large investment for start-up and maintenance, as well as operation. Everyone is waiting for everyone else to implement it first to somewhat give solid evidence of the clear benefits and ROIs; they will remain sceptical towards the technology until someone reveals those evidences. It would not be a good idea if only one party were to invest heavily towards BIM and later discover that not every other team member would follow suit leading to BIM not functioning as it should, resulting in a waste of money, time, and energy. This unfortunately has happened in Hong Kong, as reported by Chan (2014) through her survey such that more than 80% of the design firms had adopted BIM, but only 10% of their current projects were delivered with the use of BIM. This can be correlated to a previous survey done in Hong Kong by Tse et al. (2005) that revealed the main obstacle to BIM adoption was the lack of demand from clients. This experience in Hong Kong should be made an example by other countries that are pursuing for BIM adoption in their AEC industry, including Malaysia.

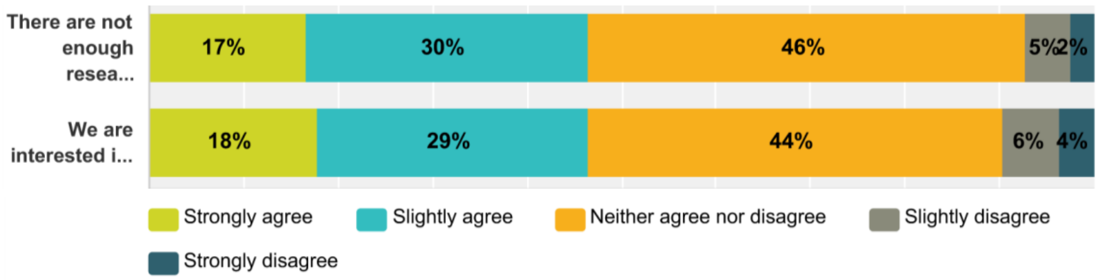
The response to the next sub-question is as anticipated when slightly more than half, 53% (N=44) agreed that BIM seems less efficient for smaller projects as compared to bigger ones. This outcome is shared by some studies including those of Penttilä (2007), Eastman et al. (2008), Liu et al. (2010), Hetherington et al. (2010), Kassem et al. (2012), Arayici et al. (2012b), Leeuwis (2012), Miller et al. (2013), Monozam et al. (2016), and Dainty et al. (2017). According to the studies, there are several reasons behind this. Firstly, small projects in general such as a house or a school block, are often looked at as having less complexity, with straightforward structures and detailing, and do not involve many parties. These projects may be too simple to see the benefits of BIM. Secondly, smaller projects would often mean smaller project costs which then reflect upon the consultation fees paid to the team members, thus results in lower profit margin. It is not surprising if these firms would not have the financial means or be willing to invest heavily on a relatively new yet expensive technology that may not even be used to its full potential, let alone guarantee any ROI. Thirdly, it is mostly the smaller firms that usually take up on small projects, which are consistent with their capabilities, both financially and labour. The reality of having limited man power would mean that it would not be very easy for them to allow their staff to attend training on a new technology. The fact that BIM has a steep learning curve could only mean that training would require longer full-time sessions, hence taking the staff away from his or her duty at work for long periods of time.



	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree	Strongly disagree (5)	Total	Weighted Average
Introducing BIM in a project will result in unclear roles/change in roles of participants	15% 13	27% 23	54% 45	1% 1	2% 2	84	3.52
Issues concerning ownership and maintenance of the BIM model are still unresolved	14% 12	29% 24	51% 43	2% 2	4% 3	84	3.48
The current legal contracts do not adequately address BIM issues	14% 12	27% 23	56% 47	0% 0	2% 2	84	3.51

	Minimum	Maximum	Median	Mean	Standard Deviation
Introducing BIM in a project will result in unclear roles/change in roles of participants	1.00	5.00	3.00	2.48	0.85
Issues concerning ownership and maintenance of the BIM model are still unresolved	1.00	5.00	3.00	2.52	0.89
The current legal contracts do not adequately address BIM issues	1.00	5.00	3.00	2.49	0.82

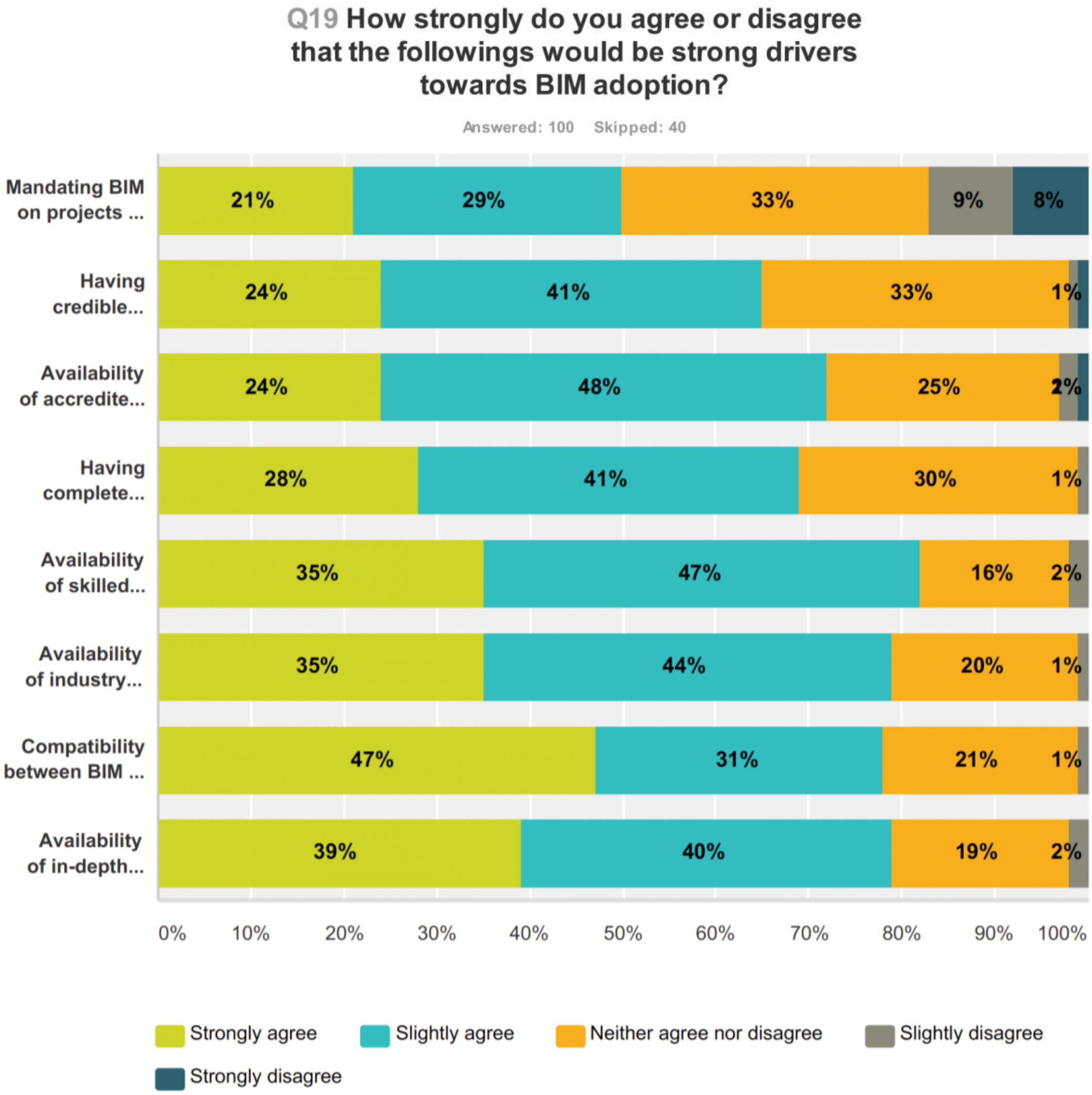
The next sub-questions 12-14 asked non-BIM users in architecture firms on BIM pertaining to roles, ownership, and legal matters. The response to all three (3) sub-questions are not much different, where slightly less than 50% agree to the questions while slightly more than 50% does not know the answers, hence giving neutral feedbacks. However, a small amount, less than 3% disagreed to any of the statements in all of the above sub-questions. This includes the following perceptions: 1) introduction of BIM in a project will result in unclear change of roles of participants, 2) there are unresolved issues concerning ownership and maintenance of BIM models, 3) current legal contracts do not adequately address BIM issues. What is interesting here is that although 83% (N= 91) of the whole survey sample reported as being fully aware of BIM and what it is about, only slightly half of them are acknowledging the above problems, while more than half are still keeping an open mind towards these issues, neither agreeing nor disagreeing. It is a positive sign that although all of the three perceived issues stated above are relatively established, not everyone is agreeing to it. This is contrary in the UK, Canada, Finland and New Zealand, where more than 80% of users and non-users of BIM claimed that BIM necessitates changes in their roles, workflow, practices, and procedures (NBS et al., 2014).



	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
There are not enough research on BIM to support its usage	17% 14	30% 25	46% 39	5% 4	2% 2	84	3.54
We are interested in using BIM, but we don't know where to start	18% 15	29% 24	44% 37	6% 5	4% 3	84	3.51

	Minimum	Maximum	Median	Mean	Standard Deviation
There are not enough research on BIM to support its usage	1.00	5.00	3.00	2.46	0.91
We are interested in using BIM, but we don't know where to start	1.00	5.00	3.00	2.49	0.97

Sub-questions 15-16 received similar responses as sub-questions 12-14. Nearly half of the non-BIM user architecture firms agreed that there is a lack in BIM research while nearly another half chose to remain neutral. This concurs with lots of literature around the world that acknowledged the lack of research in BIM (Becerik-Gerber and Kensek, 2009, Gu and London, 2010, Wong and Yang, 2010, Kim, 2011, Aram et al., 2013, Samuelson and Björk, 2013, Antón and Díaz, 2014, Johansson et al., 2014, Dainty et al., 2017). The answer to the last sub-question of Question 18 revealed that nearly half of the non-BIM user firms are interested in adopting BIM but do not know where to start. This is in accordance to the lack of research as potential users in Malaysia may have heard the hype surrounding BIM and be interested in adopting it, but they could not really find further information from established studies that could convince them to invest in the technology and guide them on implementing the technology.



	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
Mandating BIM on projects by Government	21% 21	29% 29	33% 33	9% 9	8% 8	100	3.46
Having credible accreditation process	24% 24	41% 41	33% 33	1% 1	1% 1	100	3.86
Availability of accredited trainers	24% 24	48% 48	25% 25	2% 2	1% 1	100	3.92
Having complete understanding and buy-in from all trades involved	28% 28	41% 41	30% 30	1% 1	0% 0	100	3.96
Availability of skilled professionals	35% 35	47% 47	16% 16	2% 2	0% 0	100	4.15
Availability of industry Standards	35% 35	44% 44	20% 20	1% 1	0% 0	100	4.13
Compatibility between BIM and CAD software	47% 47	31% 31	21% 21	1% 1	0% 0	100	4.24
Availability of in-depth research that covers all aspects of BIM	39% 39	40% 40	19% 19	2% 2	0% 0	100	4.16

Basic Statistics					
	Minimum	Maximum	Median	Mean	Standard Deviation
Mandating BIM on projects by Government	1.00	5.00	2.50	2.54	1.15
Having credible accreditation process	1.00	5.00	2.00	2.14	0.82
Availability of accredited trainers	1.00	5.00	2.00	2.08	0.81
Having complete understanding and buy-in from all trades involved	1.00	4.00	2.00	2.04	0.79
Availability of skilled professionals	1.00	4.00	2.00	1.85	0.75
Availability of industry Standards	1.00	4.00	2.00	1.87	0.76
Compatibility between BIM and CAD software	1.00	4.00	2.00	1.76	0.81
Availability of in-depth research that covers all aspects of BIM	1.00	4.00	2.00	1.84	0.80

Drivers of BIM (Q19). This question was meant to be answered by both BIM-users and non-BIM users for their perception of BIM. For the architecture firms that have already adopted BIM, any efforts to drive the Malaysian AEC industry further towards full BIM implementation would help them to achieve a more convenient, effective, holistic and successful use of BIM possibly for all future projects, ultimately allowing them to fully replace CAD as the current technology as to assist in project deliverables. On the other hand, as for non-BIM users, these drivers would help to assure them that strong grounds are in fact being laid for BIM to replace CAD, which will encourage them to take the necessary steps towards BIM adoption sooner than later. There have been quite a number of studies written about the drivers of BIM adoption from its early inception during the mid-2000s and have remained a relevant topic up until today, with a stretch of more than a decade that appeared to be due to one possible reason, i.e. the relatively slow adoption of BIM (Eastman et al., 2008, Succar, 2009, Becerik-Gerber and Rice, 2010, Russell et al., 2013, NBS, 2015, Davies et al., 2015, Ahuja et al., 2016, Monozam et al., 2016, Kim et al., 2016). Given the fact that many are aware of the benefits of BIM and that it is inevitably going to replace CAD, it is perplexing that the adoption rate of BIM has been relatively slow.

Based on the figure, out of all eight (8) listed drivers for the adoption of BIM, the top driver perceived by the architecture industry in Malaysia is the interoperability quality of BIM. With a rating rate of 4.24 out of 5, 78% (N=78) of the architecture firms agreed that BIM must be able to interoperate with all other CAD or modelling software. This was similar in North America during BIM's early years of gaining ground when the McGraw-Hill (2007) survey reported that "improved interoperability" of BIM was seen as one of the biggest factors influencing the use of BIM in that continent. This remained so for many more years to come as another survey by McGraw-Hill (2012a) in 2012 revealed that improved interoperability of BIM was still on the top of the list of BIM adoption drivers even though North America at that time was already leading globally in terms of BIM adoption rate. Another survey, which was done recently by Eadie et al. (2015) for UK's AEC industry revealed that software interoperability was still ranked within the top five of concerns of BIM usage; the research suggested for more effective steps to be taken to increase BIM usage. Apart from the above nation-wide surveys, other studies by Tse et al. (2005), Liu et al. (2010), Steel et al. (2012), Arayici et al. (2012a), Becerik-Gerber et al. (2012), Volk et al. (2014), Chan (2014), and Yalcinkaya and Singh (2015) also suggested the same. The fact that improving interoperability has been a long-term issue of BIM in many developed countries that had started adopting BIM much earlier than Malaysia, it is important that the AEC industry in Malaysia take note of this in its quest to champion BIM.

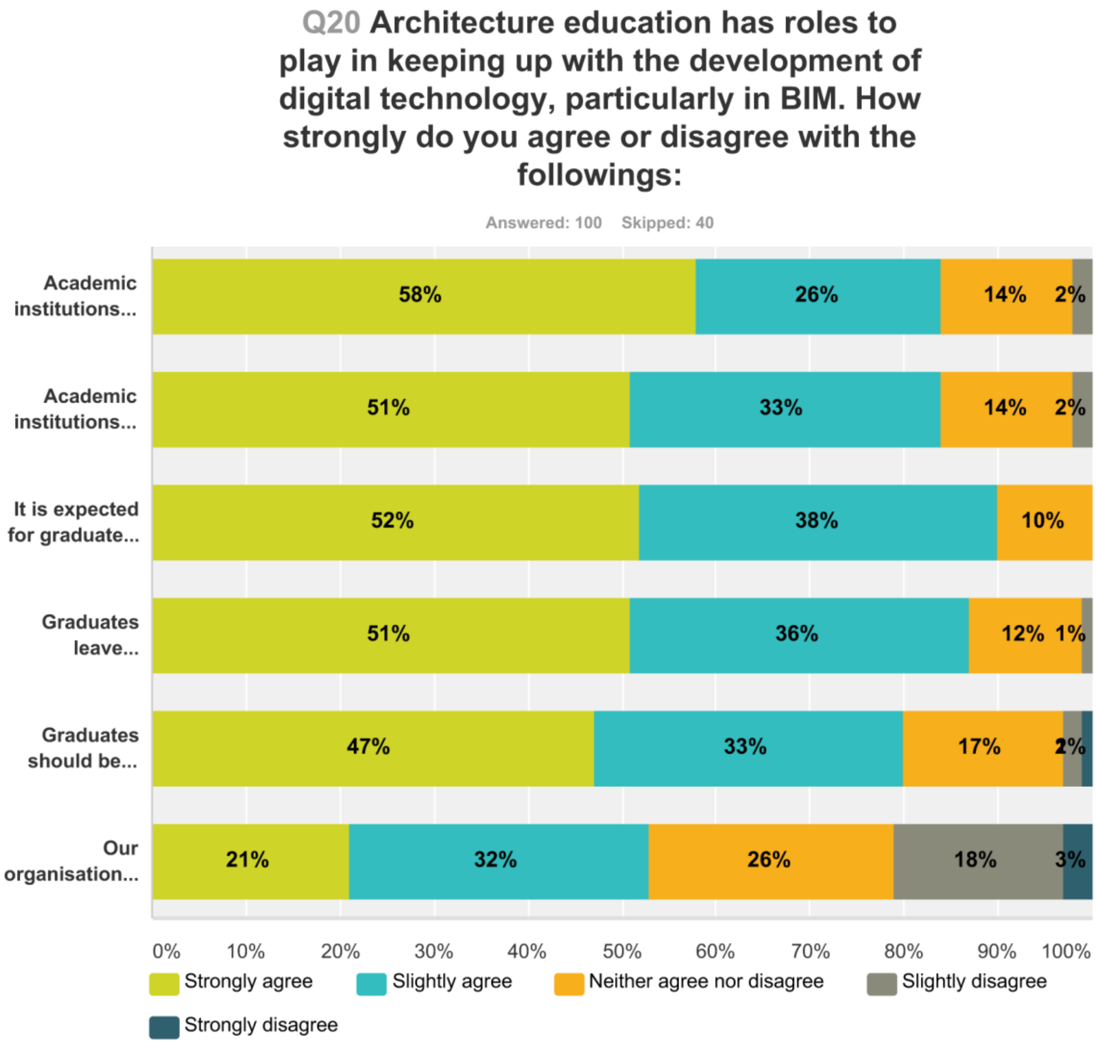
With a rating of 4.16, 79% (N=79) of the architecture firms agreed that the availability of an in-depth research that covers all aspects of BIM is very important, making it the second most important aspect that will drive towards BIM implementation in the country. This is in agreement with many literatures around the world that acknowledged the lack of research in BIM, which could have otherwise helped both users and potential users to learn, understand, compare, and have confidence towards the technology (Becerik-Gerber and Kensek, 2009, Gu and London, 2010, Wong and Yang, 2010, Kim, 2011, Aram et al., 2013, Samuelson and Björk, 2013, Antón and Díaz, 2014, Johansson et al., 2014, Dainty et al., 2017). A well-informed industry will be better equipped to adopt any new technology. With the need of in-depth research being the second most demanded driver for BIM adoption, it should be a wakeup call for all institutions, specifically the HEIs, to take up the challenge.

The third biggest driver is the availability of skilled workers, with a rating of 4.15. This relates very closely to the previous Question 18 where it was seen as the biggest barrier towards BIM adoption by non-BIM users. For this sub-question, 82% (N=82) of the architecture firms agreed that having skilled staff is a very important driver of BIM partly due to BIM being a new technology that is different from CAD and requires a new set of skills that is not very easy to acquire due to its steep learning curve. To have enough skilled man power to fill in the demand is equally important to having the technology itself, as the full benefit of BIM will only be reaped if there are people to operate it to its full potential. The importance of having enough BIM-skilled workers as one of the top drivers for BIM adoption is also echoed by other studies and surveys from around the world including Singapore (Teo et al., 2015), Korea (Won et al., 2013); the Middle Eastern countries of United Arab Emirates (UAE), Saudi Arabia, Qatar, Oman, Bahrain, Kuwait, and Jordan (McGraw-Hill, 2011); and India (Ahuja et al., 2016). As with the previous sub-question, HEIs should take serious note of this outcome from the industry as previously stated, supplying the workforce with BIM competent and skilled graduates will help turn the tables tremendously.

However, what was not expected from Q19 was that mandating BIM on government projects was considered by the architecture firms in Malaysia to be the least effective driver of BIM, in contrast to many other countries around the world such as in the UK (NBS et al., 2014), Finland (Finne et al., 2013), United Arab Emirates (UAE), Saudi Arabia, Qatar, Oman, Bahrain, Kuwait, Jordan (McGraw-Hill, 2011), China, and Australia (Liu et al., 2015b), where government mandating of BIM is considered a very important driver of BIM. In response, only 50% (N=50) of the architecture firms in Malaysia agreed for the government to mandate BIM as a way to drive BIM adoption forwards. Fundamentally, national leadership and coordination are mainly driven by government and this is expected in the case of BIM as well (Won et al., 2013) (Smith, 2014b). It is crucial for a government to provide strong support if any complex technology systems is to be successfully developed and deployed (David and Steinmueller, 1994). A probable reason as to why only half of the architecture firms agree with BIM mandating was because it was not a normal practice by the government of Malaysia to mandate certain types of new technology in a rush, as it did not happen previously with CAD. For CAD, the federal Government did not enact any regulation to make CAD usage compulsory for any projects, but instead allowed the local authorities to require submitted drawings to be drafted in CAD format. Even as of today, manually produced drawings can still be used for government projects, only that local authorities require it to be scanned and submitted in PDF format (MBAS, 2016, MPKK, 2015).

5.7.5 SEGMENT 5 – HIGHER EDUCATION INSTITUTIONS LEADING THE BIM CAUSE

Skills and training



	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
Academic institutions should produce more research on BIM.	58% 58	26% 26	14% 14	2% 2	0% 0	100	4.40
Academic institutions should lead the way in adopting and promoting BIM.	51% 51	33% 33	14% 14	2% 2	0% 0	100	4.33
It is expected for graduates to have adequate IT skills deemed by the organisation/company.	52% 52	38% 38	10% 10	0% 0	0% 0	100	4.42
Graduates leave universities with the right IT skills needed by the workforce.	51% 51	36% 36	12% 12	1% 1	0% 0	100	4.37
Graduates should be taught on the conceptual knowledge and understanding of BIM rather than the proficient skills with BIM software.	47% 47	33% 33	17% 17	2% 2	1% 1	100	4.23
Our organisation/company prefers staff to be trained in-house for IT skills rather than relying on skills taught during tertiary education.	21% 21	32% 32	26% 26	18% 18	3% 3	100	3.50

Basic Statistics	Minimum	Maximum	Median	Mean	Standard Deviation
Academic institutions should produce more research on BIM.	1.00	4.00	1.00	1.60	0.80
Academic institutions should lead the way in adopting and promoting BIM.	1.00	4.00	1.00	1.67	0.79
It is expected for graduates to have adequate IT skills deemed by the organisation/company.	1.00	3.00	1.00	1.58	0.67
Graduates leave universities with the right IT skills needed by the workforce.	1.00	4.00	1.00	1.63	0.73
Graduates should be taught on the conceptual knowledge and understanding of BIM rather than the proficient skills with BIM software.	1.00	5.00	2.00	1.77	0.87
Our organisation/company prefers staff to be trained in-house for IT skills rather than relying on skills taught during tertiary education.	1.00	5.00	2.00	2.50	1.10

Skills and Training (Q20). There is only one question in Segment 5, which its findings will answer the fourth objective of this research. The objective is slightly different to previous questions in the sense that it touches on the industry's view and practices towards the academia-industry relationship, and therefore the question was constructed on a different segment of its own. All the previous questions serve as a base for this research whereas this question on the other hand becomes the bridge to the next phase of the research, which is the final phase. The response to this question revealed how the architecture industry discerns the role of HEIs in the development of BIM in Malaysia. It is interesting that all but one of the sub-questions in this question received very high ratings of more than 4 out of 5 with a very low standard deviation of less than 1, suggesting a more uniform conjecture in supporting the hypothesis. Based on the table above, all but one sub-question received around 50% or more of strongly agree, around 33%-38% of agree, 10%-17% of neutral, and less than 3% of disagree and strongly disagree.

For the first sub-question, nearly 58% (N=58) strongly agreed and another 26% (N=26) agreed that HEI should carry out more research on BIM. In relation to the previous question (Q19), where in-depth research was considered the second most important driver of BIM adoption, the respond to this sub-question further strengthens that research is regarded very highly and is in high demand by the industry. As stated earlier, in-depth research could function as a reference and guidance to the industry to learn, understand, make comparisons, and aid them in producing a coherent strategy and planning to not just adopt BIM, but make it a tool that will actually increase their competitiveness, streamline their operations, and finally see a positive return of investment (ROI) for short and long terms.

The response to the second sub-question clearly helps in answering the research hypothesis that suggests HEIs do have a big role to play in assisting the development of BIM in the country. In fact, the responses towards this statement, which received a rating of 4.33 out of 5, has 84% (N=84) of agreed responses, revealing that not only do HEIs have a big role to play, but should in fact be in the lead in championing BIM implementation. As mentioned earlier in the thesis, many governments of advanced countries like Japan, the United States and Western European countries have launched initiatives back in the 1970s to link and foster cooperation between HEIs and the industry in their effort to escalate the rate of innovation and technology transfer and adoption (Mowery and Sampat, 2006, Cohen et al., 2002, Spencer, 2001, Blumenthal, 1994, Lowden et al., 2011). Nowadays, with research, training and related activities often involving all the three parties i.e., the industry, government agencies, and HEIs, thereby HEIs have not only taken on the role to become the provider of scientific knowledge for industrial innovation (Gunasekara, 2006, Rosenberg et al., 1995, Mueller and Cantner, 2000, Yusuf and Nabeshima, 2007, Blumenthal, 1994), but they have also broaden their scope to contribute directly in the development and transferring of new discoveries into new innovative technology (Yusuf and Nabeshima, 2007, Chesbrough, 2003, Veugelers and Del Rey, 2014).

The third statement, which enquired the architecture firms' expectation of graduates' IT skills prior to joining the industry, receives a staggering rating of 4.42 out of 5, making it the highest expectation by the industry towards HEIs. With 90% (N=90) of the architecture firms agreeing that graduates entering the workforce must be equipped with sufficient IT skills, there is no denying that HEIs must take note of the very high expectation the industry has on them. Even though it may be true that HEIs have traditionally been supplying the industry with capable workforce (Monck and McLintock, 1988, Löfsten and Lindelöf, 2002, Pruitt and Epping-Jordan, 2005, Lowden et al., 2011, UKCES, 2009), graduates are far from being the finished product (Schank, 2004) and the levels of applied skills equipped to these graduates are considered by current employers as just 'adequate' (Casner-Lotto and Barrington, 2006) which needs to be further developed, polished, and tested on real world practice (Schank, 2004). It is due to this that firms in most developed countries take on-the-job training much more seriously with more than 60% of their firms engaged in training actively throughout the year (Badescu and Loi, 2010, EuroStat, 2010). However, the situation in Malaysia is in contrast to these countries, as studies by Gilbert and Sia (2001), Chew (2005), Riege (2005), and Hooi (2010) revealed that firms and organizations place little emphasis on training whereby there is pre-existing conditions of inadequate training for familiarization of IT systems and processes. The responses by the architecture firms on this matter brings the issue further by firmly suggesting the industry's view that it is the responsibility of the HEIs rather than the industry to provide sufficient IT training into the workforce.

The third biggest expectation by the industry with a rating of 4.37 out of 5 and 87% (N=87) agreeing, is that not only HEIs must equip graduates with sufficient IT skills, but it also has to supply the right skill set needed by the workforce. The survey responses from this sub-question conforms the argument that becomes the foundation of the theoretical framework of this research. As stated earlier in Chapter 2, for a country that has its industry often relying on the government to assist them in the introduction of new technologies, it is crucial for the government, through its public HEIs to formulate the right method with the right curriculum so that graduates would be equipped with the right set of skills that will work best in compliance with the demands and requirement of the local industry. Without proper research and planning of what should be taught and instilled in students, there is the possibility of mismatching the skills acquired at the university and the skills needed by the industry (Mason et al., 2009).

Moving deeper into BIM education, 80% (N=80) of the architecture firms also posit that graduates should be taught on the conceptual knowledge and understanding of BIM rather than just the proficient skills with BIM software. On the other hand, only 3% (N=3) disagree to this notion, while the others chose to be neutral. As with CAD about a quarter decade ago, the current users in both the industry and education also finds BIM today to have very steep learning curves (Cheng, 2006, Weber and Hedges, 2008), with the exception that CAD was only a tool for drafting or drawing production (McLoughlin, 1989, Navona et al., 1994, Shen et al., 2007). BIM meanwhile is a different league altogether as it is a process or a way of thinking and action; a huge difference to CAD that results to a pedagogical shift. BIM is also about real-time collaboration between all design and construction team players; architects, engineers, surveyors, planners, specialists, contractors, project managers, and clients, that work together not just on the same platform but also on the same model; something that many architecture students would not have any experience with during studies. Therefore, it is not just about teaching the technical skills of using the software, but more about the significant changes of process, culture, and methods of deliverables that are intertwined with BIM that need to be taught to students. This is the reason why the industry prefers graduates with deep conceptual knowledge of BIM rather than those only with procedural knowledge of the software. HEIs must therefore reformulate their syllabus and curriculum with new methods that work towards achieving the above demand by the industry.

The response to the last statement from this question further strengthens the notion that the industry in Malaysia is not so keen on taking full responsibility to train their staff in-house for IT skills (New Straits Times, 2007a), but rather prefer that responsibility be taken up by the HEIs. While other statements in the question receives approximately 50% of responses or more for strongly agree, only 21% (N=21) of the architecture firms strongly agree for this particular statement. It also receives the highest disapproval as 21% (N=21) disagree and 26% (N=26) remain neutral.

5.8 SUMMARY AND CONCLUSION

The following table summarizes the whole analysis above on how these arguments will affect the syllabus for producing architecture graduates that are capable of filling in for the new roles and working skills required by BIM technology.

Table 5.2: Summary of findings for Survey A

Segment 1: Demographics	
Age	Even though there were less respondents from both ends of the age band, it was fairly distributed among the three (3) age bands in the middle, which ranges from age 25 to 54.

Size of firms	There were representatives from firms of all sizes. The ratio of the number of respondents to firm sizes are relative to the average ratio of firm sizes in most architecture industry (Baker et al., 2012) (Baker et al., 2016).
Project value	All the firms that responded are active firms with active projects valued from low (RM100,000) to high (>RM100 million) costs.
	Overall, the survey was fairly well distributed covering both ends of the spectrum by demographics means, therefore the findings should represent a fair reflection of the industry as a whole.
Segment 2: Applied Computer Technology	
Software	AutoCAD by Autodesk was the most popular and widely used software in architecture. It is the main software used by more than 80% of the firms, setting a gold standard in the industry. This is not surprising at all as according to Wurster et al. (2014) and Smirnov (2016), AutoCAD is still the market leader in the global AEC industry.
	The conventional method of deliverables by using traditional drafting software such as AutoCAD is still the industry standard in practice.
	Even though only 7.7% of the firms had used BIM software as their main software, another 31% of the firms also reported to be using BIM software, albeit as a secondary software. Considering that BIM is still a relatively new technology, it’s a positive sign that up to a third of the firms in the industry are

	experimenting with BIM software, though this may not necessarily mean having implemented the system as a whole.
Current practice	The industry still works on 2D drawings created by using CAD models/software. It is worth taking note that all electronic submission of drawings for planning and building approval by the city council must be in AutoCAD (.dwg) format (DBKL, 2013).
	Less than half of the firms use traditional CAD software to create 3D visualization. Based on Q8, most firms prefer to use 3D modelling software and BIM software for non-drafting works, including visualization. This corresponds to studies that state that BIM is often used for 3D visualisation (Becerik-Gerber et al., 2011a) (Pavelko, 2010) (Kim, 2011).
	Very few firms generate schedules, bills of quantities, simulations analysis, and clash detection from CAD models as conventional CAD software do not have these capabilities unless with the assistance of third party software. BIM on the other hand, come with these capabilities.
Drivers for new technology	For most firms, acquiring new software/technology is done on an as-needed basis; in this case, the needs are defined by project teams and clients. This shows that almost everyone is ready to adopt any new technology if needed, only that nobody dares to make the first move.
	Acquiring new software/technology also depends on the availability of graduates with the right skillset, who fills in the

	workforce from time to time. This signifies that firms are also reluctant to invest in any new software if work-ready skilled employees are hard to come by.
	The campaign for adopting new software/technology by industrial organizations such as *Pertubuhan Arkitek Malaysia* (Malaysian Institute of Architects) do not have very much influence towards the industry.
Segment 3: BIM in Practice	
BIM awareness	The industry is fully aware of BIM and its qualities. Therefore, the goal should no longer be about 'introducing', but rather about 'convincing', 'justifying' and 'supporting' BIM usage.
BIM adoption	Only one fifth of respondents within the industry were convinced of BIM and have adopted the technology, which is relatively low compared to other developed nations such as the US and Western Europe.
	Most of the BIM users have only used it less than three (3) years. It is therefore difficult to expect any full cycle report on the usage of the technology.
	However, all of the users claimed that they will keep on using the technology in the future, signifying positive experience.
	It is positive that half of the non-users are convinced with BIM technology and will adopt the technology in the future. Only a mere 4% have decided not to adopt BIM.
Views on BIM	Only a fifth of the firms posit that BIM is just about software rather than a new system or technology, indicating that

	majority are aware that BIM is system/technology rather than just a software.
	The majority in the industry agree that BIM: - is more than just producing 2D drawing /3D models/ visualisation - is about real-time collaboration between team players - is about project information - is about project management - is a platform for producing/testing sustainable design
	BIM users in Malaysia are still uncertain on the issue of BIM being a hindrance towards creativity.
	However, the majority in the industry have claimed to have limited knowledge on BIM.
BIM Experience	Attributes of BIM that the majority of architecture firms (>70%) have experienced: - Improved visualisation. - Increased coordination of construction documents. - Improved productivity. - Increased speed of delivery. - Brought cost efficiencies. - Required changes in our workflow, practices and procedures. Please take note that the majority of the others (>80%) that did not agree were uncertain as they chose neither agree nor disagree rather than disagree.

	Attributes of BIM that many of the architecture firms (50%-70%) have experienced: - Improved site logistics. - Helped produced specifications. - Required changes in roles and work scope. Please take note that the majority of the others (>80%) that did not agree were uncertain as they chose neither agree nor disagree rather than disagree (?).
	Attributes of BIM that many (>40%) were still uncertain off: - Increased our profitability & return of investment (ROI). - Helped us in producing bills of quantities.
	Approximately half of the architecture firms have a BIM unit/division that handles/supports all BIM matters, while the other half were not quite certain. There is a possibility that these firms might have a number of personnel that takes care of BIM matters, but not enough to formally form a unit/division.
	Awareness of BIM among clients has grown as nearly half of the firms claimed that clients have increasingly insisted on the use of BIM.
	It is a very encouraging sign for the development of BIM in the country when more than two-thirds of the BIM-user architecture firms in the industry claimed that they have used BIM successfully.
	Only a fifth of the BIM-user architecture firms prefer CAD to BIM.

Segment 4: General View Towards BIM	
Barriers of BIM	
Technological dimension of BIM	Approximately half of the non-BIM users in the industry are still unclear of the attributes of BIM. These firms chose *neither agree nor disagree* rather than *disagree* when queried on their perception towards the technological dimension of BIM.
	Two technological aspects of BIM that was perceived as a barrier by more than half of the respondents were: - Interoperability concerns between BIM and CAD applications. Shifting from one technology to another involves a transition period where technology usage could overlap. - BIM-compatible content/libraries was perceived to be insufficient. Most practices took years of effort to build their own CAD libraries. The thought of going through the same process all over again with BIM could hinder the intention to adopt BIM.
Human resources	The biggest perceived barrier to BIM adoption by the industry concerns the lack of availability of employees with BIM skills. This relates to the research hypothesis that HEIs have a big role to play in the development of BIM by means of supplying the local architecture industry with BIM skilled workforce.

	Another concern that ranks in the top 5 is the lack of available training of BIM to the industry. The perceived lack of sufficient training for BIM within the industry strengthens the assertion that HEIs could well step up to fill in this void.
Cost and investment	The second biggest barrier relates to the low demand by clients and followed by the high cost of the software. Many of the CAD software in the market are not far off cheaper as well, but with the support from the government though policies and mandates, adequate research that rationalise the outcomes and ROIs, and skilled workforce supplied by HEIs, it certainly helps to justify in investing on the technology.
Legal matters pertaining to BIM	Surprisingly, legal matters such as ownership and maintenance of BIM models, legal contracts and changing roles of project team players are not a big concern to the local industry.
BIM research	Close to half of the non-users claimed that research on BIM is still insufficient, while the rest were uncertain of the adequacy of available research.
	Close to half of the non-users reiterated their interest in BIM, but there is a lack of research on BIM to support and guide its usage. Note that the rest were still uncertain, rather than disagreeing to these statements.
Drivers of BIM	
	All the top three ranked drivers of BIM adoption perceived by the industry are interrelated to tertiary education and shows the

	high hopes the industry has towards HEIs. Therefore, HEIs must step up now and play an active role in supporting these drivers.
	The top driver for BIM adoption as perceived by the architecture industry in Malaysia concerns the interoperability quality of BIM, as in many other countries. It is important for the HEIs to address this issue when developing BIM curriculum for their architecture programme.
	The availability of in-depth research on BIM is perceived to be the second most important driver for BIM adoption. This coheres to earlier perception that insufficient research is a barrier for BIM adoption.
	Also, corresponding to the lack of availability of BIM skilled employees as being the biggest barrier to BIM adoption, the availability of skilled employees is ranked the third driver of BIM.
	Contradicting to many other countries, government mandate of BIM is the least favoured driver among others. It is possible that the industry in Malaysia prefer natural supply and support rather than enforcement approach.
Segment 5: Role of Academia	
	The response toward the role of academia in the development of BIM in the country were unyielding when all but one statement were agreed by more than four fifth of the architecture firms.

	The majority in the architecture industry posit that the HEIs should play a major role in leading the way to adopting and promoting BIM to the industry.
	Again, the industry strongly reiterated that HEIs should be producing more studies and research. In-depth studies and research will help enlighten the industry of the benefits and economics of implementing BIM, which would subsequently convince and lead them towards investing in the technology.
	The industry also expects graduates to not only possess sufficient IT skills (BIM in context), but also skills that are suited to the demands of the local industry. It is therefore very crucial for the HEIs to know the demands of the industry as they must tailor their programme curriculum to suit to those demands.
	Subsequently, the architecture firms were further asked of the direction for BIM education and training, to equip graduates with the conceptual knowledge and understanding of BIM, or merely the proficient skills of using the BIM software as it previously was with CAD teachings. The industry preferred the former.

CHAPTER 6: RESULTS AND KEY FINDINGS - PHASE II

6.1 INTRODUCTION

This chapter describes Survey B's questionnaire, the planning that was considered prior to undertaking the process, how it was conducted and analysed with more emphasis on the technical procedures and finally followed by the report of findings. The findings from this chapter is cross analysed with the findings from Survey A, which involved the architecture industry.

6.2 QUESTIONNAIRE OVERVIEW

A questionnaire survey was developed and distributed to all but one (1) accredited architecture school from the public HEIs in Malaysia at the point of survey. This brings to a total of six (6) universities (Rahman, 2010). As stated in previous chapters, the main purpose for this mixed method survey was to achieve objective 5, which is to find out how the HEIs respond to the architecture industry in terms of supplying a workforce with adequate digital knowledge, particularly in BIM. As previously stated, the survey for this phase was carried out only on public HEIs offering architecture programmes. The private HEIs were left out because in Malaysia it is common for private establishments to comply to the educational policies implemented in public HEIs. It is important to note that at time of survey it was a policy by the Malaysian Board of Architects; or *Lembaga Arkitek Malaysia* (LAM); to grant long-term accredited status (5 years basis) only to Part I and Part II architecture programmes offered by public HEIs, while graduates from private HEIs were assessed and accredited on a yearly basis. The board of architects; being a government arm; has formal collaboration with only the public HEIs as they work closely with the Council of Head Architecture Schools (COHAS); consisting all head of public architecture schools; for architecture education matters.

Therefore, the participating universities for this survey include Universiti Malaya (UM), Universiti Sains Malaysia (USM), Universiti Teknologi MARA (UiTM), Universiti Teknologi Malaysia (UTM), International Islamic University Malaysia (IIUM), and Universiti Putra Malaysia (UPM). The only public university that did not participate was Universiti Kebangsaan Malaysia (UKM). UKM was excluded based on two (2) reasons: 1) the researcher is a full-time employee of UKM who is responsible for all the computer related modules/matters in UKM architecture school, 2) At that time UKM was not fully accredited by LAM. These universities were approached and the survey questionnaires were electronically distributed through emails on 18 March 2013 and responds were received from all the universities between March 2013 to December 2013. In comparison to Survey A, the data collection phase for Survey B was longer as it involved open-ended questions and therefore was expected to take more time to complete than surveys with close-ended questions (Bryman, 2015).

6.3 SAMPLING APPROACH

As explained in the previous chapter, sampling was considered because surveying the whole population could be too overbearing and time consuming. However, for this survey, the targeted population were only the Malaysian architecture schools from government owned HEIs. The context of this survey is only within the boundary of

Malaysia, such that it is not entirely a huge country and has a population barely reaching 30 million people (CIDB, 2013, C.I.A, 2014). The total number of public architecture schools in the country was obtained from the LAM website, which showed that the total targeted population was only six (6) architecture schools and therefore was a feasible number to be reached upon.

According to Bryman (2012), there are certain expectations from researchers on the minimum size of samples, but there are very little agreement among researchers on the minimum size of samples. Bryman (2012) stated that what really matters is the research context and how the researcher justifies his or her sample size. This is true when Mason (2010) did a content analysis on the sample sizes used for qualitative based doctorate thesis in the United Kingdom and Ireland from 1716 to 2010 and found that it varies from 1 to 95. The study by Mason (2010) indicated that sample size was not the most detrimental factor in recognising research work and even a survey based on a very small sample size can produce conclusive results provided it is backed by a strong justification. In the context of this research, the total available sample size was only six (6) because there were only six (6) government-owned public HEIs offering accredited architecture programmes in the country.

In finding the right candidates as samples for this survey, the researcher selected academicians who not only were teaching CAD/BIM modules, but were also leading the CAD/BIM work base in their respective schools. This is to ensure that their opinions carry the opinions of the respective schools. For this, the researcher personally called every architecture school and requested the names of academicians who lead the CAD/BIM work-based at that time, and subsequently verified their names through their respective websites. Once the names conform to both sources, each personnel was then contacted via email to introduce the survey objective and provide the link to answer the survey questionnaire. The email approach saved cost in terms of human resources and related expenses, time, and also it can be controlled and monitored.

6.4 QUESTIONNAIRE DESIGN

While the questionnaire for Survey A used quantitative method and was largely adopted from the NBS (2012) and Masterspec (2012) national survey of the UK and New Zealand, the survey questionnaires for Survey B however used mixed method approach and were fully developed and constructed by the researcher. As discussed in Chapter 4, despite the fact that this research had in general showed characters of positivism, the lack of literature evidence in Malaysia on this subject matter; particularly BIM in relation to architecture education; forces the subsequent stages of the research to move towards exploring and understanding rather than just exclusively descripting and predicting. Therefore, this survey questionnaire was structured into two (2) parts; (1) a closed-ended set of questions that seek quantitative data, and (2) an open-ended set of questions that seek qualitative data. The first part has a close resemblance of Survey A, as it seeks to document user experiences, except that the data were from the HEIs instead of the industry. However, the second part seeks for elaborations of thoughts and supplying of general information on their respective research works, in which response variables could range vastly into unknown territories and therefore should not be restraint into a certain range of answers. This suits to the small survey sample size of 6 respondents and should open to the possibility of a more in-depth findings of the subject matter that could lead to unexpected discoveries.

This self-completion questionnaire was also developed using the SurveyMonkey online survey tool and comprised a total of 12 close-ended questions and 12 open-ended questions that were allotted into four segments. Segment 1 inquire demographics information and contains four (4) open ended questions. Even though these questions were open-ended, the answers were single, controlled, and expected as the survey questionnaires were personally distributed to a small pre-determined sample of six (6). This is followed by Segment 2 that looks into the current usage of digital technologies in architecture schools; which contains one (1) multiple choice-multiple answer question and two (2) Likert-type scale questions. Segment 3 is about the awareness and experience of BIM in architecture education, and contains six (6) multiple choice-single answer questions and three (3) Likert-type scale questions. The fourth segment, which is the last segment, contains eight (8) open-ended questions that inquire on the respondents' respective institution's stand on the role and direction they took in teaching BIM, and research work that the institutions carried out on BIM. In constructing the questionnaire, the researcher has also referred to the guidelines and suggestions provided by Creswell (2013b), Neuman (2014), Bryman (2015), and Saunders et al. (2015) to ensure that the finished questionnaire is sufficiently brief, reads well, and unbias in its design. The contents of the survey questionnaire were based on extensive literature review of books, research papers, and industry best-practice reports, as summarised in the following tables.

Segment 1: Demographics

No.	Demographics	References
1	Basic data of employer/employee	Masterspec (2012) NBS (2012) IBC and NBS (2013) Phillips et al. (2013) McGraw-Hill (2009) Bryman (2012) Creswell (2013b)

Segment 2: Applied Computer Technology

No.	Applied Computer Technology	References
2	Usage of digital technologies at establishment.	Picon (2010) Becerik-Gerber et al. (2011a) Joannides et al. (2012) Khiati (2011) Sampaio et al. (2010) Wang (2009) Cheng (2006), Andia (2002) Asperl (2005) Berwald (2008) Johnson and Gunderson (2009) Bratton (2009) Bridges (1997) Brown (2009) Erdener and Gruenwald (2001) García et al. (2007) Hassan et al. (2010b) Ibrahim and Pour Rahimian (2010) Maher (2008) Mara (2010) McLoughlin (1989) Mohd-Nor et al. (2009) Wynne (2009) Stackpole (2009) Breen (2004) Bridges (1997) Dvorák et al. (2005) Erdener and Gruenwald (2001) García et al. (2007) Groak (1988) Pektas (2007)

Segment 3: BIM in Architecture Education

No.	BIM in Architecture Education	References
3	Awareness and BIM experience	Masterspec (2012) NBS (2012) IBC and NBS (2013) BuildingSMART (2012) Barison and Santos (2012) Becerik-Gerber et al. (2011a) Becerik-Gerber and Kensek (2009) Berwald (2008) Both (2012) Burke (2012) Bybee and Fuchs (2006) Cheng (2006) Cory and Schmelter-Morrett (2012) Crumpton et al. (2008) Cuesta and Salverda (2009) Denzer and Hedges (2008) Eom (2011) Gu and de Vries (2012) Hassan et al. (2010a) Hietanen and Drogemuller (2008) Joannides et al. (2012) Kim (2011) Macdonald (2012) Mohd-Nor et al. (2009) Morton (2012) Mutai and Guidera (2010) Scheer (2006) Wong et al. (2011b)

Segment 4: Role and direction HEIs in developing BIM Curriculum

No.	General View Towards BIM	References

4	BIM curriculum and research	Giddings and Horne (2008) Ivarsson (2010) Lee and Hollar (2013) Seletsky (2006) Sharag-Eldin and Nawari (2010) Yori (2011) Yori (2011) CREAM (2013) CREA (2011) Becerik-Gerber and Kensek (2009) (Gu et al., 2008) Joannides et al. (2012) Rossignac (2004) Succar (2009) Whyte (2012) Wong and Yang (2010)

Table 6.1: Survey B questionnaires segments.

6.5 CONSIDERATIONS

Similar to Survey A, the survey questionnaire for Survey B was also tested and improved through a series of discussions with a number of PhD students from the University of Strathclyde, professional colleagues in the Universiti Kebangsaan Malaysia; and through previous surveys studies done by the researcher during his time as a lecturer before commencing his PhD studies (Mohd-Nor et al., 2009). Even though these studies and surveys were done much earlier outside the term of this PhD, the study topic was similar and this thesis is a continuation of that research, but on a greater depth and scale. Therefore, the previous surveys carried out by the researcher was taken to serve as a partial pilot study to improvised the questionnaire, specifically for Segment 2 and Segment 3. As for Segment 1 and Segment 4, no pilot studies were done despite being the first qualitative survey to be conducted by the researcher. However, the contents for these segments were constructed by referring to established literature and guidelines (refer to the above table) and as previously stated, it was tested and improved through a series of discussions with researchers from University of Strathclyde and Universiti Kebangsaan Malaysia.

6.6 DATA ANALYSIS

The data analysis for this survey has been described in detail in Chapter 3. Basically, there were three stages involved in the data analysis phase for this survey. These are as followings:

6.6.1 DATA COLLECTION AND PREPARATION

As with the previous survey in Phase I, this survey was also distributed through email by SurveyMonkey; an online development cloud-based software. Even though the sample size was not huge in numbers, the location of some of the HEIs that were surveyed were located far from Kuala Lumpur; one in the far North while another in the far South of the country. The response data were then received and gathered in SurveyMonkey's own cloud-based database, which kept all information records including the dates and time of the distribution and receiving of data, Internet Protocol (IP) address from where each response was collected from, and the percentage of completion for every respond of questionnaire.

6.6.2 DESCRIPTIVE STATISTICS

Survey B took on a similar deductive route as in Survey A, which made the research being objective and structured. However, since there were limited literatures on the subject in Malaysia, it was difficult to develop a fixed-choice format answers to some of the questions, particularly questions that seek deeper opinions and general data that was specific and unique to their respective institutions. These led to the use of both close-ended and open-ended questions for the questionnaire, resulting in a mix-method of quantitative and qualitative approach. All the answers to the close-ended questions were later described using descriptive statistics. Similar to Survey A, for every question and sub-question, the researcher also intended to provide descriptive elaboration with graphic analysis and calculations in the attempt to present the data in a manageable form and reach deductions that exceed the immediate data alone. To help describe the statistics of the numerical data for the close-ended questions, three basic statistical measures were used; distribution, central tendency and dispersion (Neuman, 2014, Bryman, 2015).

6.6.3 CODING OF OPEN-ENDED QUESTIONS

The answers to all of the open-ended questions were coded to formulate a distinct theme in the responses. The researcher designed a coding frame or coding list that identifies the received answers associated with its questions and their respective codes. The type of adopted coding was descriptive coding; essentially forming summary descriptions of all the answer texts from open-ended questions to ensure the survey remains objective. Descriptive coding supports the deductive approach of the research.

6.7 QUESTIONNAIRE RESULTS

Results obtained from the questionnaire surveys were divided into five (5) segments; demographics, applied computer technology, BIM in practice, general view towards BIM, and HEIs leading the BIM cause. The results are shown as a combination of frequency histograms, percentages, charts, with some responses including bullet point summaries of the comments expressed by the respondents.

6.7.1 SEGMENT 1 - DEMOGRAPHICS

Basic data of employer/employee

Q1 Name :

Answered: 6 Skipped: 0

Name (Q1). The first question identified the names of the respondents, whereby each name was expected and conformed to the group of individuals that the researcher approached for participation. All six (6) respondents were recommended by their respective departments as personnel in charge of CAD/BIM matters for their architecture programmes at the time of survey. However, the names were only required to make the respondents identifiable to the research but not being disclosed in this thesis as to protect the confidentiality and anonymity of the respondents from the public readers of the research.

Q2 Position :

Answered: 6 Skipped: 0

#	Responses	Date
1	Ledturer	12/6/2013 10:59 AM
2	Lecturer	10/31/2013 5:19 PM
3	Lecturer	10/28/2013 2:46 AM
4	lecturer	6/17/2013 4:22 AM
5	Lecturer	3/27/2013 6:16 AM
6	lecturer	3/21/2013 7:15 AM

Position (Q2). This question asked the respondents position in their establishments. All six (6) respondents were full-time lecturers.

Q3 Department :

Answered: 6 Skipped: 0

#	Responses	Date
1	Architecture	12/6/2013 10:59 AM
2	Department of Archtitecture	10/31/2013 5:19 PM
3	Architecture Programme	10/28/2013 2:46 AM
4	Architecture	6/17/2013 4:22 AM
5	Department of Architecture	3/27/2013 6:16 AM
6	architecture	3/21/2013 7:15 AM

Department (Q3). As stated earlier, only full-time academicians that teach architecture programmes and based in architecture departments were approached for this survey. This is because the research focuses only on BIM within the architecture education scope in Malaysia.

Q4 Institution :

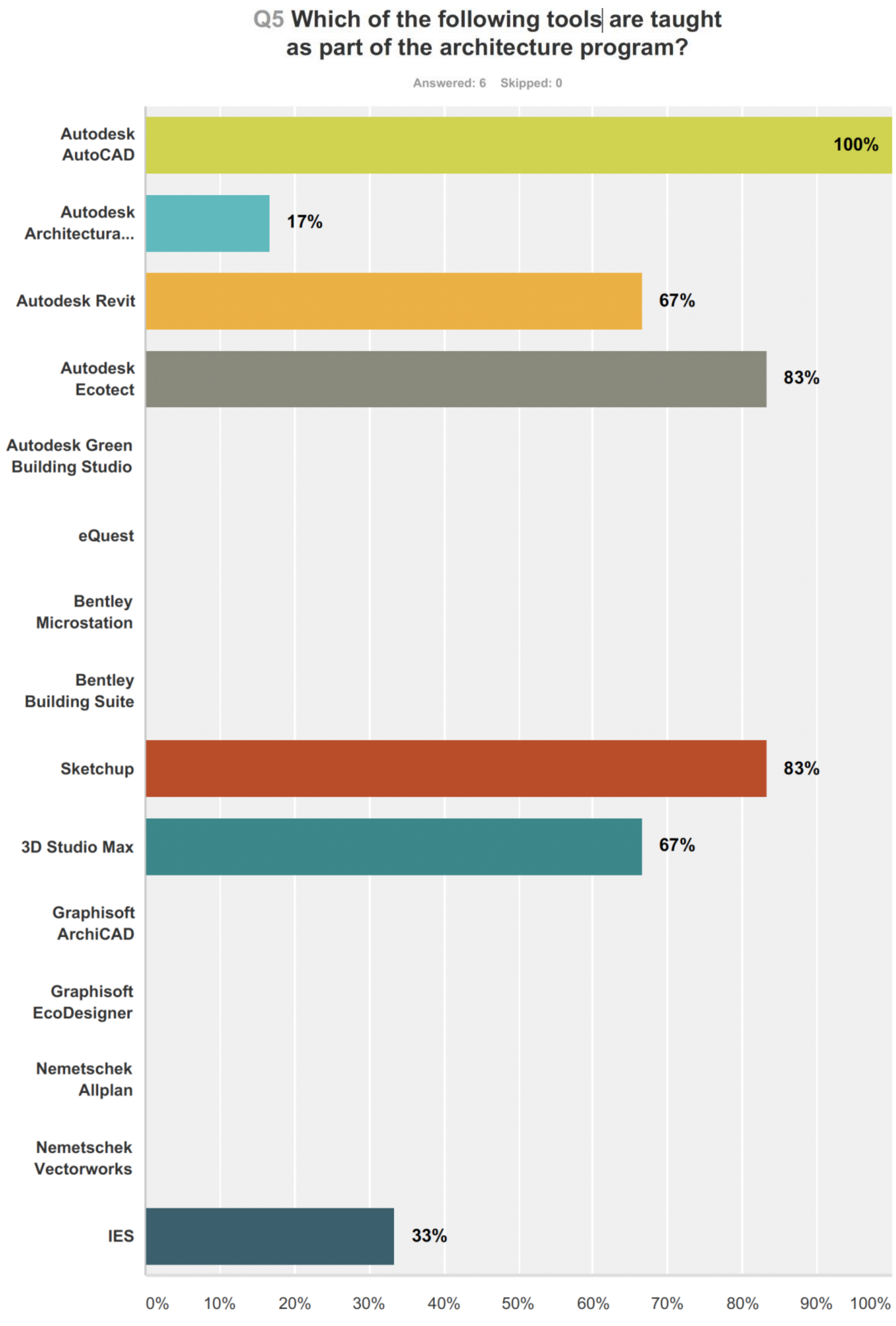
Answered: 6 Skipped: 0

#	Responses	Date
1	UiTM	12/6/2013 10:59 AM
2	Universiti Teknologi Malaysia	10/31/2013 5:19 PM
3	Universiti Sains Malaysia	10/28/2013 2:46 AM
4	Higher Education	6/17/2013 4:22 AM
5	Kulliyyah of Architecture, International Islamic University Malaysia	3/27/2013 6:16 AM
6	univeristy putra malaysia	3/21/2013 7:15 AM

Institutions (Q4). All six (6) respondents represented the six public HEI's that offered undergraduate (LAM/PAM Part I) and post-graduate (LAM/PAM Part II) programmes for architecture. This include UiTM, UTM, USM, UM, IIUM and UPM. Note that respondent number 4, who identified himself as working at *'Higher Education*', was actually Asrul Sani Razak from UM.

6.7.2 SEGMENT 2 – APPLIED COMPUTER TECHNOLOGY

Usage of digital technologies at establishment.



Answer Choices	Responses	
Autodesk AutoCAD	100%	6
Autodesk Architectural Desktop	17%	1
Autodesk Revit	67%	4
Autodesk Ecotect	83%	5
Autodesk Green Building Studio	0%	0
eQuest	0%	0
Bentley Microstation	0%	0
Bentley Building Suite	0%	0
Sketchup	83%	5
3D Studio Max	67%	4
Graphisoft ArchiCAD	0%	0
Graphisoft EcoDesigner	0%	0
Nemetschek Allplan	0%	0
Nemetschek Vectorworks	0%	0
IES	33%	2
Total Respondents: 6		

#	Other (please specify)	Date
1	Rhino + Grasshopper	3/27/2013 6:17 AM

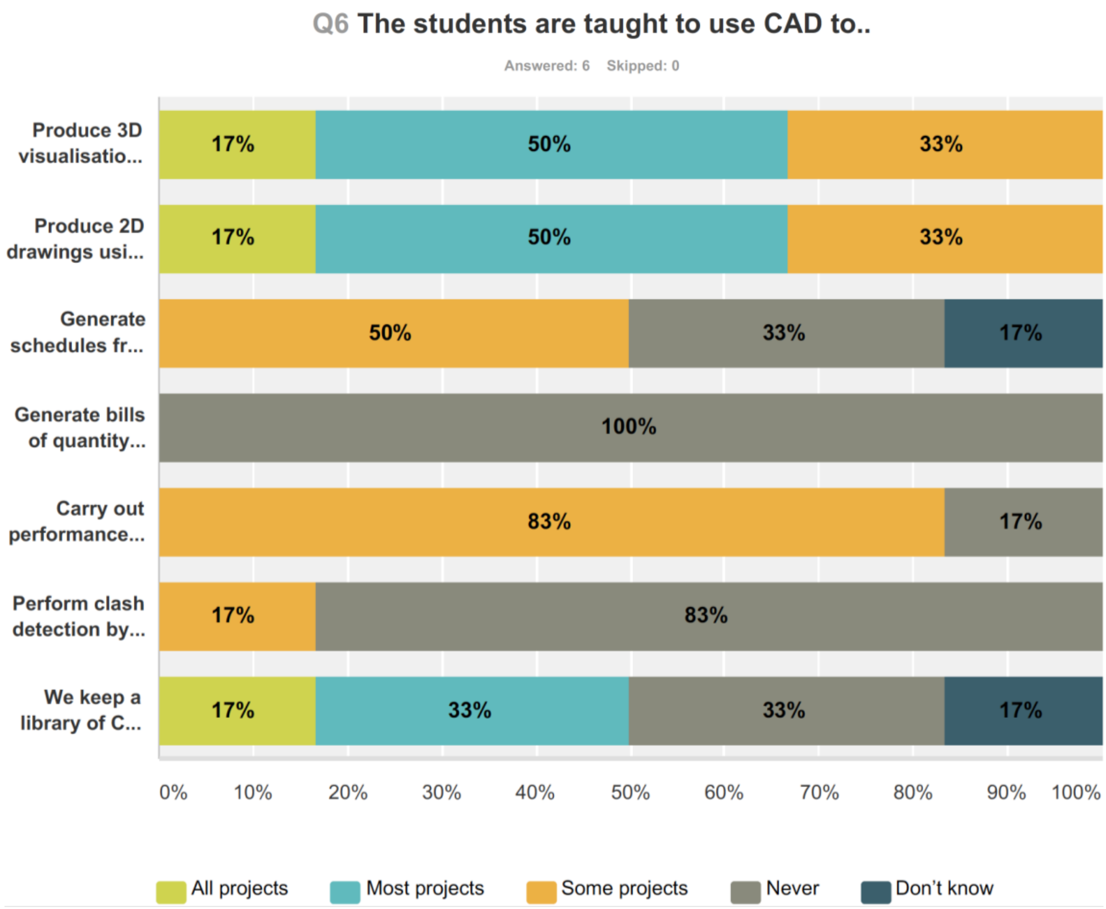
Software (Q5). As it was deemed necessary to enquire knowledge on the usage of software in the industry, it is equally crucial to enquire on the usage of software in the HEIs. This is simply because there is a connection between the two when the HEIs supply the workforce with graduates that possess skillsets deemed useful to the industry. The above figure shows the types of software applications that were taught in the architecture programmes offered by all six public architecture schools in the country. Based on the responds, *AutoCAD* by *Autodesk* was the most popular and widely used software where it was taught in all six (6) HEIs. Next in second place are jointly held by *Sketchup* by *Google* and *Ecotect* by *Autodesk* with all but one HEI teaching it to their students. The third most widely taught software were jointly held by *Revit* of *Autodesk* and *3D Max*, also by *Autodesk*, where each of the application were taught at four (4) HEIs.

The wide usage of *AutoCAD* by *Autodesk* directly reflected the wide usage of the software application in the industry. As stated earlier, *AutoCAD*, a software traditionally used for the production of 2D drawings, was one of the first 2D drafting application introduced in the country. Therefore, being one of the earliest 2D drafting application, coupled with tremendous marketing effort during its introduction, the *AutoCAD* name has been synonymous to architects and draftsmen when it comes to 2D drafting (Harrington, David, 2001). Being a traditional 2D-based software, it is therefore clear that all architecture HEIs were still teaching students with the traditional method of 2D drafting when it comes to producing drawings.

The teachings of *Sketchup* and *3D Max*; both 3D modelling software that work by conventional means; in the majority of the HEIs proved that HEIs are still supplying students with traditional 3D modelling skills. It is worth noting that the majority of the HEIs resorted to teaching both software despite being conventional 3D modelling software. This could be due to the different attributes of the software, where *Sketchup* is reckoned to be simple, direct, very easy to learn, and is best used for schematic stages of design (Singh et al., 2013) (Garde et al., 2011) (Khiati, 2011), whereas 3D Max is more powerful and robust, yet has a much steeper learning curve, and is suited for complex tasks of modelling and rendering (Khiati, 2011) (Elliot, 1998). Nevertheless, the teaching of both software by the majority of the HEIs signify that the industry were still demanding graduates with skills of traditional 3D modelling.

An interesting revelation from the responds from this question is that BIM has made an inroad to the HEIs in Malaysia. Despite retaining the teachings of traditional 2D drafting and 3D modelling software, the HEIs in Malaysia have begun to take the step forward in introducing BIM software to its students. Four out of the six HEIs have taught *Revit* software by *Autodesk*; a BIM software; as part of their architecture education curriculum. This was in line with the trends in America and Europe, where BIM has gained a relatively strong footing in the tertiary level of AEC education, as reported by surveys done by Johnson and Gunderson (2010), Barison and Santos (2010a), Becerik-Gerber et al. (2011a), Joannides et al. (2012), Barison and Santos (2012), and Sacks and Pikas (2013). This development, in regards to the Malaysian context, is important as it showed that the HEIs have responded to the global trends of equipping students with BIM skills as the global demand for BIM in general has increased by the day.

Besides BIM software, the public HEIs in Malaysia have also taken steps to introduce building performance simulation software in the form of *Ecotect* by *Autodesk*. *Ecotect*, which has an interactive analysis function that allows users to simulate building performances from the earliest stages of conceptual design, augments directly to the *Revit* BIM environment. In fact, since 2015 the software was no longer sold as a standalone software, but was been fully integrated into the *Revit* software, expanding its BIMs capabilities to include performance simulation functions. The usage of *Ecotect* showed that the HEIs have also further expanded the BIM platform to allow students to simulate and analyse the performance of their design work.

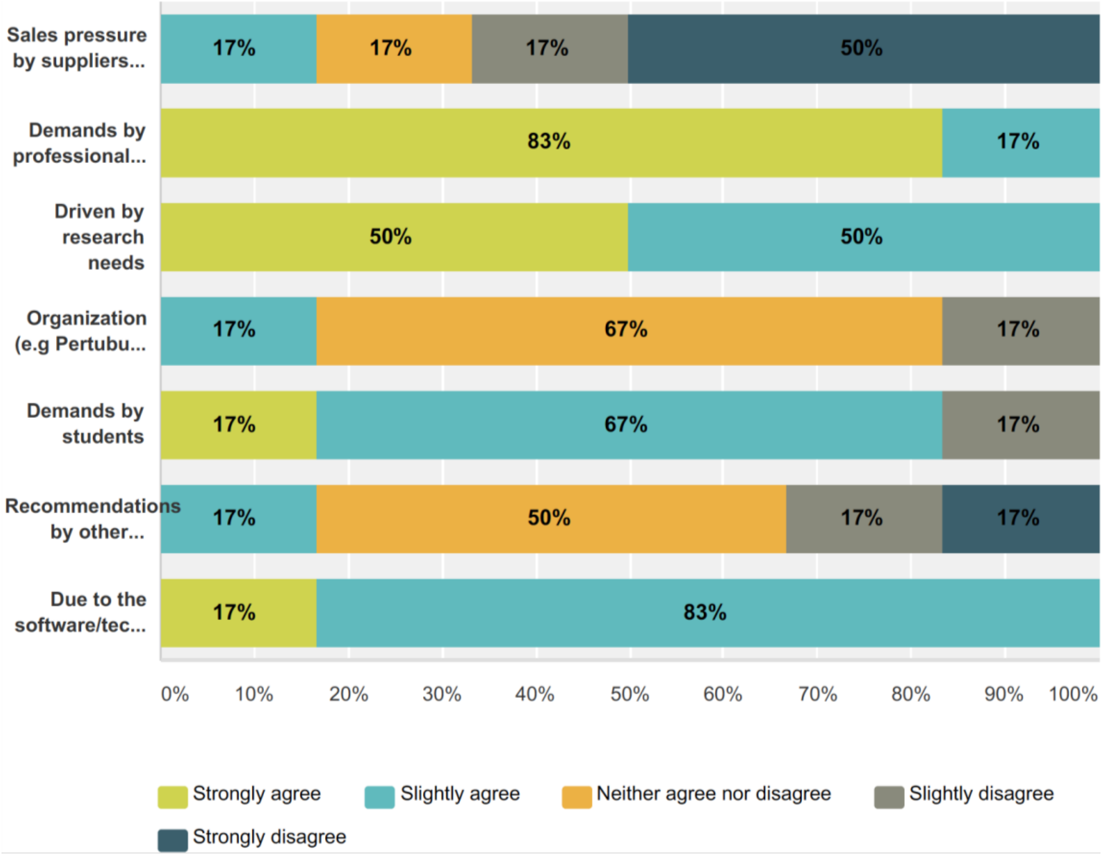


	All projects (1)	Most projects (2)	Some projects (3)	Never (4)	Don't know (5)	Total	Weighted Average
Produce 3D visualisations using our CAD models	17% 1	50% 3	33% 2	0% 0	0% 0	6	3.83
Produce 2D drawings using our CAD models	17% 1	50% 3	33% 2	0% 0	0% 0	6	3.83
Generate schedules from our CAD models	0% 0	0% 0	50% 3	33% 2	17% 1	6	2.33
Generate bills of quantity from our CAD models	0% 0	0% 0	0% 0	100% 6	0% 0	6	2.00
Carry out performance analysis (energy consumption/structural/acoustic) on our CAD models	0% 0	0% 0	83% 5	17% 1	0% 0	6	2.83
Perform clash detection by collaborating with others through the use of CAD models	0% 0	0% 0	17% 1	83% 5	0% 0	6	2.17
We keep a library of CAD objects we create for reuse	17% 1	33% 2	0% 0	33% 2	17% 1	6	3.00

Function of CAD software (Q6). This question enquired on the type of functions that CAD was used by their students. Based on the above table, all six of the HEIs have taught their students to use CAD technology for 2D drawings production and 3D visualisation, the traits of a traditional CAD software. These correlates to the findings from the previous question where all HEIs reported of using *AutoCAD*, a traditional 2D software, and traditional 3D modeller like *Sketchup* or *3D Max*. However, other functionalities of CAD were not fully utilised. Only three (3) HEIs use CAD to generate schedules, even so only on some projects. None of the HEIs taught their students to use CAD application to generate bills of quantity (BQ) and only one claimed to use CAD to perform clash detection function on their design works. Even though the HEIs have taught students to use CAD application to use clash detection function, it was only for some of the projects rather than being a standard tool for most projects. These are not surprising as most of CAD application do not offer these functions in their package, or would have needed a third-party plugins or extensions to perform those tasks. It is worth to note here that having a proper CAD library tool is a standard practice for three out of the six HEIs, as in accordance to the standard practice in the industry (Whyte et al., 1999, Connolly, 2009).

Q7 The main factor that drives the architecture program to adopt new kinds of software/technologies would be..

Answered: 6 Skipped: 0



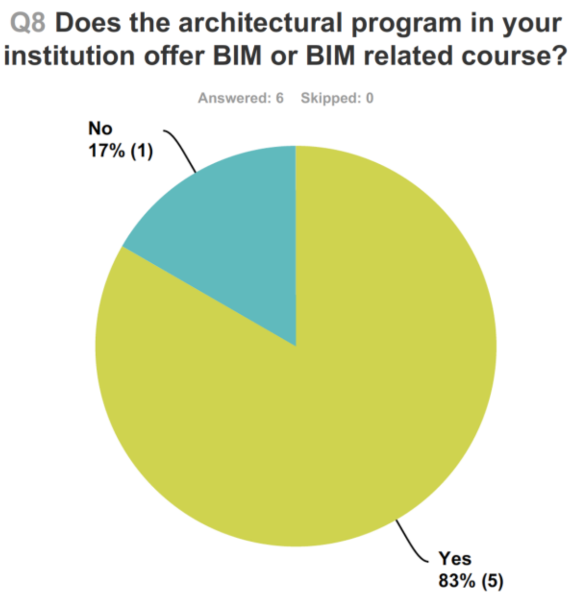
	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
Sales pressure by suppliers and vendors	0% 0	17% 1	17% 1	17% 1	50% 3	6	2.00
Demands by professional practices	83% 5	17% 1	0% 0	0% 0	0% 0	6	4.83
Driven by research needs	50% 3	50% 3	0% 0	0% 0	0% 0	6	4.50
Organization (e.g Pertubuhan Arkitek Malaysia)	0% 0	17% 1	67% 4	17% 1	0% 0	6	3.00
Demands by students	17% 1	67% 4	0% 0	17% 1	0% 0	6	3.83
Recommendations by other institutions	0% 0	17% 1	50% 3	17% 1	17% 1	6	2.67
Due to the software/technology's global reputation	17% 1	83% 5	0% 0	0% 0	0% 0	6	4.17

Basic Statistics	Minimum	Maximum	Median	Mean	Standard Deviation
Sales pressure by suppliers and vendors	2.00	5.00	4.50	4.00	1.15
Demands by professional practices	1.00	2.00	1.00	1.17	0.37
Driven by research needs	1.00	2.00	1.50	1.50	0.50
Organization (e.g Pertubuhan Arkitek Malaysia)	2.00	4.00	3.00	3.00	0.58
Demands by students	1.00	4.00	2.00	2.17	0.90
Recommendations by other institutions	2.00	5.00	3.00	3.33	0.94
Due to the software/technology's global reputation	1.00	2.00	2.00	1.83	0.37

Drivers for new technology (Q7). This suggested seven (7) different factors that could be considered when adopting new software or technology. However, only four (4) factors were agreed upon by the HEIs. Out of the four factors, the strongest factor that drives the decision to adopt new technology or software is industry demands, with five (5) respondents *strongly agreed* and one *slightly agreed*. The second strongest factor was due to research needs, where a half of the HEIs *strongly agreed* while another half *slightly agreed*. The third factor was due to the software or technology global reputation. Judging products by its reputation is at times considered imprudent as reputation is a subjective matter, differing between individuals and respective preferences. Under certain circumstances, it can impose on an individual to incline towards a particular brand, thinking it may be the best option but in actuality it is not; or an individual may also be over-charged to a premium, deceived by its false reputation. However, this is something to be expected. Reputation on brand attitude were previously studied from the surveys done by Jung and Seock (2016) and Shandwick (2011), who revealed that a brand or product reputation does contribute to one's purchasing decision. However, in the case of technology acquisition, brand reputation often relates to the factor of compatibility or interoperability, where a globally reputable technology from established brand names are often perceived as having high compatibility or interoperability across different product lines (Forman, 2001, Rahardjo, 2006, Dawson et al., 2006, Spulber, 2008). The fourth factor for software or technology acquisition comes from student demands. For this, four (4) HEIs claimed to *strongly agree*, while one (1) HEI *slightly agree* to this notion. This showed that the HEIs do take into account of students' opinions and demands, albeit slightly frivolous as students may not have a wide exposure or enough experience on the subject of technology to be able to offer feasible suggestions.

6.7.3 SEGMENT 3 – BIM EXPERIENCE

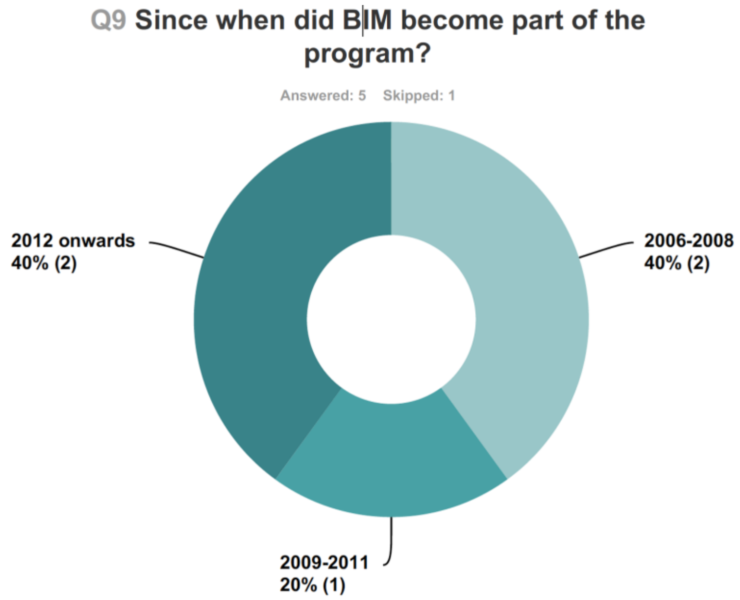
Usage of BIM at establishment.



Answer Choices	Responses	
Yes (1)	83%	5
No (2)	17%	1
Total		6

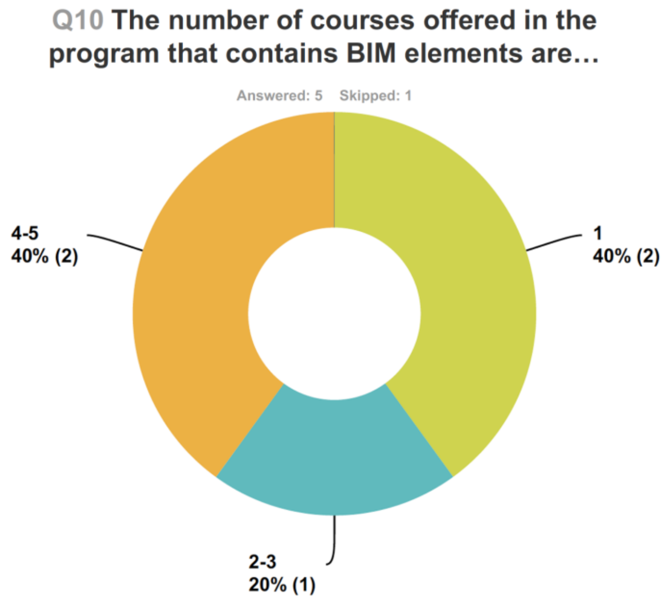
Basic Statistics				
Minimum 1.00	Maximum 2.00	Median 1.00	Mean 1.17	Standard Deviation 0.37

BIM in Academia (Q8). This question, which asked about BIM inclusion in architecture programme in the HEIs, is a very important question and is core to the research. The importance of equipping graduates with BIM skills has been highlighted by many researchers and academicians, such as Deutsch (2011), Kaner et al. (2008), Kiviniemi (2014), Aranda-Mena et al. (2009), Smith and Tardif (2009), Morton (2012), Barison and Santos (2010b), and Becerik-Gerber et al. (2011a). Even though Q5 might have given us some indication on the possibility of BIM being integrated into architecture programmes; the response revealed usage of BIM-based software; it is worth noting that any usage of just a few particular tools from the software alone may not be considered as 'fully adopting' the BIM technology. As mentioned earlier, some may use these software for visualization purpose only rather than to fully utilize the full capability of the technology that goes beyond into other capabilities such as clash detection, collaboration, design performance simulation and many others. However, the response to this question answers the above concern when it showed that all but one of the six (6) HEIs have claimed to be teaching BIM to their students. The survey cloud database showed that the only HEI that have not taught BIM was USM.



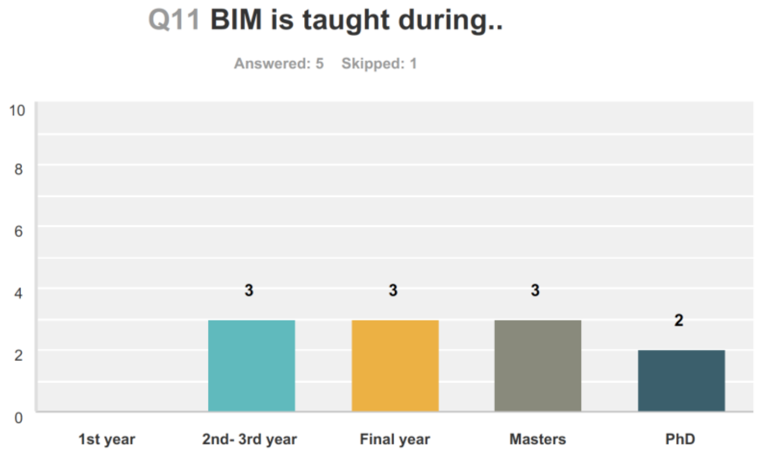
Answer Choices	Responses	
before 2003	0%	0
2003-2005	0%	0
2006-2008	40%	2
2009-2011	20%	1
2012 onwards	40%	2
Total		5

Years of experience (Q9). The answers to this question showed that BIM is still relatively very new to the HEIs in Malaysia. Based on the above chart, BIM was taught earliest between year 2006 to 2008 by two of the HEIs, namely IIUM and UM. This was followed by UTM between year 2009-2011. The two (2) other HEIs that have just recently taught BIM after year 2012 were UiTM and UPM.



Answer Choices	Responses	
1	40%	2
2-3	20%	1
4-5	40%	2
5-6	0%	0
more than 6	0%	0
Total		5

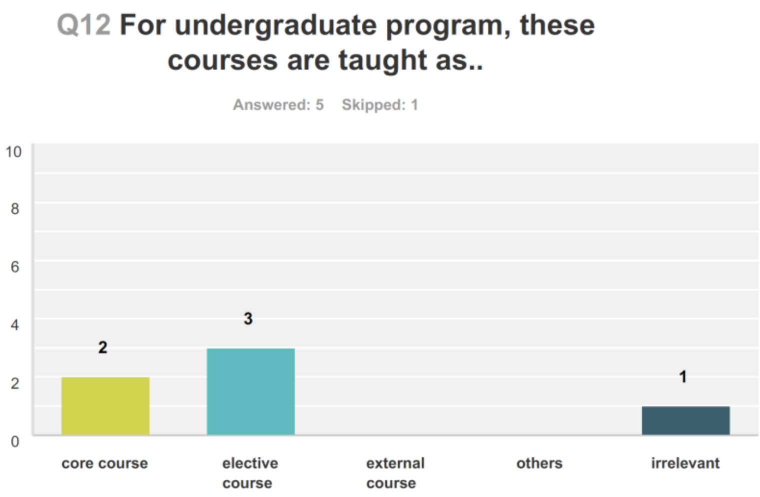
BIM in core programme (Q10). This question refers to the number of modules offered in the programme that contains BIM elements, regardless whether the module being a standalone BIM module or as part of other modules. In regards to this, the most number of BIM-related modules offered for architecture programmes in the country were offered by UTM and UM, with each having 4 to 5 BIM related modules. IIUM comes second with its architecture programmes offering 2-3 modules with BIM elements. On the other hand, the two HEIs that have most recently started its BIM modules; UiTM and UPM; were offering only one (1) module with BIM element, making it the least among the HEIs.



Answer Choices	Responses		Institutions		
1st year	0.00%	0			
2nd- 3rd year	60.00%	3	UTM	UM	UPM
Final year	60.00%	3	UiTM	UTM	IIUM
Masters	60.00%	3	UTM	UM	IIUM
PhD	40.00%	2	UM	IIUM	
Total Respondents: 5					

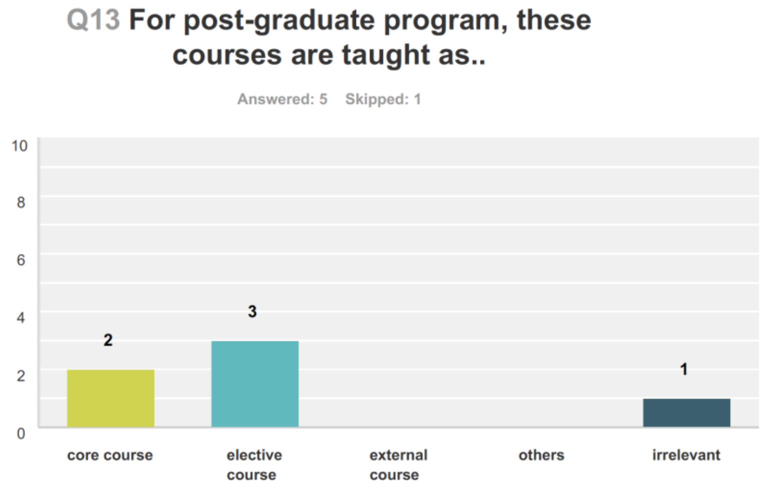
BIM years (Q11). This question goes deeper by asking where did the HEIs placed their BIM modules in their architecture programmes. Based on the above figure, all the HEIs that offered BIM for their architecture programmes were offering it as early as Part 1 level. UTM, UM and UPM have BIM introduced to their students at 2^{nd}-3^{rd} year of their Part 1 architecture programme while IIUM and UiTM did so during the final year of their Part 1 architecture programme. Despite having to offered BIM during 2-3^{rd} year, UTM were also offering BIM again during the final year of their programme. As for Part 2 architecture programme; Master's degree; only UTM, UM and IIUM have included BIM in their curriculum. It is interesting to note that UTM, being the HEI to offer the most number of BIM related modules, was the only one to have offered BIM related modules at nearly every year of both their Part 1 and Part 2 architecture programmes. As for PhD level, only UM and IIUM have offered BIM modules as part of their PhD programme. Findings from this question is not surprising, as a survey by Joannides et al. (2012) on the implementation of BIM in North

America's architecture schools also revealed that BIM is mostly taught during Junior (3rd year), Senior (4th year or Final year of Part 1) and Graduate (Masters) years.



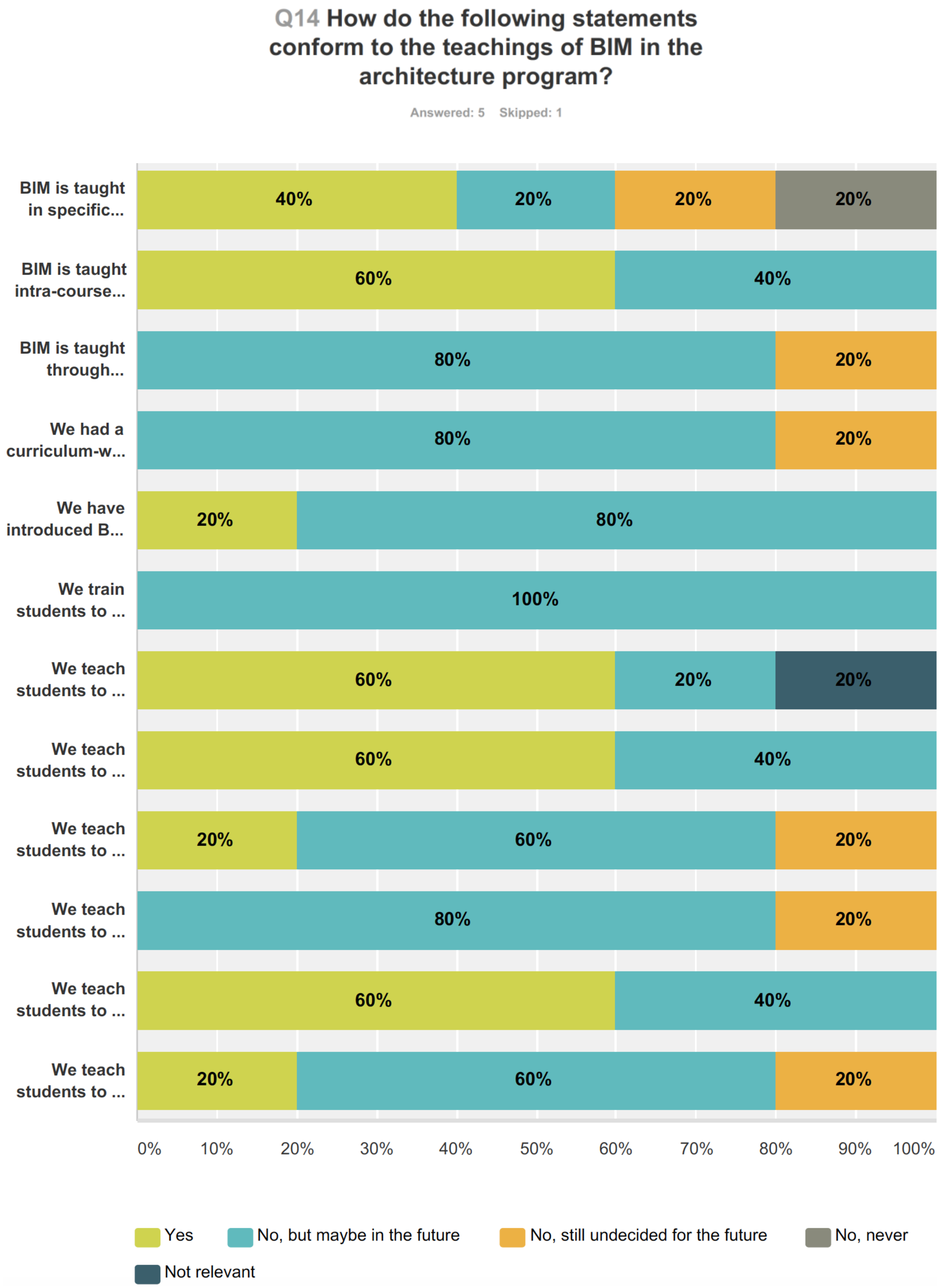
Answer Choices	Responses		Institutions		
core course	40.00%	2	UTM	IIUM	
elective course	60.00%	3	UiTM	IIUM	UPM
external course	0.00%	0			
others	0.00%	0			
irrelevant	20.00%	1	UM		
Total Respondents: 5					

BIM for Undergraduates (Q12). There have been various approaches taken by HEIs around the world in teaching BIM. Besides being taught as a stand-alone or as being part of another module, another subject that comes to mind is whether BIM is taught as a core (required) module, elective module or an external module. As for the undergraduate programmes (PAM/LAM Part 1), only two (2) HEIs; UTM and IIUM; have taught BIM as core modules while UiTM and UPM have taught BIM as an elective module. IIUM however have taught BIM as both core module and elective module to their students. UM on the other hand have claimed this to be irrelevant.



Answer Choices	Responses		Institutions
core course	40.00%	2	UTM IIUM
elective course	60.00%	3	UiTM IIUM UPM
external course	0.00%	0	
others	0.00%	0	
irrelevant	20.00%	1	UM
Total Respondents: 5			

BIM for Post-graduates (Q13). It is interesting to know that the HEIs have maintained the same approach for BIM curriculum from undergraduate programmes to post-graduate programmes. Again, for the postgraduate programmes (PAM/LAM Part 2), only two (2) HEIs (UTM and IIUM) taught BIM as core modules while UiTM and UPM taught BIM as an elective module. However, IIUM have taught BIM as both core module and elective module to their students. UM on the other hand have claimed this to be irrelevant. It is worth to note that all of the HEIs that offered BIM has done so in-house, either as elective or core, and not by external modules for distance learners. Some HEIs, such as the Polytechnic University of Madrid in Spain offers BIM in the form of external modules (Lopez-Zaldivar et al., 2017).


Q14 How do the following statements conform to the teachings of BIM in the architecture program?
Answered: 5 Skipped: 1
BIM is taught in specific...
40%
20%
20%
20%
BIM is taught intra-course...
60%
40%
BIM is taught through...
80%
20%
We had a curriculum-w...
80%
20%
We have introduced B...
20%
80%
We train students to ...
100%
We teach students to ...
60%
20%
20%
We teach students to ...
60%
40%
We teach students to ...
20%
60%
20%
We teach students to ...
80%
20%
We teach students to ...
60%
40%
We teach students to ...
20%
60%
20%
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Yes
No, but maybe in the future
No, still undecided for the future
No, never
Not relevant

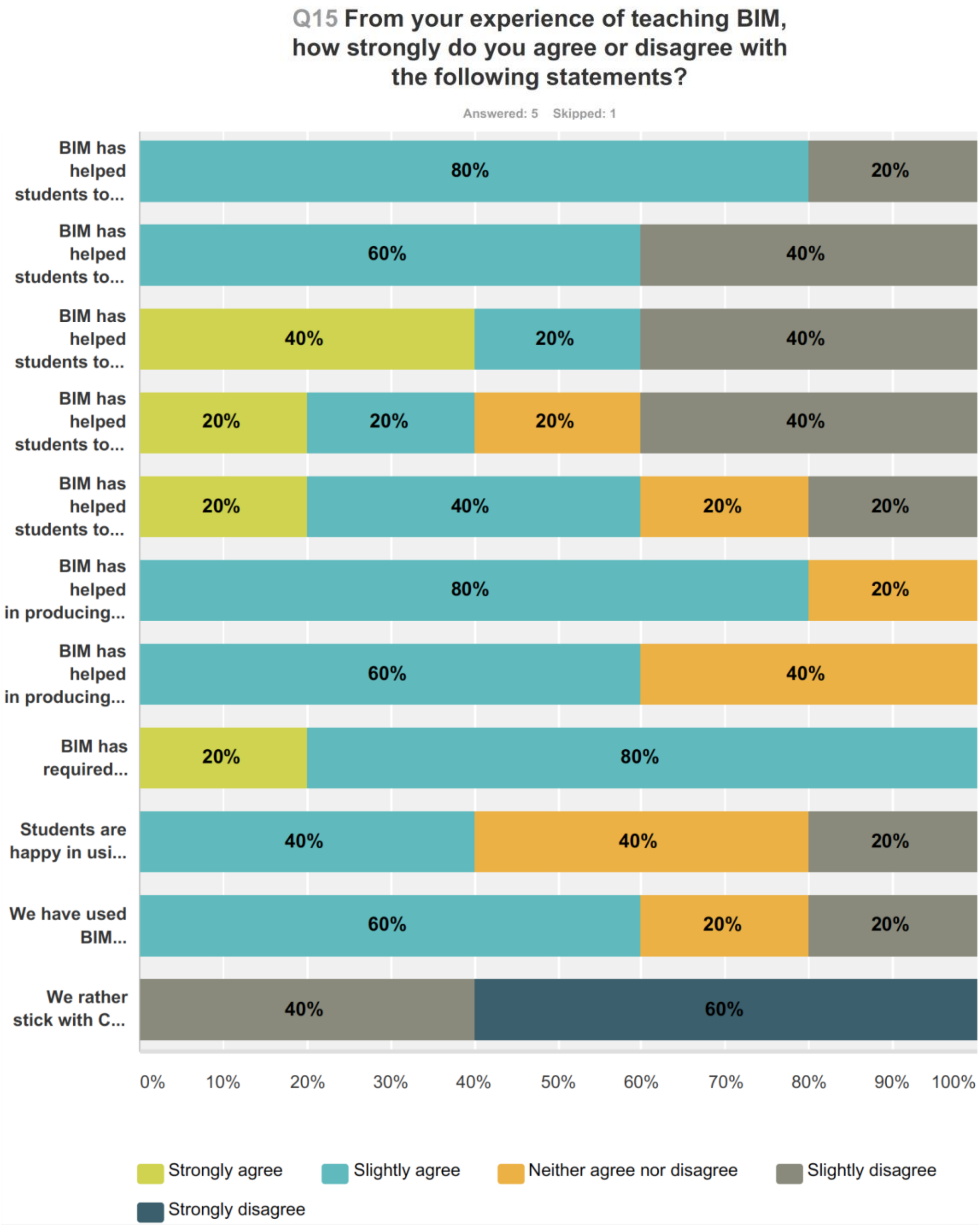
	Yes (1)	No, but maybe in the future (2)	No, still undecided for the future (3)	No, never (4)	Not relevant (5)	Total	Weighted Average
BIM is taught in specific single-course(s)	40% 2	20% 1	20% 1	20% 1	0% 0	5	3.80
BIM is taught intra-courses throughout the curriculum	60% 3	40% 2	0% 0	0% 0	0% 0	5	4.60
BIM is taught through interdisciplinary courses and distance collaboration	0% 0	80% 4	20% 1	0% 0	0% 0	5	3.80
We had a curriculum-wide coordination due to implementing BIM	0% 0	80% 4	20% 1	0% 0	0% 0	5	3.80
We have introduced BIM into our Design Studio courses	20% 1	80% 4	0% 0	0% 0	0% 0	5	4.20
We train students to use BIM as the main collaborative tool in team projects.	0% 0	100% 5	0% 0	0% 0	0% 0	5	4.00
We teach students to use BIM for 3D visualization purpose	60% 3	20% 1	0% 0	0% 0	20% 1	5	4.00
We teach students to use BIM for constructability purpose	60% 3	40% 2	0% 0	0% 0	0% 0	5	4.60
We teach students to use BIM to tie schedules to models	20% 1	60% 3	20% 1	0% 0	0% 0	5	4.00
We teach students to use BIM to tie estimates to the models	0% 0	80% 4	20% 1	0% 0	0% 0	5	3.80
We teach students to use BIM models for further energy simulation / operations analysis.	60% 3	40% 2	0% 0	0% 0	0% 0	5	4.60
We teach students to use BIM to perform clash detection on design projects.	20% 1	60% 3	20% 1	0% 0	0% 0	5	4.00

BIM teaching curriculum (Q14). This question enquired the HEIs on the BIM practice in their programme. The sub-questions or statements contained in Q14 were designed to survey how the HEIs are teaching BIM and also look into the contents of their BIM syllabus in general. Firstly, the HEIs were divided and did not share a same view as to teach BIM through a single-module or having it taught intra-module throughout the curriculum. For this, two (2) HEIs; UiTM and UTM; opted for the former, while three (3) others; UM, IIUM and UPM; opted for the latter. Secondly, even though BIM's strength is seen by its ability to perform as a real-time collaborative tool between team players, none of the HEIs in Malaysia have taught BIM through interdisciplinary modules and distance collaboration projects. However, all but one of the HEIs acknowledged on the importance of this role and function, and are considering to implement this in the future.

Studies have shown that it is not an easy process to conduct a curriculum-wide coordination for revision of curriculum just to include a new system or practice (Woo, 2007, Lucas, 2014, Dossick and Anderson, 2017, Sabongi, 2009). Even though BIM itself is a technology application, it is an application that imposes an entirely new system that would impact the whole process of work deliverables, hence requiring all related matters, or in this occasion the taught modules, to be reviewed or even revised. Considering this, it is not surprising that none of the HEIs in Malaysia have conducted a full-scale curriculum-wide coordination when incorporating BIM into their curriculum. This shows that the incorporation of BIM into their curriculum may have not been done in the best possible way. This suggests that BIM could have been introduced into their curriculum in a hastened way as a quick respond to the demand of the industry.

The uncoordinated inclusion of BIM into the HEIs in Malaysia is reflected in the way how BIM was integrated into their curriculum. Despite being a technology that promotes real-time collaboration between team players, none of the HEIs have taught their students to use BIM as a collaborative tool in team based projects. In fact, only one of the HEIs have incorporated BIM into their design studio modules; a project-based module that forms the core of the architecture programmes. This is contrary to the circumstances in America, whereby a survey done by Barison and Santos (2010a) revealed that more than 50% of the architecture HEIs in the States have incorporated BIM into their design studio modules. The findings from this question also unravelled that the majority of the HEIs in Malaysia use BIM for visualisation and constructability purposes, aside from performance or operations analysis. As BIM were not incorporated into the HEIs design studio modules, except for only UTM, these aspects of BIM were mostly taught through other complementary modules, such as

Computer/Architecture Graphics, Building Construction/Technology and Environmental Design. On the other hand, BIM was not widely taught to tie schedules to models, generate estimates, and surprisingly to perform clash detection. Despite this, the majority of the HEIs agreed that these will be incorporated into their BIM syllabus in the future, indirectly signifying that their BIM curriculum was still at a very early stage. Adding these aspects of the tool will certainly require changes to their curriculum.



	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
BIM has helped students to enhance design creativity	0% 0	80% 4	0% 0	20% 1	0% 0	5	3.60
BIM has helped students to improve visualisation	0% 0	60% 3	0% 0	40% 2	0% 0	5	3.20
BIM has helped students to improve productivity	40% 2	20% 1	0% 0	40% 2	0% 0	5	3.60
BIM has helped students to increase speed of delivery	20% 1	20% 1	20% 1	40% 2	0% 0	5	3.20
BIM has helped students to consider cost efficiencies in design	20% 1	40% 2	20% 1	20% 1	0% 0	5	3.60

Basic Statistics

	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has helped students to enhance design creativity	2.00	4.00	2.00	2.40	0.80
BIM has helped students to improve visualisation	2.00	4.00	2.00	2.80	0.98
BIM has helped students to improve productivity	1.00	4.00	2.00	2.40	1.36
BIM has helped students to increase speed of delivery	1.00	4.00	3.00	2.80	1.17
BIM has helped students to consider cost efficiencies in design	1.00	4.00	2.00	2.40	1.02

BIM teaching experience (Q15). While the previous question enquired the HEIs on how they practice BIM, this question inquire on the experiences from practise and the effects BIM is having on their students. The first sub-question touches on a topic that has raised concern from many BIM researchers; that BIM hinders creativity. Studies and reports by researchers and architects, like Horne et al. (2005), Sah and Cory (2008), Denzer and Hedges (2008), Berwald (2008), Becerik-Gerber et al. (2011a), Barison and Santos (2012), Morton (2012), and Magiera (2013), have all suggested that BIM may hinder creativity due to its nature of being precise, technical, difficult to construct complex geometry, having interoperability issues, and users' inclination towards using predefined materials and assemblies contained in the application. However, the response by all but one of the HEIs in Malaysia; albeit *slightly agree* rather than *strongly agree*; was that BIM has actually helped students to enhance their design creativity. This is indeed a positive development of BIM among the Malaysian public HEIs, as opposed to many studies mentioned earlier. There is a possibility that the experiences by these HEIs comply to more recent findings or studies, notably by

Ahmad et al. (2013) and Aranda-Mena (2016), who stipulated that BIM can actually enhance the creativity process by exploring and testing the impacts of conceptual ideas from the very beginning of the design process, resulting in a more ‘effective’ creative idea. The second sub-question touches on the ability of BIM to offer improved visualisation. As it is generally acknowledged, BIM’s parametric and information rich attribute offers very detailed yet easily generated 3D renderings, providing comprehensive and better 3D visualization for all users across the discipline (McGraw-Hill, 2012b, Becerik-Gerber et al., 2011b, Kymmell, 2008). The response from the HEIs in Malaysia is a mixed one, with three (3) *slightly agreeing* while another two (2) *slightly disagreeing* with the notion. However, this compares to surveys done by Becerik-Gerber and Rice (2010) and Kreider et al. (2010) in North America where 60%-63% of their respondents in academia and the industry agreed that visualisation was one of BIM’s most popular function. The next perception of BIM yields a slightly stronger response, when three (3) of the HEIs - two (2) *strongly agree* and one (1) *slightly agree* - claimed that BIM has certainly helped students to improve productivity. Numerous studies and reports, such as those by Eastman et al. (2008), Becerik-Gerber and Rice (2010), Kaner et al. (2008), Smith and Tardif (2012), Azhar (2011) and McGraw-Hill (2014a), have shown that BIM increases productivity. However, two (2) of the HEIs have not shared the same view; both citing *slightly disagree* in regards to the statement. Sub-question 4, which enquired on BIM’s ability to increase the speed of work delivery showed a divided response. Two (2) HEIs have *agreed*, another two (2) *disagreed*, while one (1) *neither agree nor disagree*. In terms of BIM’s ability in helping students to consider cost efficiencies in design, three (3) of the HEIs *agree* to it, only one (1) *disagree*, while another *neither agree nor disagree*.

What seems to be unexpected for sub-question 1 to 5 was that the responses were not as strong and conclusive as nearly all of these sub-questions received mixed reviews. This is out of line with many of the studies from around the world that acknowledged on the wholesome benefits of BIM, including its ability to improve or increase design creativity, visualisation, productivity, speed of delivery and cost efficiency in design. Looking at this trend, it is possible that the HEIs in Malaysia are still in the early phase of developing and experimenting on BIM curriculum and it will tentatively take some time before things fall into place and the full effect of BIM takes place. As stated by Cheng (2006), introducing a new all-inclusive technology like BIM can be impossibly taxing and very demanding, thus increasing the risk of overwhelming both students and academicians. She also emphasised that with the introduction of BIM, comes two competing philosophies: BIM's *answer-driven*, and design thinking's *question-driven*, that may not blend easily to one another.

	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
BIM has helped in producing specifications	0% 0	80% 4	20% 1	0% 0	0% 0	5	3.80
BIM has helped in producing bills of quantities	0% 0	60% 3	40% 2	0% 0	0% 0	5	3.60

Basic Statistics

	Minimum	Maximum	Median	Mean	Standard Deviation
BIM has helped in producing specifications	2.00	3.00	2.00	2.20	0.40
BIM has helped in producing bills of quantities	2.00	3.00	2.00	2.40	0.49

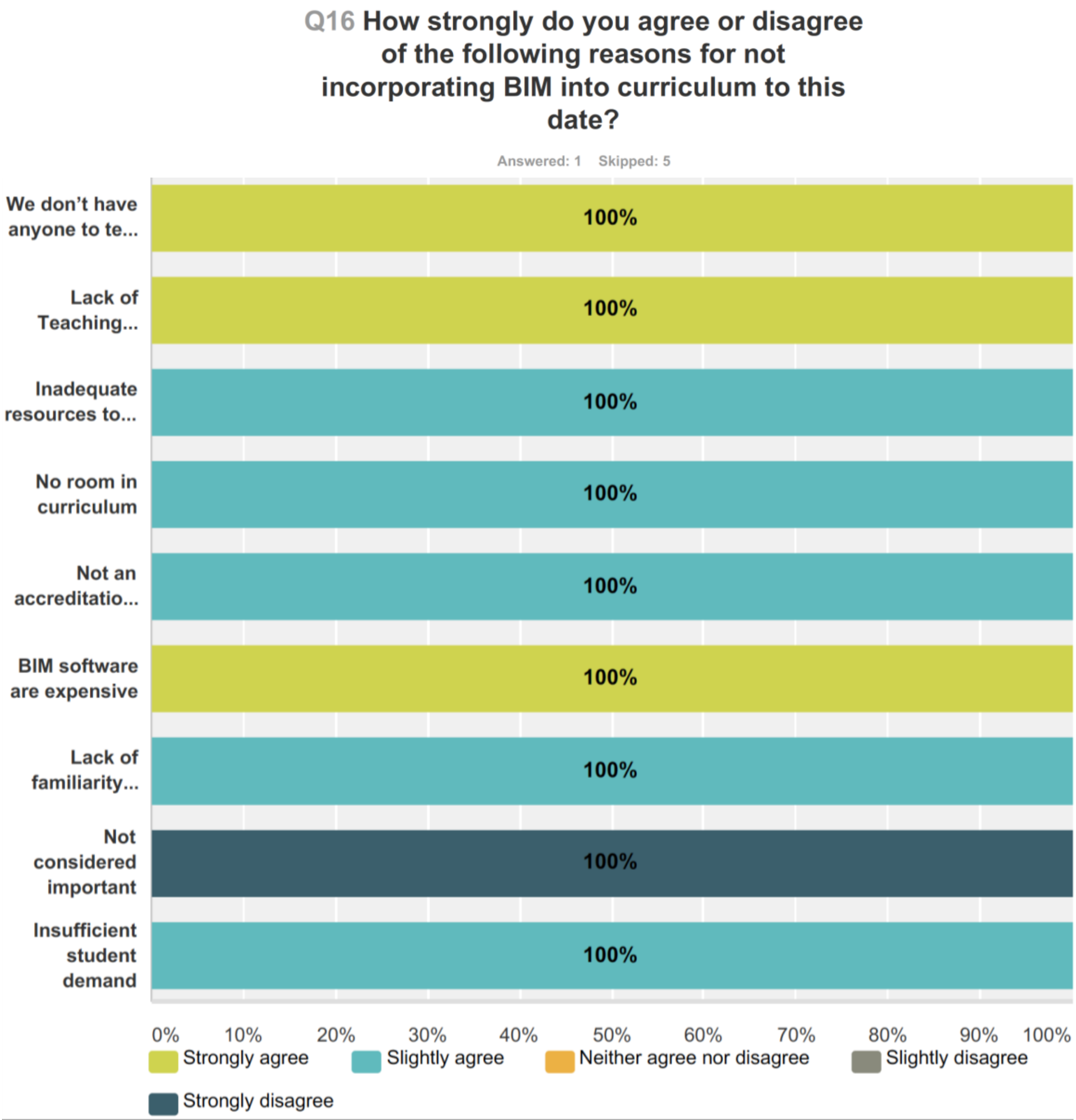
The next two sub-question enquired on tasks that architects could perform, but not often practised, which are producing specifications and bills of quantities. In the context of Malaysia, detailed specifications for construction drawings are a normal practise in the industry. However, students are not often asked to provide too much detailed specifications in their design drawings. Producing bills of quantities (BQ) on the other hand is a task often carried out by quantity surveyor rather than architects, both at education and industry level. For both enquiries, more than half of the HEIs claimed that BIM have helped their students in these two departments albeit preferring to *slightly agree* rather than to *strongly agree*. This light acknowledgment could be due to the fact that these two tasks are not often carried out by architecture students.

	Strongly agree (1)	Slightly agree (2)	Neither agree nor disagree (3)	Slightly disagree (4)	Strongly disagree (5)	Total	Weighted Average
Students are happy in using BIM	0% 0	40% 2	40% 2	20% 1	0% 0	5	3.20
We have used BIM successfully	0% 0	60% 3	20% 1	20% 1	0% 0	5	3.40
We rather stick with CAD than adopt BIM	0% 0	0% 0	0% 0	40% 2	60% 3	5	1.40

Basic Statistics

	Minimum	Maximum	Median	Mean	Standard Deviation
Students are happy in using BIM	2.00	4.00	3.00	2.80	0.75
We have used BIM successfully	2.00	4.00	2.00	2.60	0.80
We rather stick with CAD than adopt BIM	4.00	5.00	5.00	4.60	0.49

The next three sub-question gives some background as how to sum up the above experiences by the HEIs. From the five HEIs, only two (2) have lightly claimed that their students were happy with using BIM. Two (2) more HEIs have yet to learn from their students on this matter, while one (1) HEI have lightly claimed that their students were not so happy in using the technology. This indicates that none of the HEIs could conclude that the majority of their students are having a great experience with BIM, reflecting the overall user experience of BIM and its effectiveness in the architecture education in Malaysia. These experiences of introducing BIM into the curriculum of the HEIs in Malaysia were typical to some HEIs in North America. Sabongi (2009), who did a survey on construction based programmes in North America, reported that findings have shown that many students were not very pleased with the introduction of BIM programmes in their respective HEIs and cited the complexity of BIM and lack of support being major factors. Weber and Hedges (2008) from the University of Wyoming and later Taiebat et al. (2010) from Virginia Tech, have also reported on their initial experience of implementing BIM, and both stated that students were also not keen or pleased on their initial experience of learning BIM due to its steep learning curve. However, eventually the conditions were found to improve and by the end of the programme, most of the students agreed that the benefits of learning BIM outweigh the early struggles and that it was the right decision to take up BIM. The response by the HEIs in Malaysia towards the last two sub-questions somehow relates to the above experiences. Despite only three (3) out of the five HEIs have only lightly claimed that they have adopt BIM successfully, which was not wholly conclusive, none of the HEIs posit that moving from CAD to BIM was a wrong step.



BIM barriers (Q16). As stipulated earlier, the only HEI that did not adopt BIM into their curriculum is USM. Therefore, this question, delves into the reasons and related matters as to why BIM was not adopted, was only answered by USM. Based on the response above, all but one of the statements were agreed upon by USM. Among those agreed, three (3) statements were *strongly agreed* and five (5) statements were *slightly agreed*. Those that fall under the first category include not having anyone qualified to teach BIM, lack of teaching assistant support, and the high cost of the BIM software application. Those fall under the latter category include inadequate resources to fully revise the curriculum for effective BIM inclusion, no room to include any new syllabus into the existing curriculum, not a required criterion for programme accreditation by LAM, lack of familiarity and expertise of the BIM technology, and having insufficient demand from students. However, USM still strongly acknowledged the importance of BIM. The findings to this question seems to be in comparable to the findings of Becerik-Gerber et al. (2011a), who surveyed 101 AEC programmes in the United States in 2011. According to the survey, the HEIs that have not adopted BIM cited the following reasons for not doing so: not having anyone to teach BIM, inadequate resources to revise the curriculum for effective BIM inclusion, not enough room in their curriculum to integrate BIM modules, and lack of accreditation specificity for BIM. However, similar to USM, these HEIs in the United States that have not adopted BIM also fully acknowledged the importance of BIM towards AEC education.

Q17 "It is important to focus in teaching students on the conceptual knowledge and understanding of BIM rather than on the proficient skills of BIM software".Do you agree or disagree? Please elaborate.

Answered: 5 Skipped: 1

#	Responses
1 UiTM	Disagree. Its necessary to teach students to be slightly proficient in bim. They need to understand so that its easier to make concrete decision once they are working in the architectural profession. Bim is a powerful tool for decision making... However during studying students have also other knowledge they need to learn n understand in a short period of time. Conceptual knowledge n understanding of bim would be relevant to other profession such as project managers, stakeholders. Questions post earlier in the questonaires are relevant. It would be better if the questions are separated for part 1 and part 2 of the architectural training...
2 UTM	It depends on which level we're teaching them. At the lower levels, particular towards the end of Part 1, a strong conceptual knowledge and understanding of BIM is needed. BIM covers a wide range of capabilities, some crucial at the earlier stage, while others more essential towards the end. Even to the experienced CAD users, BIM can be very foreign. Students in UTM are first exposed to AutoCAD (in 1st year) as a drafting tool, and Sketchup as a modelling tool. It's easier to approach BIM (at the end of 2nd year) using their current understanding of those software as a framework. By understanding what BIM can do and what it can offer, it's much easier for them to grasp the tool in their hands, and eventually move on to specialise themselves at the upper level. In the final semester of 3rd year and eventually in the Part 2 programme, students are imbued with specialised BIM skills like energy simulations, project development through time, advanced structural modelling and such. This is of course assuming that they've already acquired the necessary basic skills and proper understanding of BIM.
3 USM	Yes, I agree. Architecture students should understand the fundamental principles of BIM; its pros and cons. The ideal scenario is that architecture students are able to operate and manage BIM effectively. In other words, BIM for architects is for managing design, construction and cost - not for purely operating the tools only.
4 IIUM	Strongly agree. The reasons as below: 1. The student knows the appropriate method & technique for the design experimentation & exploration. 2. Fully utilized the technologies offered in BIM, directly respond to performative architectural design. 3. The design process will become faster as meet design requirements. 4. Meet the objectives & learning outcomes of the architectural institution.
5 UPM	both are required. the proficiency in the use of BIM encourages the usage of BIM.....just undertanding BIM and its conceptual knowledge without really utilizing it well will result in the 'NO' or less/lack of usage. Thus making BIM not useful..

BIM curriculum direction (Q17). According to many BIM educationist and researchers, there are two distinct philosophies in teaching BIM; equipping students with the conceptual knowledge and understanding or teaching them to master procedural knowledge of using BIM applications (Taiebat and Ku, 2010b, Ku and Taiebat, 2011, Barison and Santos, 2012, Kiviniemi, 2014). The huge difference BIM has brought to the field as compared to CAD, brings a new dilemma to the educationists that have aspire to equip graduates with the skills and thinking deemed best to generally fit the workforce. This is the reason why this question is crucial, as the outcome from the response to this question, together with the views from the industry, will assist in forming the direction of BIM teaching philosophy in Malaysian architecture education. This question was posted to all HEIs that have implemented BIM into their teaching curriculum. As for that matter, USM did not participate in this question as they have not implemented BIM into their curriculum.

Based on the table above, IIUM, UM and UTM agreed that the philosophy of BIM teaching should be geared towards teaching students on the conceptual knowledge and understanding of BIM rather than on the proficient skills of the software, while UiTM disagreed and UPM quoted both approach as being equally important. The reasons quoted by UM was that it is more important to know how BIM could be used on a wider scale of the profession and industry, as the roles of an architect goes beyond just operating software tools. IIUM quoted that students needed to know the right way on how to effectively use BIM during design development stage, as this process is no longer going to be the same as during the CAD era. This is because BIM projects real-time collaboration between consultants, and becomes a platform for other software to perform performative analysis, even during design development stage. UTM also added that students needed to be introduced to BIM first through the understanding of its wider role in work deliverables and its holistic features, which is very different from CAD. This was also due to the fact that CAD and conventional 3D modelling was still part of the curriculum and it is more convenient for the students to learn the software skills of BIM only after they have become accustomed to CAD and 3D modelling. However, UTM posit that BIM teaching for post-graduate program should focus on the technical skills of using the software, when students would be better prepared.

UPM, while not disagreeing to the importance of the conceptual knowledge and understanding of BIM, posit that equipping students with the software skills is equally important. This is because theoretical and practical knowledge on any matter needed to go along hand in hand, as the former will support the latter and vice versa. Needless to say, UPM's view, though may sound the ideal, may not be as easy to attain, because the effort to introduce too many BIM modules into an already saturated curriculum might be impractical. UiTM on the other hand was the only one to entirely disagree entirely to the question statement. While acknowledging that students needed to have the conceptual knowledge and understanding of BIM, it is rather more important for HEI to spend their very limited time to equip students with proficient skills of using the software. This is due to the fact that the curriculum may already be too saturated and if it is needed to choose between equipping students with conceptual knowledge and understanding, or equipping students with the procedural knowledge of using the software, it is better to choose the latter. There is a possibility that UiTM may have looked upon the local culture in the profession where fresh graduates are often given specific roles or tasks in the lower tier of projects, which necessitate technical skills rather than at the managerial level, which require comprehensive understanding and proficiency on the overall process.

Q18 "Keeping the curriculum in line with the needs of industry is an important challenge given that the AEC industry is poised for rapid transformation. However, AEC education should be setting the pace rather than keeping the pace with the industry."(Becerik-Gerber, Gerber et al. 2011)Do you agree or disagree that Academic institutions should lead the way in adopting and promoting BIM? Please elaborate.

Answered: 5 Skipped: 1

#	Responses
1 UiTM	In the case for Architectural training.. Disagree. BIM is not the only tool in design teaching. Training of design is a totally different subject matter as compared to bim alone. For the management of design project, yes, it is necessary that bim is taken into account as part of the curriculum. Its agreeable that the academic institution should lead in the research of adopting n promoting bim.
2 UTM	Assuming the institution is already geared to fully train the students in BIM, I strongly agree. The problem with schools particularly in Malaysia is their reluctance to embrace BIM as the next step of the evolutionary ladder. Even in UTM the resistance towards BIM is still strong, and it was until PAM (Pertubuhan Akitek Malaysia) deliberately pressed Architecture Education Providers (AEP) in Malaysia to start focusing in BIM did the members of the school start to give way to it. Once the school is ready, then they should be allowed to develop BIM to fit the needs of the industry. Until they do, the industry has to keep pressing the schools to do so.
3 USM	I disagree. For me, both education and industry sector should collaborate and work together to achieve what best BIM can provide for the construction industry. Future collaboration will provide the necessary path for both sectors to progress simultaneously.
4 IIUM	Strongly Agree. The revolution of BIM has to start with the researches (conference or seminar), with concrete scientific findings before applying it to the real world.
5 UPM	agree..but somehow industry needs must be taken into consideration too. if the industry is not utilizing or incorporating BIM in the daily activities..then the skills of the graduates will not be put into good use.. but it is always an advantage for the graduates to be skillful in BIM when they graduated. the 'popularity' of BIM in the industry should be increased.

Academia role in leading BIM (Q18). This question takes the survey deeper by quoting Becerik-Gerber et al. (2011a) that not only architecture HEIs must equip their students with BIM skills and knowledge, but they should in fact lead the way in adopting and promoting BIM within the AEC field in the country. As with the previous question, this question was posted to all the HEIs that have implemented BIM and therefore USM did not participate in this question as they have yet to implement BIM. The response to this question revealed that majority of the HEIs (UTM, IIUM and UPM); agreed that HEIs should lead the way in championing BIM rather than just keeping pace with the industry, while UiTM and UM disagreed. According to UPM, graduates with BIM skills are seen as having an advantage over those who do not, and supplying the industry with graduates who possess such skills and understanding of BIM could lead the architecture firms into adopting the technology, hence how HEIs indirectly led the way. UPM have however cautioned that any effort to champion BIM has to be in touch with the reality on ground as not to allow any effort becomes too excessive and therefore end up being wasteful. UTM, while also agreeing that HEIs should lead the way in championing BIM, expressed disappointment that many in the architecture education have also been reluctant to change to fully accommodate BIM, and architecture associations like PAM must step in and collaborate with the HEIs in championing BIM. IIUM, which also agreed that BIM implementation should be led by HEIs, posit that the best way to do it is by research. This notion is also shared by UiTM, who also suggested that if HEIs were to champion BIM, it should be through research. This is in line with the thoughts of many BIM researchers that there is a lack of research that could help guide the industry towards implementing BIM (Becerik-Gerber et al., 2011a, Kim, 2011, Gu and London, 2010, Aram et al., 2013).

However, UiTM disagreed if HEIs were to champion BIM through architecture training of graduates. According to UiTM, for architectural training, emphasis must be given to the training of design thinking, which is fundamental in architecture education. BIM on the other hand is deemed to be just one of the many tools used to train design thinking. UM, another HEI that disagreed to the question statement, posit that HEIs and the industry should cooperate instead, in promoting BIM and not let just one party to carry the burden all by itself. Collaborative effort in the near future will allow for both sectors to progress simultaneously.

6.7.4 SEGMENT 4 – BIM RESEARCH

Current BIM research in Malaysia's HEIs.

Q19 Number of overall projects (research grants)

Answered: 5 Skipped: 1

#		Responses
1	UiTM	not known
2	UTM	None currently.
3	USM	- not known -
4	IIUM	More than 10 projects.
5	UPM	no information

Q20 Value of grants for the above research (in RM)

Answered: 4 Skipped: 2

#		Responses
1	UiTM	not known
2	UM	- not known -
3	IIUM	More than 100k
4	UPM	no information

Research grants on BIM (Q19 & Q20). As for these two question, only IIUM provided with the necessary information as an insight into their research work. Based on the response, it can be considered that IIUM are active in BIM research with more than 10 active research grants worth more than RM100,000 (£19,000) in total. UTM stated that they did not have any active research grants on BIM at the time of survey and all the other HEIs have not provided with any information on this matter. It is worth noting that some HEIs may be reluctant to reveal any information that involves the fiscal details of on-going research works of high value until the research has completed and made public.

Q21 Research within the department

Answered: 4 Skipped: 2

#		Responses
1	UiTM	Research in relation to information modelling.
2	UTM	Revit for Measured Drawing - This research looks into adopting BIM as a tool for Measured Drawing to replace traditional CAD drafting. Information collected from Measured Drawings are now stored in a database, and can easily cross-referred to. On the students' side, this research also looks into methods of learning BIM (via Revit) sufficient enough to allow the students to construct a complete Measured Drawing exercise. This research began in May 2012.
3	UM	1. Evaluating the use of BIM in architecture education 2. Applying the BIM knowledge with interested industry 3. Integrating BIM across architecture, building surveying and quantity surveying fields.
4	UPM	no info

Research on BIM (Q21). As previously stated, the AEC industry is in need of more research that could provide them with a deeper insight into the technology and possibly guide them in their evaluation of the technology; possibly leading them into adopting the technology (Becerik-Gerber et al., 2011a) (Kim, 2011) (Gu and London, 2010) (Aram et al., 2013). This question enquired the HEIs on their current active research on BIM within their departments. Out of the six (6) HEIs, only three have claimed to be running BIM related research. UiTM stated that they do run BIM related research albeit without any detailed description. UTM have started to evaluate their action of replacing CAD with BIM as the main tool used to produce technical drawings for their *Measured Drawings* module. For this, the effectiveness and usefulness of BIM as an effective drafting tool capable of replacing CAD is under study. It would be interesting to know the level of success UTM could obtain from this. If it is proven that BIM can easily and comfortably replace CAD even for 2D drafting; a feat synonym to CAD; it would convince others to follow suit. The third HEI to have BIM research, UM, listed three (3) on-going research on BIM. These are 1) Evaluating the use of BIM in architecture education, 2) Applying the BIM knowledge with interested industry, and 3) Integrating BIM across architecture, building surveying and quantity surveying fields. All three topics pursued by UM can be seen as being relevant to an industry in a country that is about to venture into a new technology that would shape a new trajectory of working culture in the field.

Q22 Inter disciplinary research across the university

Answered: 4 Skipped: 2

#		Responses
1	UiTM	not known
2	UTM	None. So far there is only a small task-force to look into cross-discipline learning of BIM. There's no output of the task-force that I'm aware of.
3	UM	1. Applying BIM in small scale projects
4	UPM	no info

Inter disciplinary research on BIM (Q22). As a technology that prides in itself as a tool for effective collaboration working practices, it is therefore expected that research or studies should be carried out enquiring into that aspect. According to Macdonald (2012), collaborative working using BIM requires not only the learning of specific skills of using the software, but also the learning of a new way of working. However, a survey by Becerik-Gerber et al. (2011a) on 101 AEC HEIs in the U.S have found out that the majority of the HEIs are lagging behind in moving towards preparing graduates for more collaborative working practices, which was surprisingly contrary to the trends within their industry. This seems to be the same case in Malaysia where only one (1) of the HEIs that has inter-disciplinary research on BIM across the university; UM. Even so, UM reportedly admitted that that research was of small scale and did not further elaborate on the nature of the research. UTM on the other hand, while currently not having any cross disciplinary research, have at least formed a task force to look into the matter.

Q23 Joint research with the industry

Answered: 4 Skipped: 2

#		Responses
1	UiTM	Not known
2	UTM	None so far.
3	UM	- in progress -
4	UPM	no info

Joint research with the industry (Q23). Only UTM and IIUM have given some insights to this question. UTM have disclosed of not having any joint research on BIM with the industry. IIUM, which has more than 10 on-going BIM related research projects worth more than RM100,000 (£19,000) have only indicated that their research involves the industry and that progress is still ongoing.

Q24 Joint research with foreign institutions/industry

Answered: 4 Skipped: 2

#		Responses
1	UiTM	not known
2	UTM	None so far.
3	UM	- in progress -
4	UPM	no info

Joint research with foreign institutions/industry (Q24). As with the previous question, only UTM and IIUM have given some information to this question. Again, UTM have disclosed of not having any joint research on BIM with the foreign institutions or industry. IIUM, only indicated that their research on BIM also involve foreign institutions/industry and that progress is still ongoing.

6.8 SUMMARY AND CONCLUSION

The following table summarizes the whole analysis above and how these will affect the syllabus for the production of architecture graduates who can fill in the new roles and working skills required for the implementation of BIM technology.

Table 6.2: Summary of findings for Survey B

Segment 1: Demographics	
Name and position	There were six (6) respondents from six (6) public HEIs from all over Malaysia. All of the respondents are full-time lecturers.
Department and Institutions	All the respondents were representatives from all public HEIs that offers accredited architecture programs; both LAM Part I and LAM Part II. The six HEIs include UiTM, UTM, USM, UM, IIUM, and UPM. Only these public architecture schools have obtained full accreditation for their architecture programmes.
Segment 2: Applied Computer Technology	
Software	AutoCAD by Autodesk was the most popular and widely used application software among the HEIs. This is anticipated as AutoCAD is still the market leader in the global AEC industry in accordance to Wurster et al. (2014) and Smirnov (2016).
	Four (4) HEIs used Revit, a BIM software, while five (5) HEIs used Autodesk Ecotect, also a BIM related software.
Current practice.	CAD technology is still practiced by all six (6) HEIs for 2D drawings production and 3D visualization.

Drivers for new technology	The industry itself is the main driver for demanding and adopting new technology. This is followed closely by research requirements and the reputation of the technology or application.
	Campaigns by *Pertubuhan Arkitek Malaysia* (Malaysian Institute of Architects) to encourage adopting new software/technology have only small significance towards the HEIs.
Segment 3: BIM Experience	
BIM usage	All but one of the six (6) HEIs have claimed to be teaching BIM to their students. The HEI that did not participate in teaching BIM was USM.
	None of the HEIs have BIM experience of more than six years. Among all the HEIs, UM and IIUM were leading in terms of experience, having taught BIM since 2006-2008, followed by UTM (2009-2011), and UiTM and UPM (2012 onwards).
Number of BIM modules and its placement	There is a mixed finding to this aspect. Two (2) HEIs have up to 4-5 BIM related modules in their curriculum, one (1) HEI have 2-3 BIM related modules while another two (2) HEIs offers only a single BIM related module.
	None of the HEIs have taught BIM during the students' first year. Most of the BIM modules were taught during the 3rd and final year of Bachelor's degree, and also for post-graduate programme.
Nature of BIM modules	For undergraduate programme, two HEIs have BIM as core module and three HEIs as elective module. The same applies for post-graduate programmes.

BIM practice	The HEIs did not share the same view on whether to teach BIM through a single-module or having it taught intra-module throughout the curriculum.
	None of the HEIs have taught BIM through interdisciplinary modules and distance collaboration projects.
	None of the HEIs have conducted a full-scale curriculum-wide coordination when incorporating BIM into their curriculum.
	None of the HEIs have taught their students to employ BIM as a collaborative tool in team-based projects or environment.
	Only 1 of the HEI have incorporated BIM into their design studio modules.
	The majority of the HEIs in Malaysia use BIM for visualization and constructability purpose, or for performance and operations analyses.
BIM teaching experience	The majority of HEIs posit that BIM has actually helped students to enhance design creativity.
	There were mixed reviews as to the ability of BIM to 1) offer improved visualization, 2) improve productivity 3) increase the speed of work delivery 4) helping students to consider cost efficiencies in design The responses to the above were not strong and conclusive.
	There were also mixed reviews on the following statements: 1) students were happy with using BIM 2) HEI's have successfully implemented BIM

	However, all of the HEIs acknowledged the importance of BIM and none of the HEIs posit that moving from CAD to BIM was a wrong step.
BIM barriers	The top 3 barriers for not adopting BIM were: 1) not having anyone qualified to teach BIM 2) lack of teaching assistant support 3) the high cost of the BIM software application
BIM teaching philosophy	Mixed responses; albeit a slight majority posit that BIM curriculum should be taught on its conceptual knowledge and holistic understandings of the technology rather than only the proficient/procedural skills on the software.
HEIs to lead BIM adoption.	A mixed response; albeit a slight majority posit that HEIs should lead the way in championing BIM.
Segment 4: BIM Research	
Current research	Only IIUM have received grants for BIM research. Others have none.
	Out of the six (6) HEIs, only three (3) have claimed to be executing BIM related research within their department.
	Only one (1) have inter disciplinary research across the university.
	Only one (1) HEI was currently having joint research with the industry and foreign institutions/industry.

CHAPTER 7: DISCUSSION AND FRAMEWORK DEVELOPMENT

7.1 INTRODUCTION

The purpose of this chapter is to discuss the development of a framework that proposes recommendations for the implementation of BIM into architecture degree programmes in Malaysia based on the analysis and key findings obtained from Survey A and Survey B. The main findings presented in Chapter 5 and 6 that cover the trends, issues, and impacts on the current use of digital technologies including BIM in professional practices and architecture education were analysed and presented individually. In this case, the reports were presented separately without conducting cross-case analyses between the two sample groups for the purpose of preserving the originality of the data. However, it should be noted that the data were cross analysed but only within its own sample groups and presented in a narrative format. Nevertheless, the current research progressed further by employing a comparative approach for the dual-track survey by cross analysing the findings from Survey A and Survey B. Hence, the findings obtained from the cross analysis generate the points of considerations in developing the framework of recommendations. In regard to this matter, it may be clear that the nature of the framework is not prescriptive, but the main aim is to offer a comprehensive set of considerations that will assist HEIs in Malaysia to infuse BIM into their respective architecture undergraduate programmes.

On another note, the framework of recommendations for the present study was developed according to UKM's Policies of Teaching and Learning (UKM, 2016), which is aligned to MQA's Guidelines to Good Practices (MQA, 2011) and The

Manual of Accreditation for Architecture Programme by LAM (2013), and based on full course load, maintaining accreditation criteria.

7.2 FACTORS OF CONSIDERATION

On a more important note, it is imperative to identify and outline the factors of considerations that act as the guiding aspects in constructing the framework of recommendations for BIM integration. Moreover, it is believed that these considerations will ensure that the points of recommendations are practical, realistic, and able to adhere to the requirements of the authoritative bodies that are responsible to govern and oversee the development of architecture education in the country. Hence, the factors of considerations are described as follows: 1) BIM best practice as outlined by various literatures around the world, 2) LAM's accreditation requirements, 3) the Malaysian Qualifications Agency (MQA) standard requirement, and 4) Universiti Kebangsaan Malaysia (UKM) standard requirement, which will be further discussed in the following subsection.

7.2.1 BIM CURRICULUM AMONG ARCHITECTURE SCHOOLS

Up to the present time, BIM best practice and curriculum among HEIs has been an ongoing subject of academic discourse following the introduction of BIM into the architecture scene. In relation to this matter, there is a considerable amount of literature on BIM practices among HEIs around the world. However, it is important to ensure the suitability of the practices to the local context on where BIM is to be integrated into the curriculums instead of only focusing on the applied field such as architecture, construction management, engineering, and others. The followings are literatures that can be used as reference in regard to the study of BIM's integration into tertiary education, particularly within the architecture field:

Table 7.1: Current studies on BIM integration into tertiary education.

No.	Title	Author
1	The Potential of BIM to Facilitate Collaborative AEC Education	Macdonald and Mills (2011)
2	A framework for collaborative BIM education across the AEC disciplines	Macdonald (2012)
3	Experience and Lessons Learned Through Integration of Building Information Modeling (BIM) in the Architectural Science Curriculum: An Overview of The Current Pedagogy Approach	Orooji and Aly (2017)
4	From CAD to BIM: The Experience of Architectural Education with Building Information Modeling	Berwald (2008)
5	From CAD to BIM: Constructing Opportunities in Architectural Education	Livingston (2008)

7.2.2 LAM ACCREDITATION REQUIREMENT

Generally, architects are bounded by laws and acts considering that it is a professional practice. Hence, it is deemed crucial for an individual to obtain a formal education with a certain standard that reflects the level of high technicalities and professionalism required by the profession in order to become an architect. In other words, it is compulsory for those who are venturing into the architecture programmes to seek accreditation from the profession's statutory authority body, i.e. Lembaga Arkitek

Malaysia (LAM). More specifically, LAM is the responsible body in establishing the threshold standard in formal education for the profession of architects in the country that conforms to an international benchmark for standards in architectural education (LAM, 2013). On top of that, the Malaysian law stresses the importance of licensing requirement by emphasizing that individuals must possess accredited university degree with a successful completion of exams. Therefore, it is clear that graduates from non-accredited programmes would not be allowed to practice.

The accreditation process in Malaysia is known as a formal process that carries certain values and requires the fulfilment of certain criteria and standards set by HEIs in order to obtain recognition for the architecture programmes as required by the Malaysian Qualification Act 2007 (Act 679) and the Architects Act 1967 (Section 10(1)(a) and Section 4(1) (LAM, 2013). The principles and values for the programme accreditation that are taken into consideration for this research include the followings (LAM, 2013):

a) HEIs must ensure that the programme is able to contribute to the establishment of a route for professional qualification that conforms to the international standards of architecture education.

b) The HEIs must seek to ensure that the standards attained by graduates are adequate with regard to the knowledge and skills required by the profession/industry.

c) The accreditation criteria must be treated as the basis for curricular design of the architecture programme. However, HEIs are highly encouraged to venture into forming their own distinctive interpretations of the knowledge and skills as required by the industry.

Apart from that, in regards to proposing a framework of recommendations to integrate BIM into the architecture undergraduate programme, this research have also taken into deliberation on the criteria and standards required by LAM (2013) for all architecture curriculum that seeks accreditation status. Hence, the following table describes the criteria adopted by the current research in developing the proposed framework of recommendations for the integration of BIM into architecture curriculum:

Table 7.2: Criteria for developing framework of recommendations for BIM integration.

a.	Criterion 1	The programme contents (curriculum) must clearly define its i) aims and objectives ii) learning outcome (LO) iii) course outline (CO) iv) mode of delivery v) mode of student assessment
b.	Criterion 2	HEIs shall have sufficient autonomy over academic matters and its policies in developing the programme's curriculum as long as it does not differ from LAM's provisions.
c.	Criterion 3	The programme is encouraged to offer collaborative mode of learning and multi-disciplinary linkages and collaborations across the institution.
d.	Criterion 4	Supporting modules should be planned to support Design Studio through integration with evidence shown by students'

		ability to integrate the acquired knowledge into their design studio projects.

In addition, several other aspects of the accreditation criteria by LAM (2013) that is taken note are as follows:

a) The use of 2D and 3D graphics, computer generated modelling, and digital and electronic techniques are part of the *Communication* category of modules (core and electives) in the curriculum and considered as architectural design representation; not as a tool for collaboration, generating design, or simulation of construction and performances.

b) Building Information Modelling or Building Performance Simulation have yet to appear in the accreditation requirement. However, as earlier stated, HEIs must seek to ensure that their graduates are adequately equipped with regard to the knowledge and skills required by the profession/industry. Hence, the matters related to BIM integration must be taken into serious consideration because BIM is rapidly growing into an industry standard worldwide.

c) BIM would also fit into the *Design* and *Technology and Environment* category of modules based on its ability to support the objectives of these two sets of modules even though 2D and 3D graphics, computer generated modelling, and digital and electronic techniques may be part of the *Communication* category of modules.

7.2.3 MALAYSIAN QUALIFICATIONS AGENCY (MQA) STANDARD REQUIREMENT

Generally, all tertiary education programmes from foundation level to PhD level must be accredited by the Malaysian Qualifications Agency (MQA). Hence, it is compulsory to comply with all MQA's comprehensive quality assurance guidelines such as The Malaysian Qualifications Framework (MQF); The Code of Practice for Programme Accreditation (COPPA); The Code of Practice for Institutional Audit (COPIA); Programme Discipline Standards; and Guides to Good Practices. However, in the case of professional programmes or professional qualifications such as architecture, the MQA consigns the task of developing policies and coordinating accreditation process to the board of the profession's statutory authority (LAM, 2013) that falls under the Malaysian Qualifications Agency Act (MQA 2007) (Act 679):

Clause 37: (3) The Agency or, in the case of a professional programme, professional qualification or higher education provider, the relevant professional body, may direct that the Framework or any part of the Framework may not apply to any programme, qualification or higher education provider subject to such terms and conditions as it deems fit.

Clause 43: In the case of provisional accreditation of a local or foreign professional programme or professional qualification, the Agency shall cooperate and coordinate with the relevant professional body for the purpose of-

(a) considering an application under subsection 38(1) and granting or refusing to grant the application under section 39;

Clause 52: (1) After having considered the recommendation of the Joint Technical Committee under section 51, the relevant professional body may –

(a) approve the granting of accreditation; or

(b) refuse the granting of accreditation, stating the grounds for refusal.

Clause 54: The relevant professional body may, upon recommendation of the Joint Technical Committee at the time of or at any time after a certificate of accreditation has been issued under subsection 52(2), impose such conditions as it may deem necessary or expedient and may vary, amend or revoke any such conditions or impose new or additional conditions from time to time.

Hence, the above statements suggest that LAM is responsible in developing the policies and scrutinizing all architecture programmes offered by the HEIs despite the fact that MQA is named as the authority body for the accreditation of tertiary education programme for the country. Therefore, in this case, all architecture curriculum syllabus must adhere to LAM's policies and guidelines, refer to 7.1.2.

7.2.4 UNIVERSITI KEBANGSAAN MALAYSIA (UKM) STANDARD REQUIREMENT

In general, all HEIs in the country including University Kebangsaan Malaysia, are required to develop their programme curriculum based on the policies and guidelines provided by the Malaysian Qualifications Agency (MQA) (MQA, 2008, MQA 2007) (UKM, 2016). However, it is compulsory for architecture curriculum at all architecture schools including UKM to adhere to LAM's standards considering that all the tasks of professional based programme are consigned to professional bodies as recommended by MQA. Hence, any changes or additions to UKM's architecture curriculum must be based on the guidelines of LAM that can be referred in *The Manual of Accreditation for Architecture Programme* (LAM, 2013). Nevertheless, it should be noted that the accreditation provisions by LAM are not overly rigid, thus suggesting that HEIs have their own autonomy to carve their own curriculum design to a certain degree as long as it meets LAM's accreditation provisions.

The curriculum of the undergraduate programme at the Department of Architecture in UKM was largely built according to the Problem Based Learning (PBL) and Outcome Based Education/Learning (OBE/L) approach. More specifically, the programme provides tasks that involve challenging problems which requires the students to have different skills such as problem solving, decision making. and investigative skills as well as the ability to understand the outcome determined by educator (Johar et al., 2013, Rahmat, 2012, Salin, 2011). Hence, the approach adopted by UKM complies with LAM's accreditation provisions, thus it will be the base for the proposed framework of recommendations in regard to the integration of BIM into the architecture undergraduate programme. Nevertheless, it is important to note that the features of this framework may not be completely in line with other HEIs' curriculum considering that HEIs possess the autonomy that allow them to have their own unique features. However, this framework can be a solid basis that represents other HEIs because PBL approach is widely adopted among other public HEIs. Apart from that, OBL is the approach that should be adopted by HEIs based on the suggestion of MQA (Yusof et al., 2005, Awang and Ramly, 2008, Hussain et al., 2007, MQA, 2011).

7.3 DEVELOPING FRAMEWORK FOR BIM SYLLABUS: CROSS ANALYSIS BETWEEN INDUSTRY AND ACADEMIA PRACTISE

7.3.1 FRAMEWORK CRITERIA FOR BOTH SURVEYS

The main process of developing the framework involves the adoption of comparative approach by cross analysing the findings obtained from Survey A and Survey B. In this case, the dual-track survey method was adapted due to its ability to ask comparable questions between two different samples of different background for the purpose of investigating the gap and similarities on views, perceptions, practice, and culture of a topic, which in this case refers to the comparison between the industry (architecture practice) and HEIs (architecture education). Moreover, this comparative approach was employed with the purpose of answering Objective 5, 6, and 7 of this research. Specifically, the purpose is to identify the similarities and differences of the practices between the industry and education, expectations of both sides towards each other on the basis of a simple supply-demand correlation, and the subsequent steps and strategies that are able to fulfil the need of the industry and at the same time be a practical method to the HEIs.

Hence, the findings from the cross analysis performed on both surveys will then be theoretically validated by the factors of considerations that have been previously described in this chapter, particularly referring to the accreditation requirements and standards developed by LAM, MQA, UKM as well as the common practice of other HEIs from abroad that have adequate experience in the integration of BIM into their curriculum. Overall, this process generates valuable categorical data that are able to provide a wider understanding on what the industry and HEIs aspires from each other in regard to the introduction of BIM within the architecture undergraduate curriculum.

Figure 7.1: Connection between BIM industry-education research framework criteria for assessment.

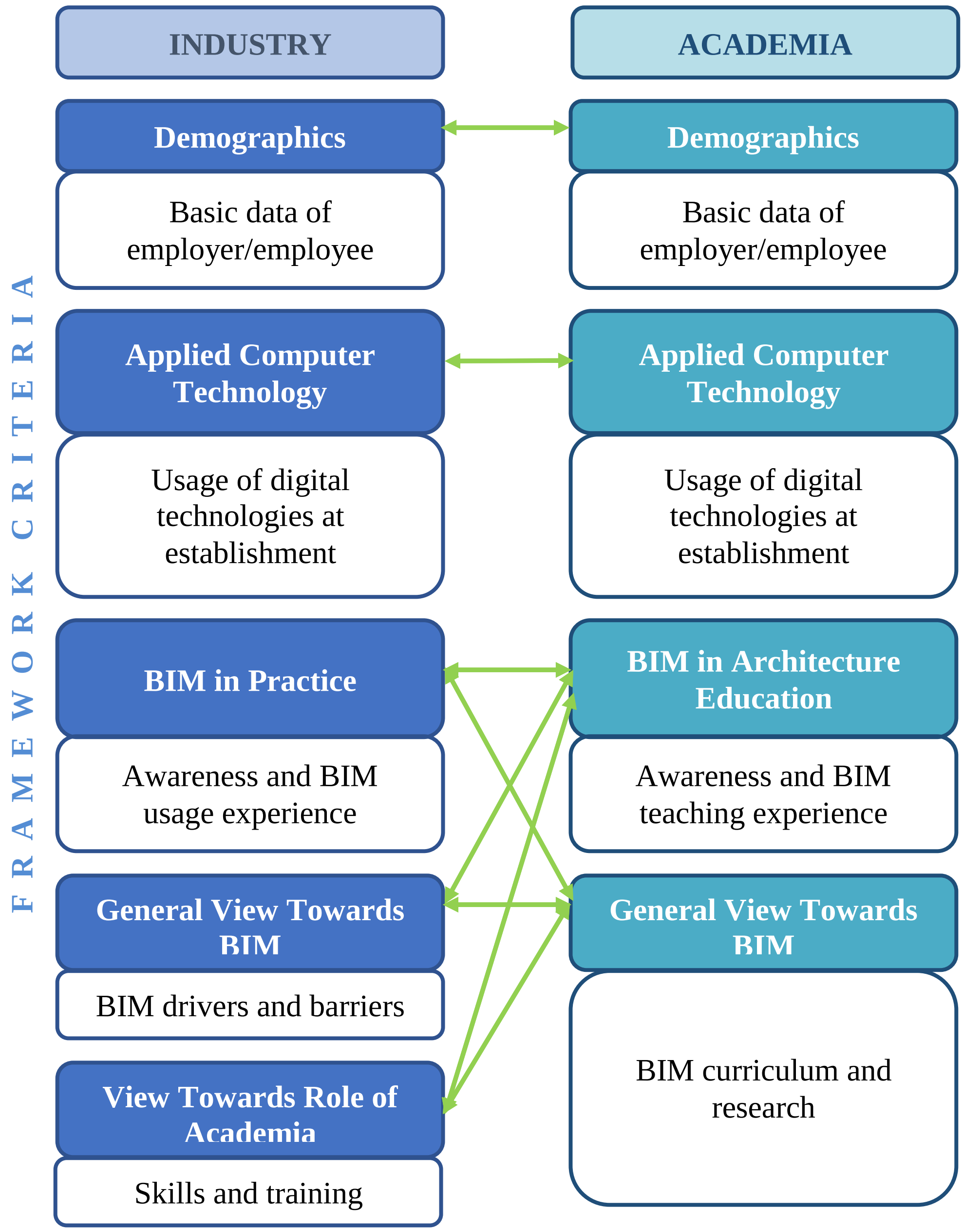


Figure 7.1 presents the research framework criteria for assessment that was previously developed and built in Chapter 3 based on the review performed on various literatures. In particular, the review explored, appraised, and synthesized the relevant literature pertaining to BIM in professional practices and academia by focusing on the relationship between the industry and academia. Subsequently, the review was summarised by quantifying the findings of the literature into an outline that builds up the case for knowledge inquiry that will be further utilised to develop the theoretical framework for the current research. As can be observed in the same figure., the framework criteria for the industry are divided into five different segments described as follows: (1) demographics, (2) applied computer technology, (3) BIM in practice, (4) general view towards BIM, and (5) view towards the role of academia. On the other hand, the framework criteria for the HEIs are divided into four segments as the followings: (1) demographics, (2) applied computer technology, (3) BIM in architecture education, and (4) general view towards BIM. In relation to this, it is important to note that the first four segments of both the survey questionnaires share the same perspectives of inquiries, whereby the difference can only be observed in the fifth segment of Survey A that involves the question regarding the views towards the role of HEIs. On another note, the first and second segments of both surveys were cross analysed to each other. However, segments 3, 4, and 5 from both surveys were not only cross analysed between the respective segments but also the across segments considering that the findings from these segments were found to correlate to each other. The tables below show the findings from both surveys that were analysed, discussed, and summarised.

7.3.2 CROSS ANALYSIS OF DUAL-TRACK SURVEY

7.3.2.1 DEMOGRAPHICS			
		Industry	**Academia**
i	**Country**	Malaysia	Malaysia

Table 7.3: Cross analysis of Dual-Track Survey in terms of demographics.

i. Geographical context

The purpose of this segment is to point out that the context of this survey is within Malaysia. In the case of this study, the samples for Survey A are comprised of only local architectural practice, while samples for Survey B involved accredited public architecture schools in the country. The purpose is to ensure that the comparison performed on the two surveys are within the same geographical context.

7.3.2.2 APPLIED COMPUTER TECHNOLOGY			
		Industry	**Academia**
i	**Software**	2D Drafting software – Actively in use *AutoCAD* > 80% usage	2D Drafting software – Actively taught *AutoCAD* – 100% taught
		3D software – Actively in use *Sketchup*	3D software – Actively taught *Sketchup*
		BIM software – 30% BIM users	BIM software – 5/6 taught BIM

ii	**Current Practice - CAD**	Conventional CAD is still industry standard.	Traditional 2D CAD syllabus is still implemented in all HEIs
		ES submission by local authorities - 2D format (DWG or PDF)	
iii	**Drivers of new technology**	Dependant on the skillset commanded by graduates. This signifies that firms are also reluctant to invest in any new software, especially if work-ready skilled employees are difficult to be obtained.	The industry is the main driver for the demand and adoption of new technology.
		As-needed basis - the needs are defined by project teams and clients.	Research requirements.
		Campaign by organizations such as *PAM* have a small significance towards the industry.	Campaigns by *PAM* have a small significance towards the HEIs.

Table 7.4: Cross analysis of Dual-Track Survey in terms of Applied Computer Technology.

i) Software

The cross analysis found that both the industry and the HEIs remain to be actively using CAD as their main drafting tools. This finding is not surprising considering that *AutoCAD* is among the pioneering CAD software that has been synonymous to architects and draftsmen when it comes to drafting which caused it to be widely regarded as the industry standard (Harrington David, 2001). Meanwhile, another finding showed that Sketchup remains the most popular software for 3D modelling. On the other hand, BIM software has gained popularity albeit more at tertiary education level with nearly all, but one has integrated it to a certain level. Hence, this indicates that traditional software specifically AutoCAD remains to be high in demand as the industry standard and must continue to be taught at tertiary education level in regard to the architecture curriculum. On top of that, it is well agreed that the architecture curriculum is commonly regarded as a cramped and crowded curriculum (Macdonald, 2012, Silverio et al., Becerik-Gerber et al., 2011a); hence, Sketchup will be a more suitable choice if there is a need to drop the teachings of any particular software to make way for BIM. The reason for this is because Sketchup is easy to learn and intuitive for both experts and novice users (Singh et al., 2013, Sun et al., 2013), whereas AutoCAD can be very technical and provides a steeper learning curve (Grossman and Fitzmaurice, 2010, Matejka et al., 2011).

ii) Current Practice – CAD

In regard to the current practice, the demands of CAD skills in the industry has led to the notion of retaining CAD syllabus in the architecture curriculum considering the fact that the Electronic Submission of drawings for building plan approval by the local authorities (local governments) still requires for 2D format rather than 3D format and must be in either DWG or PDF format. In this case, it is true that drawings generated by BIM software can be formatted into DWG or PDF; however, it may not seem justifiable to invest on a new technology because the authorities only require the formatting of the old technology that is already in-place in their respective firms. Therefore, this further enforces the fact that CAD software such as AutoCAD must still be taught in HEIs and should be retain in the curriculum.

iii) Drivers for new technology

The findings on this matter is very important due to the imminent relationship of supply and demand between the industry and HEIs. Many employers in developed nations provide continuous trainings to their staff for the purpose of enhancing their knowledge and skills level as part of their own initiative even though it is generally accepted that tertiary education is a source of supply for knowledgeable and skilful workforce. Hence, the overall expectation of HEIs is to produce ‘competent products’ rather than ‘finished products’. However, the main driver of adopting a new technology in Malaysia refers to the availability of graduates that are equipped with ready-made skills of the latest technology. As a result, this had driven HEIs to cite the demand of the industry as their main driver to adopt new technology. Hence, it is expected for HEIs to work towards ensuring that their graduates are well equipped with the appropriate skills which are deemed useful by the local industry rather than replicating ‘best practices’ developed by overseas HEIs. Therefore, the mechanism to gather information on the demands of the industry such as Survey A is deemed vital.

	7.3.2.3 BIM IN PRACTICE AND EDUCATION – EXPERIENCE AND GENERAL VIEWS		
		Industry	**Academia**
i	**BIM adoption and awareness**	Awareness of BIM and its benefits is high (>80%) within the industry. However, only 20% use BIM for projects on ground, and its usage is expected to continue in the future. Meanwhile, half of the non-user will adopt BIM, while another half are undecided.	Majority of HEIs already adopt BIM in their curriculum (>80%).
		Majority of users have < 3 years' experience. This signifies that BIM is still in the introductory phase; hence, more focus should be put on the beginner/intermediate level.	Only 2 HEIs have >3 years' experience, while another 3 have < 3 years' experience, and 1 with no experience. This signifies that BIM is still in in the introductory phase; hence, more focus should be put on the beginner/intermediate level.

Table 7.5: Cross Analysis of Dual-Track Survey in terms of experience and general views of BIM's adoption and awareness from industry and academia perspectives.

i) BIM adoption and awareness

In regard to this matter, it is considered a good start considering that both the industry and the HEIs have high level of awareness towards BIM. However, only one fifth of the industry have adopted the technology, while all but one of the HEIs have already taken the steps to adopt BIM. Meanwhile, majority of the users within the industry have less than three years' experience which seems consistent to architecture education based on the fact that majority of the HEIs have been teaching BIM for less than three years. In this case, it can be indicated that BIM is still in its infancy stages; hence, it will be inappropriate to put excessive expectations on the level of expertise that must be possessed by graduate. More importantly, HEIs should emphasise on providing BIM skills only at the beginner and intermediate level considering this factor as well as the current crowded curriculum.

Continue..			
		Industry	**Academia**
ii	**Understanding of BIM (User experience)**	Users strongly agree on the following BIM effects: - require changes in roles, procedures and workflow. - has unit or set of staff that is equipped with BIM skills and able to handle BIM related tasks.	Majority of the users seem to agree on the followings: - to conduct curriculum-wide coordination to integrate BIM. - BIM should be taught through intra-modules throughout the curriculum. - BIM must be taught through interdisciplinary modules and distance collaboration projects - BIM should be integrated into design studio. - BIM must be taught during 2^{nd}-3^{rd} or/and 4^{th} year of the programme. No collective practice or agreement in the followings:

			- BIM has to be offered as specific single-module. - BIM has to be offered as elective or core module

Table 7.6: Cross Analysis of Dual-Track Survey in terms of experience and general views on the understanding of BIM from industry and academia perspectives.

ii) Understanding of BIM (User experience)

Majority of BIM users in the industry have strongly posit that BIM requires changes in roles, procedures, and workflow. Hence, it is important for HEIs to take this issue into consideration due to the present phenomenon considering that it is not similar to CAD. However, the nature of BIM is different from CAD because CAD only requires graduates to focus solely on the proficient skills of using the application without having to worry about the procedures and workflow of architecture practice. In relation to this, the changes that comes with the adoption of BIM require graduates to understand the bigger picture of BIM effects on the practice, including how they would fit into the overall scheme. Therefore, equipping graduates with the conceptual knowledge of BIM is deemed as the most appropriate option because it provides them with the micro and macro understanding of BIM instead of only focusing on its procedural knowledge. Apart from that, introducing a multi/inter-disciplinary course that involves students from other courses such as construction management, quantity survey, engineering and others will further expose the students with new roles, procedures, and workflow that are involved in the usage of BIM for a project.

On a more important note, the relatively short experience of HEIs in teaching BIM have led to the following conclusions: (1) a need to conduct a curriculum-wide coordination to integrate BIM, (2) BIM should be taught through intra-courses throughout the curriculum, (3) BIM must be taught through multi/inter-disciplinary courses and distance collaboration projects which are deemed consistent considering that an understanding of the impacts that BIM has on the roles, procedure, and workflow can be achieved, (4) BIM should be integrated into design studio because it will train students to deliver full scale design projects using BIM, and (5) BIM is suggested to be taught during third or/and fourth year of programme. Moreover, it is best to teach BIM at the second, third, and fourth year of the programme because various studies by researchers posited that BIM requires certain level of technical knowledge to ensure that it can be effectively used (Woo, 2007, Roth, 2017, Clevenger et al., 2010, Zakaria et al., 2013). However, there is not a collective consensus among the HEIs as to whether BIM should be mainly taught as core courses or elective courses, or whether it should be offered as a single standalone course or integrated into other existing courses. On a similar note, BIM has been taught in the U.S as being part of both core and elective courses that are respectively represented as 50% and 70% elective courses (Becerik-Gerber and Rice, 2010).

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		Industry	**Academia**
iii	**BIM features (user experience)**	Most users agree on the following BIM features: - a system, not just simply a software to produce 2D or 3D drawings. - for real-time collaboration.	Majority have agreed on the followings: - BIM must be taught and used for collaboration purposes

		- for visualisation - to produce green & sustainable architecture design - for project management - coordination of construction drawings/documents - for project information - for producing specification	- BIM should be used for 3D visualisation. - BIM must be used for further energy simulation/operation analysis. - BIM should be used for constructability purposes - BIM can be be used for clash detection. - BIM must be used to tie schedules to models - BIM must be used to tie estimates to models

Table 7.7: Cross Analysis of Dual-Track Survey in terms of experience and general views on BIM features from industry and academia perspectives.

iii) BIM features (user experience)

As can be observed in the above table, it can be concluded that the industry and the HEIs seem to agree on the usage of several BIM features. In regard to this, it is important for these features to be included into the syllabus of BIM-related courses and be taught to students because these features have been used by architecture firms in the country for their work deliverables. On the beginner/introductory level, students can be provided with the knowledge on several aspects as follows: (1) the conceptual understanding on the BIM system and its attributes, (2) 2D and 3D visualisation, (3) the understanding on how simulation features on BIM can be of help in producing green and sustainable design, and (4) the projection of information and specification. On the *intermediate level*, more advanced features can be added on top of the features that are taught during beginner's level which include the followings: (1) BIM as a real-time collaboration tool, (2) run energy/performance simulation and operation analysis, (3) for constructability purposes, (4) for clash detection, (5) to tie schedules to models, and (6) to tie estimates to models. On top of that, students should be made aware on how BIM can be used to manage a project (through *Professional practice* course) as well as coordinate construction/design drawings (*Cross/Multi-disciplinary Design Studio* courses) considering that these features are currently in use by the industry.

Continue..			
		Industry	**Academia**
iv	**BIM barriers and drivers**	Majority agree on the followings: - there is need for interoperability and compatibility between BIM-CAD - in-need of BIM skilled staff - in-need of training - in-need of credible accreditation process - inadequate demands for BIM from clients - in-need of complete understanding from all parties - in-need of industry standards - in-need of more research	

Table 7.8: Cross Analysis of Dual-Track Survey in terms of experience and general views on BIM barriers and drivers from industry and academia perspectives.

iv) BIM barriers and drivers

The above table shows the drivers and barriers of BIM usage among architecture firms in the industry. The first point touches the need of interoperability and compatibility between BIM and CAD that should be taken into consideration by HEIs and included into the teaching curriculum. In regard to this matter, it is crucial for undergraduate students to be taught with the knowledge on both AutoCAD and BIM because the former is still regarded as the industry standard, while the latter is the rising technology that is rapidly growing into becoming the next industry standard. In this transition period, it is necessary to ensure that graduates are able to work on both applications and cross use it whenever the need arises without complication.

The second point addressed by the industry concerns the need for all parties involved in a project that required the use of BIM to have a complete understanding on BIM. Hence, this relates back to section ii) and iii) where multi/cross-disciplinary studio course can be considered as the key to address this concern. In this case, students from all backgrounds of built environment programmes will be able to play their respective role in a project that involves BIM usage. More importantly, this will expose the students to the expectations of the working world. Research by Barison and Santos (2010a), Becerik-Gerber et al. (2012), Singh et al. (2011), McGough et al. (2013), Macdonald (2012) and Tang et al. (2015) managed to demonstrate the above notion.

In relation to sub-table 7.3.2.2, the industry reiterates that they are lacking in training and skilled staff. Therefore, it is expected of HEIs to come up with appropriate solution in handling this issue considering that the industry may not be capable of solving this alone and that HEIs can provide the necessary assistance. This finding is in line with the findings from earlier studies by Chew (2005) and Hooi (2010).

7.3.2.4 INDUSTRY – EDUCATION RELATIONSHIP			
		Industry	**Academia**
i	**Views towards Education and HEIs**	Majority agree on the followings: - HEIs should produce more research - should champion BIM - HEIs graduates are expected to have adequate IT skills - graduates should possess the right IT skills needed by industry - HEIs should teach conceptual knowledge of BIM rather than proficient skills	Majority agree on the followings: - the conceptual knowledge of BIM should be taught rather than proficient skills - HEI should lead the way in championing BIM - there is limited number of research on BIM at present. Only 50% are conducting research on BIM.

Table 7.9: Cross Analysis of Dual-Track Survey in terms of the industry and education relationship.

The final segment of the survey questionnaires seeks to explore the level of expectations of the industry towards HEIs as well as how HEIs perceive their own capability in coping with the demands of the industry, particularly in regard to BIM. On a more important note, both parties agree that the graduates should be taught the conceptual knowledge of BIM rather than focusing on the proficient/procedural skills of using the software. This finding is consistent with many views around the globe that states the importance for graduates to understand the whole concept of BIM as its implementation brings changes to the roles, procedures, and practices, and project workflow, which is very different from CAD (Taiebat and Ku, 2010a, Taiebat and Ku, 2010b, Ku and Taiebat, 2011).

On another note, it is worth noting that both the industry and HEIs agree that HEIs should lead the way in championing BIM. Hence, one of the ways is to produce more research on BIM apart from training graduates with the right skills, which will help convince the industry on adopting BIM (Bordass and Leaman, 2013, Becerik-Gerber et al., 2011a, Demian and Walters, 2014).

7.4 CONSTRUCTING THE FRAMEWORK FOR BIM SYLLABUS

A framework of recommendations was developed at the final stage of the research based on the findings obtained from the comparative approach of cross analysing Survey A and Survey B. More importantly, this framework follows the following criteria required by the authoritative body of LAM and MQA: (1) aims and objectives, (2) learning outcome (LO), (3) mode of delivery, and (5) mode of assessment. The course outline (CO), which provides recommendations for the overall plan and schedule for the module throughout the semester, were general in nature without being too detailed. This is because a detailed weekly planning of the module should be tailored to fit the wider scale planning of the curriculum of the particular HEI; hence, it is highly recommended for the weekly planning to be further developed by all respective HEIs themselves.

7.4.1 MODULE CATEGORIES

The pedagogical framework of the present study proposes four types of modules according to the method that is employed to integrate BIM into the architecture curriculum as described below:

i) Integrated modules

A certain percentage of the content in the existing modules in the curriculum of the architecture programme (LAM Part I and Part II) should be replaced with BIM syllabus. In this case, the following two methods can be employed to realise the replacement of the content: (1) a certain percentage of the original content is removed and replaced with BIM syllabus, or (2) the original module content has to be compressed to allow for the inclusion of BIM syllabus. The existing modules that suit this purpose, which are often core modules, are *digital graphics (DGR)*-based modules that include the teaching of CAD, 3D modelling and image editing software.

According to the studies and surveys carried out by Sabongi (2009), Ghosh (2013), Mandhar and Mandhar (2013), Sacks and Pikas (2013), Dobelis (2015), and Abdirad and Dossick (2016), the integration of BIM syllabus into the existing digital graphics (DGR) modules has become the most popular method used by HEIs around the world. in relation to this, several reasons have been quoted by the studies in regard to this situation. First, a high number of HEIs are not willing to replace the existing DGR modules with the full BIM syllabus. Moreover, it should be noted that most graphic software including CAD are still being taught due to the continuous demands of the industry despite the urgent need to introduce

BIM to students. Second, there is a general consensus that the conceptual understanding of BIM technology needs to be introduced to students at an early level (Barison and Santos, 2014). However, it is important to understand that the Year 1 or Year 2 students are only required to be receive early exposure to BIM instead of being taught the full-scale syllabus considering their limited knowledge on construction. In other words, only a portion of the module syllabus is necessary for the introductory purposes. Third, the integration of BIM into the existing modules may seem as a safer approach in regard to maintaining the fulfilled requirements for accreditation status. In general, it is safe to say that to carry out revisions on the contents of existing module syllabus is considered much easier than developing a fully new module which may involve a long and intricate process.

ii) <u>Standalone modules</u>

The standalone modules refer to the new modules whereby the module contents are made up with only BIM syllabus. Obviously, it is different from the *integrated module* considering that the course outline (CO) of a *BIM standalone module* for the whole semester will be completely filled with only BIM syllabus. Similarly, there are also two methods to implement this plan which involve the followings: (1) an existing standalone module is removed and replaced with BIM standalone module, or (2) adding an additional standalone module into the existing curriculum which will result in extra work load for the teaching staffs as well as the students. However, it is crucial to note that BIM standalone module will be made as an elective module rather than a core module because it is a full-scale module of its own that is sequence to the introductory phase of BIM. Hence, this may only be appealing to students who wish to expand their basic knowledge and skills in the technology.

In regard to the above matter, it is worth highlighting the findings from the studies conducted by Clevenger et al. (2010), Wu and Issa (2013a), and Sacks and Pikas (2013) which state that it is a common practice among HEIs to offer BIM standalone module as a sequence to BIM integrated module. In fact, a survey by Wu and Issa (2013a) carried out in North America showed that both BIM standalone modules and BIM integrated module are offered by approximately 50% of the HEIs with AEC programmes, which further demonstrates the substantial demand from the students for intermediate/advanced level BIM module. Apart from that, this also indicates that the HEIs have been increasingly responding to the needs of the industry and recognising the need to offer full-scale BIM module to its students despite the potential complications.

However, it is worth to note that the offerings of standalone BIM modules by HEIs came with numerous concerns. There have been critics from a few researchers on the suitability of teaching BIM as a standalone module as opposed to other approaches. Studies by Ghosh et al. (2013) and Clevenger et al. (2010) argued that providing standalone BIM modules without continuous exposure of BIM in other modules would not be able to help the students with their long-term learning considering that they will be a risk of losing the skills by the time they enter the workforce. In addition, Wu and Issa (2013a) further indicated that a standalone BIM module can be disruptive due to the nascent nature of BIM within the curriculum. More importantly, the teaching of BIM that is conducted without proper context can definitely magnify different learning experience; albeit in a negative way due to the fact that BIM is very much considered as a new technology with topics related to many other modules within the curriculum. Nevertheless, the current research posit that such outcomes can possibly be avoided if BIM syllabus is developed and implemented based on the entirety of the proposed framework despite the critics on the implementation of standalone BIM module. First, the framework suggests that the standalone BIM module should be offered to third year students as an elective module which acts as the sequence to the BIM integrated core module that introduces the students to BIM. Apart from that, it should also be subsequently preceded by a multi/inter-disciplinary design studio and applied BIM modules as elaborated in the next sub-chapters. In this case, it safe to say that the standalone BIM module provides the opportunity to students who are interested in expanding their basic knowledge and skills on the technology. Furthermore, the existence of various types of BIM-related modules as stipulated by the framework may be able to prevent the learning experience of BIM from becoming obscure and shockingly different.

Lastly, it is also important to note that the BIM standalone module shall be a 3-credit course with 1 actual credit representing 40 notional hours (MQA, 2014). This is aligned to most other elective modules within the *Communication* and *Technology* category offered by other HEIs in the country (USM, 2014, UTM, 2017, IIUM, 2017, UKM, 2018). In other words, there shall be 3 *contact hours* and 4-6 hours of *individual learning* every week that runs on a stretch of 14-week semester. The BIM standalone module is the only module that comes with a proposed credit value due to its 100% BIM content in the syllabus while the credit value of other types of BIM-related modules will be determined by the respective

HEIs based on the percentage of BIM content in relation to the overall content of the syllabus of the particular module.

iii) Multi/Inter-Disciplinary Design Studio

In this case, the Year 4 conventional design studio is suggested to be replaced by the inter/multi-disciplinary collaborative design studio module which brings together undergraduate students from multiple built environment backgrounds such as landscape architecture, quantity surveyors, engineers, and others. This studio functions as a capstone module which is modelled on the *design development* process of a true-life project through the introduction of Integrated Project Delivery (IPD) approach to the students, while BIM is utilised as the platform for formal team collaboration. However, the BIM syllabus in this module will not include the teaching of any procedural skills of digital modelling, but instead focuses more on BIM tools for collaboration, simulation, and analysis purposes given that this module requires the *integrated BIM module* as the prerequisite module.

It is important to note that there are concerns regarding the integration of BIM into the architecture design studio which have received considerable attention among the researchers in the architecture education field. This comes to no surprise as Renée Cheng (2006) from AECbytes once argued that BIM is 'answer-driven', while design thinking is 'question-driven'. The architecture design studio is often based on the 19th century École des Beaux-Arts which has always had the tendency to treat design artefact as an 'art' as well as to pursue innovation and creativity above all else (Pihlak et al., 2011). However, BIM has been challenging numerous philosophies on traditional ‘good’ design with its rigour processes and quantitative inputs. Nevertheless, both the industry and the HEIs are left with no choice but to address the dynamics of a new professional context that involves technological innovation such as BIM for the purpose of staying competitive and relevant to the population. In regard to this matter, the core to architecture education that is known as the design studio must be re-structured in order to allow itself to hybridize with BIM and its integrated practice without having to sacrifice the comprehensive nature of design thinking, thus further reflecting the much-evolved practice in the current industry. Therefore, careful steps should be taken when taking into account that a careless introduction of BIM to the design studio could negatively affect the design thinking pedagogy as well as the studio’s role in architecture education.

On a more important note, it is crucial to understand how the objective approach of BIM can affect the subjective approach of design creation, particularly when searching for the suitable blueprint to integrate BIM into the design studio. Furthermore, it has been generally accepted that the process of generating architectural ideas is often delicate which requires the freedom to explore. Hence, it should be understood that a quantitatively rigorous analysis performed at a very early stage is not considered as the normal practice because such actions are often deemed to be limiting the creative process (Denzer and Hedges, 2008). Moreover, it is interesting that the creative development of architectural ideas often involves a chronology of ideating, exploring, and modifying steps that are carried out over a number of cycles which is expected to lead to a final design that is creative yet tangible, meaningful, and executable. Hence, with regards to achieving the mentioned objective, a test and analysis performed on any creation of architectural design that is provided with quantitative input will be able to guide the designer to perform the necessary modifications required to improve the design creation. Overall, this practice will aid the overall creative development of the design considering that the input from BIM plays a significant role in turning creative decisions into meaningful decisions.

The current framework recognises the importance of integrating BIM into the process of design thinking considering all of the mentioned factors, which leads to the proposal that BIM syllabus should be integrated into the design studio module. However, this is only to be applied for a single semester of the 4th Year level (or 1st Year M. Arch) in a cautious attempt to delicately integrate BIM into design thinking pedagogy, particularly in regard to a multi/inter-disciplinary approach involving senior undergraduate students from various built environment undergraduate programmes. In addition, there are several reasons that leads to this situation. First, BIM requires a certain level of proficiency on the construction and technical understanding of designs, thus indicating that the integration of BIM is more suitable to be performed on senior students of Year 4 and above considering that they have managed to acquire such level of knowledge input. In other words, students who are still at the beginner stage are probably not equipped with the necessary level of technical knowledge required by BIM for design work. Second, the students of Year 1 to Year 3 are still at an early stage of developing their *design thinking*; hence, emphasis should be put on the freedom to explore creativity as well as the need to understand the fundamentals of design instead of testing design creation with rigour quantitative processes. All the students are expected to progress towards the completion of the programme, which further indicates that more and more emphasis should be given towards testing and demonstrating the efficiency and practicality of their design. Third, it is time for the students who have acquired the fundamentals of design thinking in their first three years of study to be introduced to a *real-world* practice scenario which involves high-level collaboration among team players of different backgrounds that are assigned with specific roles and responsibilities. In this case, architecture students will be challenged to produce designs that can be valued and technically understood by other 'consultants' within the team by working hand in hand throughout the *design development* process. Therefore, this process is deemed to involve the cycles of tests, simulations, analysis, and modifications to both the aesthetics and technical aspects of the design that will be conducted on BIM platform.

iv) Applied modules

These modules may not contain formal BIM syllabus, but BIM is highly required to be used by the students in handling their tasks or project deliverables. On a similar note, it is also possible for the applied modules to be mapped together with the integrated or standalone modules of BIM which can be realised through joint assessments. In this case, the contents of the tasks will be assessed by the former, while the techniques of delivering the tasks should be assessed by the latter. Nevertheless, there is an argument that states the applied BIM module is a form of integrated module considering that the method also involves the integration of BIM into the existing core or elective modules. However, it should be understood that this type of module actually differs in terms of not having formal BIM syllabus in the course content (CO) because BIM is only utilised for the execution of domain specific activities such as reviewing *building technology*, *construction* or *structure* matters.

On another note, the applied BIM module is an approach of infusing BIM into the curriculum by the means of spreading its usage across the curriculum which has recently gained considerable attention among the HEIs in developed countries (Forsythe et al., 2013, Puolitaival et al., 2016). Contrary to the previous three types of BIM modules, a BIM applied module will not include BIM as a part of its teaching syllabus because BIM will only be utilised for supporting roles such as providing visualisation, aiding in calculations, and producing design representations; which performs an overall function as an avenue for the communication and teaching of the traditional modules. For example, the teaching staff of *Building Construction* module can use BIM as an effective visualisation aid when teaching construction technology. Moreover, students will be able to observe more and gain deeper understanding on the technical details of different construction systems as a result of the highly detailed BIM models. Another example can be taken from the *Structure/Structural System* module, whereby BIM models allow the students to obtain information or even perform an evaluation on the structural aspects of a design. In summary, applied BIM modules can definitely help the spread of BIM usage across the curriculum without requiring the teaching staffs to be highly skilled in BIM due to the absence of the formal teaching syllabus of the technology application.

7.4.2 FRAMEWORK FOR BIM SYLLABUS

7.4.2.1 AN INTRODUCTION TO BIM – BEGINNER'S LEVEL

Table 7.10: Framework for BIM Syllabus – Introduction to BIM.

DIGITAL GRAPHICS IN ARCHITECTURE		
1	Course level & placement	Beginner Year 1 or Year 2 – B.Sc. (Arch) (LAM Part I)
2	Course approach	BIM Integrated Module (BIM to be integrated into existing core module i.e. Digital Graphics or CAD)
3	Aims and objectives	1) To provide conceptual understanding on the principles and key concepts of using design software application in architecture; i.e. drafting, conventional modelling, parametric modelling, image editing, visual communication, collaboration and simulation. 2) To provide basic procedural/technical skills of computer software applications for 2D drafting, 3D modelling and image editing purposes, which acts as part of visual communication in architecture. 3) To provide simple understanding on the interoperability between various software applications.
4	Learning outcome (LO)	1) Recognise the importance of the above technology applications. 2) Understand how the technology applications work within the architecture practice and education. 3) Understand the process of using basic tools and features of the application. 4) Able to produce and represent a design project in relation to design studio project. 5) Able to cross transfer models from CAD to BIM and vis-à-vis; and at the same time able to addressing interoperability function.

5	Course outline (CO)	A semester of 14 weeks is divided into: CAD - 4 weeks BIM - 5 weeks Image editing – 3 weeks Quizzes and lab works- 2 weeks
6	Mode of delivery	Lectures Tutorials
7	Mode of assessment	Lab based assignments Projects - integrated into Construction Drawings module and Design Studio. Final project involves producing Design Studio's final project representation using the taught software application.

7.4.2.2 BIM TECHNOLOGY – INTERMEDIATE LEVEL

Table 7.11: Framework for BIM Syllabus – BIM Technology.

BUILDING INFORMATION MODELLING		
1	Course level & placement	Intermediate Year 3 – B.Sc. (Arch) (LAM Part I)
2	Course approach	BIM Standalone Module (Elective Module)
3	Aims and objectives	1) To address the principles and key concepts of BIM in a deeper level. 2) To provide understanding on the classes and categories of BIM tools. 3) To provide intermediate level of procedural/technical skills of BIM for the purpose of 2D drafting, parametric 3D modelling, visualisation and rendering. 4) To introduce the functions and tools of BIM for collaboration and integrated practice.

		5) To introduce BIM features and tools for constructability purpose.
4	Learning outcome (LO)	1) Understand the phased structure of a BIM project. 2) Understand the classes and categories of BIM tools. 3) Able to use BIM features to model conceptual massing, building elements, interiors, circulation and detailing. 4) Able to use BIM for visualization and renderings of design models. 5) Understand how BIM can be used for collaboration and integrated practice. 6) Understand how BIM can be used to understand the constructability aspect of a design.
5	Course outline (CO)	Each week shall consist of one single session of 3 *contact hours* and 4-6 *individual learning* hours. A semester of 14 weeks is divided into: Introduction - 1 week Modelling tools - 6 weeks Components and Families/Libraries – 1 week Collaboration/Integrated practice – 1 week Materials, Lighting and Rendering – 2 weeks Constructability and analysis – 1 week Quizzes and lab works- 2 weeks
6	Mode of delivery	Lectures Tutorials
7	Mode of assessment	Lab based assignments Projects – integrated into Design Studio. (i.e. the presentations for Design Studio's final project be produced by using BIM).

7.4.2.3 BIM INTER-DISCIPLINARY DESIGN STUDIO – INTERMEDIATE LEVEL

Table 7.12: Framework for BIM Syllabus – Inter-Disciplinary Design Studio.

INTER-DISCIPLINARY STUDIO		
1	Course level & placement	Intermediate Year 4 – B. Arch (LAM Part II) *or* Year 1 – M. Arch (LAM Part II)
2	Course approach	BIM Inter-Disciplinary Collaborative Module * potential inclusion of students from i) Architecture ii) Landscape Architecture iii) Civil/Structural Engineering iv) Mechanical and Electrical Engineering v) Construction Management (Design Studio - Core Module)
3	Aims and objectives	1) To expose students with real-life collaboration and Integrated Project Delivery (IPD). 2) To develop the ability to effectively communicate both verbally and with digital graphic programs i.e. BIM 3) To develop the understanding on the roles and responsibility of team players in conjunction of using BIM. 4) To provide skills in using BIM tools that will enable the development and inspection of the constructability aspects. 5) To provide skills in using BIM tools for design performance simulation.
4	Learning outcome (LO)	1) Able to interact, collaborate and function on multi-disciplinary teams.

		2) Able to understand the different roles and functions of individuals in the team. 3) Able to effectively communicate both verbally and with digital graphic programmes i.e. BIM 4) Able to demonstrate understanding on the aspects of constructability by using BIM. 5) Able to utilise the design/energy performance simulation in developing design. 6) Able to co-ordinate various simulation by other team players into the design. 7) Able to co-ordinate design changes using BIM throughout the design development process.
5	Course outline (CO)	A semester of 14 weeks is divided into: Introduction – 1 week Theoretical Input and Planning – 2 weeks Schematic Design Stage – 2 weeks Design Development & Simulation – 6 weeks Documenting – 3 weeks
6	Mode of delivery	Concurrent studio periods (all disciplines) Lectures by internal staff and invited industry stakeholders Tutorials by internal staff and invited industry stakeholders Field trips and investigations Studio discussion and collaboration
7	Mode of assessment	Active participation and team involvement – 20% Project work – 80%

7.4.2.4 BIM APPLIED MODULES

Table 7.13: Framework for BIM Syllabus –BIM Applied Module.

TECHNOLOGY RELATED MODULES i.e. *advanced building technology, advanced building construction* **DRAFTING AND TECHNICAL DRAWINGS RELATED MODULES** i.e. *technical drawings, measured drawings*		
1	Course level & placement	Intermediate Year 2-3 - B.Sc. (Arch) (LAM Part I) *and* B.Arch or M.Arch (LAM Part II)
2	Course approach	BIM Applied Module (Part of existing Core Modules i.e. i) Technology related modules i.e. *Advanced Building Technology, Advanced Building Construction* ii) Drafting and technical drawings related modules i.e. *Technical/Construction Drawings, Measured Drawings*)
3	Aims and objectives	1) To allow students to use BIM as a medium to develop and accomplish tasks. 2) To allow BIM to be used as a medium to convey tasks intent by means of representations.
4	Learning outcome (LO)	1) Able to develop and accomplish tasks by using BIM, which is one of the various possible methods allowed by the module. 2) Able to describe or explain the technicality aspects of the tasks by using design software i.e. BIM. 3) Able to use BIM, as one of the various digital methods allowed, to represent tasks intent.
5	Course outline (CO)	Not relevant – *BIM only used as assisting tool/medium.*
6	Mode of delivery	Not relevant – *BIM only used as assisting tool/medium.*

7	Mode of assessment	The *Assessment Rubrics* or *Marking Sheets* for assignments and projects to contain an unsubstantial percentage dedicated for BIM usage.

7.5 VALIDATION OF THE DEVELOPED FRAMEWORK

In Chapter 3, a detailed discussion was presented on the processes involved to develop a framework of suggestions in regard to the integration of BIM into the architecture programme in Malaysia. As can be seen earlier in this chapter, the main process of developing the framework involves the adoption of a comparative approach by performing a cross analysis on the findings attained from Survey A and Survey B. In this case, investigations were conducted to identify and appraise the gaps and similarities in terms of the opinions, expectations, practice, and culture between the two samples in regard to the research questions. The findings were subsequently crosschecked and connected to the accreditation requirements and standards developed by LAM, MQA, UKM as well as the literature review accumulated earlier in this thesis considering that it is a theoretical source of reference that was utilised in the development of a set of conceptual frameworks that would support the integration of BIM into the architecture curriculum. However, the framework can still be regarded as theoretical, thus explaining the need to validate the framework in order to obtain consensus from the HEIs to generalise and commend the framework prior to its adoption. In particular, the validation of the framework was performed by measuring the feasibility and validity of the individual criteria that make up the framework. Finally, the data and findings obtained from the validation process were then used to refine the framework prior to the establishment of the final framework.

7.5.1 SURVEY OVERVIEW

As discussed earlier in the chapter, all the academicians representing the accredited architecture school from the public HEIs that participated in Survey B were approached again and requested to complete a follow-up survey that would support the validation of the framework. The HEIs that were involved in the present study include Universiti Malaya (UM), Universiti Sains Malaysia (USM), Universiti Teknologi MARA (UiTM), Universiti Teknologi Malaysia (UTM), International Islamic University Malaysia (IIUM), and Universiti Putra Malaysia (UPM). Furthermore, there was a new addition to the validation survey which is Universiti Sains Islam Malaysia (USIM) due to the fact that its newly formed architecture programme had been accredited by LAM at the time of the survey (LAM, 2018). Furthermore, it is worth noting that the same individuals that participated in Survey B were selected again to represent their institutions on the grounds that they are still active full-time lecturers who are responsible in teaching *architecture digital graphics*-related modules at their institutions. In addition, the survey questionnaires were electronically distributed through emails to all seven HEIs on 12 April 2018, while the responses from all the HEIs were returned by 18 April 2018.

7.5.2 SURVEY DESIGN AND APPROACH TO ANALYSIS

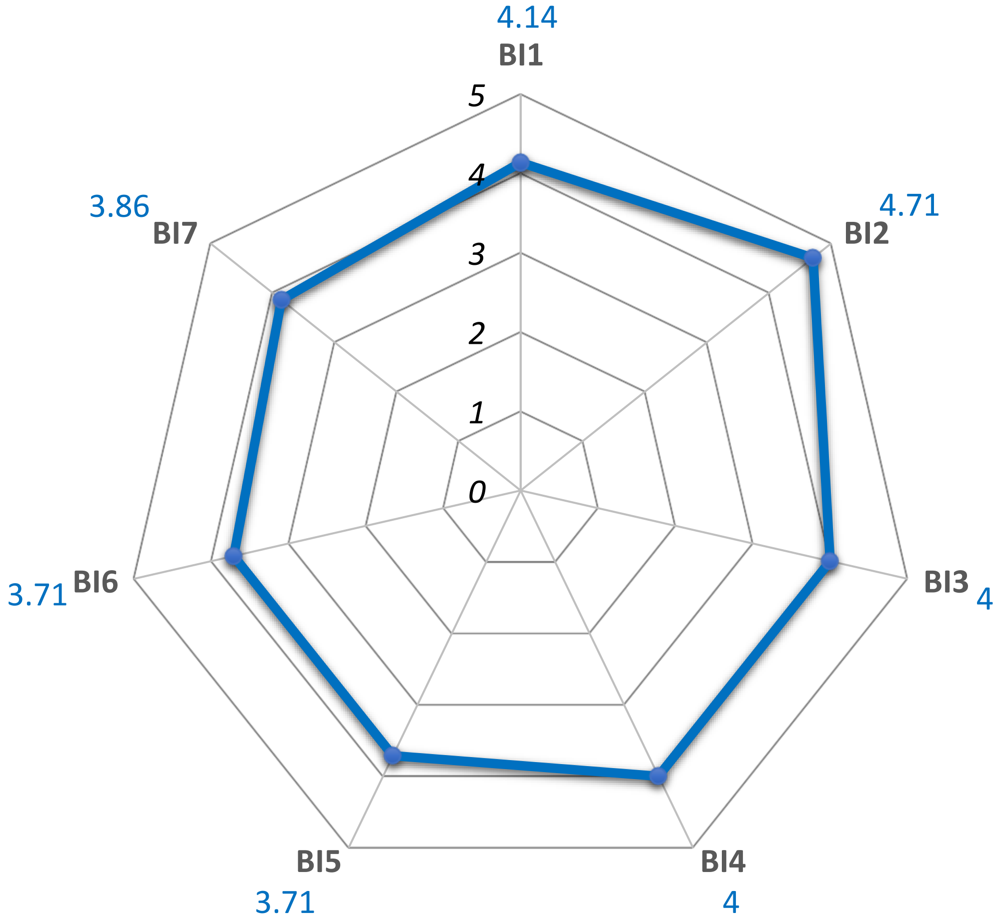
A quantitative approach was adopted in the present study to ease the respondents' responses through the distribution of self-completion questionnaire. In this case, the questionnaires were developed using the SurveyMonkey online survey tool as can be referred in Appendix C. More specifically, the survey questionnaires were made up of four segments which individually represent each of the four framework outlines for

BIM syllabus, followed by seven close-ended questions. In the section of the first segment, respondents were presented with the first BIM integration outline of the framework known as the *Introduction to BIM* with the purpose of obtaining their opinions on the feasibility and validity of each criteria that is responsible in forming the framework outlines that must be applied to their respective programme. The same process was then carried out one by one for the remaining three segments of the questionnaires which comprise of several framework outlines, particularly for *BIM Technology*, *Inter-Disciplinary Design Studio*, and *BIM Applied Module*. On another note, the data collected from the questionnaire were then analysed using the Weighted Average Index (WAI) analysis, whereby the attained value represents an average rating of the responses obtained based on the Likert Scale. In the present study, a 5-points Likert Scale were adopted for the questionnaires which are represented as follows: (1) Highly Feasible & Valid, (2) Feasible & Valid, (3) Neutral, (4) Infeasibly & Invalid, and (5) Very Infeasibly & Invalid. Apart from that, it is highly important to note that the quantitative approach employed in this survey was not intended to generalise a sample of population on a national level, but rather to demonstrate a form of consensus made by the respondents for the purpose of representing the architecture schools of public HEIs in the country.

7.5.3 RESULT AND DISCUSSION ON VALIDATION

This sub-chapter further discusses the analysis of the results obtained from the validation survey. Unlike the previous analysis for Survey A and Survey B that employed individual charts and diagrams to represent every single question, this particular analysis performed to validate the survey was carried out by gathering and grouping the responses together based on the segments, while the radar chart was adopted to depict the Weighted Average Index (WAI) value of the responses for the set of criteria within a whole segment. In the case of this study, the results and discussions are organised and presented into four segments based on the following four framework outlines: (1) Introduction to BIM, (2) BIM Technology, (3) Inter-Disciplinary Design Studio, and (4) BIM Applied Module.

7.5.3.1 AN INTRODUCTION TO BIM – BEGINNER'S LEVEL



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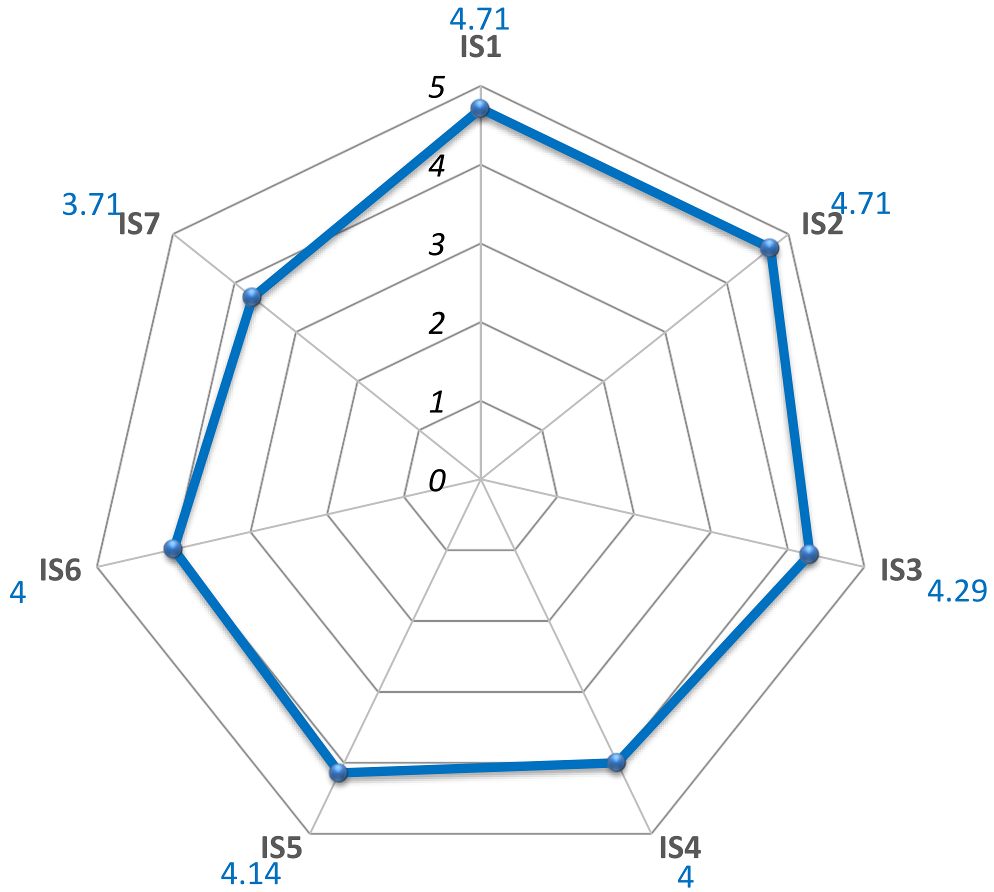
Value	Level of Feasibility & Validity
5	Highly Feasible & Valid
4	Feasible & Valid
3	Neutral
2	Infeasibly & Invalid
1	Very Infeasibly & Invalid

Figure 7.2: Average Index Radar Chart of Level of Feasibility and Validity for BIM Framework for BIM Syllabus – Introduction to BIM

Figure 7.2 shows the findings of W.A.I analysis on the feasibility and validity of implementing the first segment of the framework for BIM syllabus which particularly refers to the Introduction to BIM. The results of the analysis show that each criterion within this framework manage to obtain W.A.I value above 4.00 but with the exception of three criteria, namely BI5: Course Outline, BI6: Mode of Delivery, and BI7: Mode of Assessment. In this case, it is important to note that this was not expected because it was stated earlier that HEIs have their own autonomy to carve the details of their own curriculum design (LAM, 2013). Nevertheless, a score above 3.50 W.A.I value for the three criteria can still be considered feasible and valid because it is in close proximity to the value of 4.00. The significant findings of this segment can be described by the agreement of the HEIs in regard to the framework's criteria for BI1: Course Level and Placement, BI2: Course Approach, BI3: Aims and Objectives, and BI4: Learning Outcomes (LO) because all of them are feasible and valid for implementation purposes. The individual response provided by each respondent and the distribution of answers can be referred in Appendix 3.0.

7.5.3.2 BIM TECHNOLOGY – INTERMEDIATE LEVEL

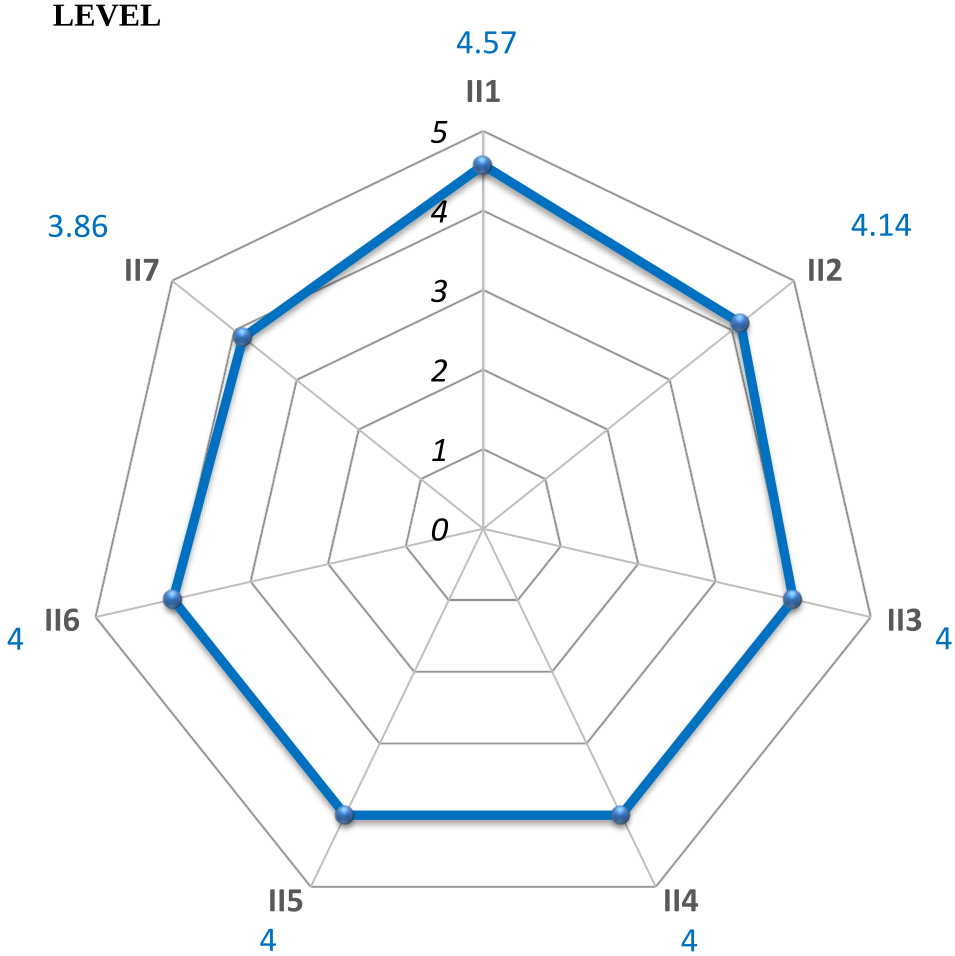


Value	Level of Feasibility & Validity
5	Highly Feasible & Valid
4	Feasible & Valid
3	Neutral
2	Infeasibly & Invalid
1	Very Infeasibly & Invalid

Figure 7.3: Average Index Radar Chart of Level of Feasibility and Validity for BIM Framework for BIM Syllabus -BIM Technology

Figure 7.3 summarises the findings of W.A.I analysis on the feasibility and validity of implementing the second segment of the framework for BIM syllabus which is referred to as BIM Technology. In this case, the results from the analysis of the second segment show that the criteria for the BIM standalone module are far better accepted and endorsed by the respondents compared to the first segment of the framework, which is proven by a total of six criteria obtaining the W.A.I value above 4.00. As can be observed, IS7: Mode of Assessment is the only criterion that scores W.A.I value below 4.00, with the exact value of 3.71. As has been previously mentioned, it is acceptable for some of the HEIs to have a slightly different view of how a module should be assessed considering that they should be aligned with the HEIs' own policy. However, the most important criteria from all segments of the framework that need to be validated by the HEIs involve the first four criteria as follows: (1) IS1: Course Level and Placement, (2) IS2: Course Approach, (3) Aims and Objectives, and (4) Learning Outcomes by bearing in mind that all four criteria manage to obtain the W.A.I value above 4.00. In fact, it is also worth highlighting that both IS1 and IS2 receive a very high score of 4.71 out of 5. This further indicates that HEIs are more inclined to offer BIM as a standalone module in their curriculum despite the feasibility found in the integration of BIM syllabus into the existing core modules such as *Digital Graphics (DGR)*.

7.5.3.3 BIM INTER-DISCIPLINARY DESIGN STUDIO – INTERMEDIATE LEVEL

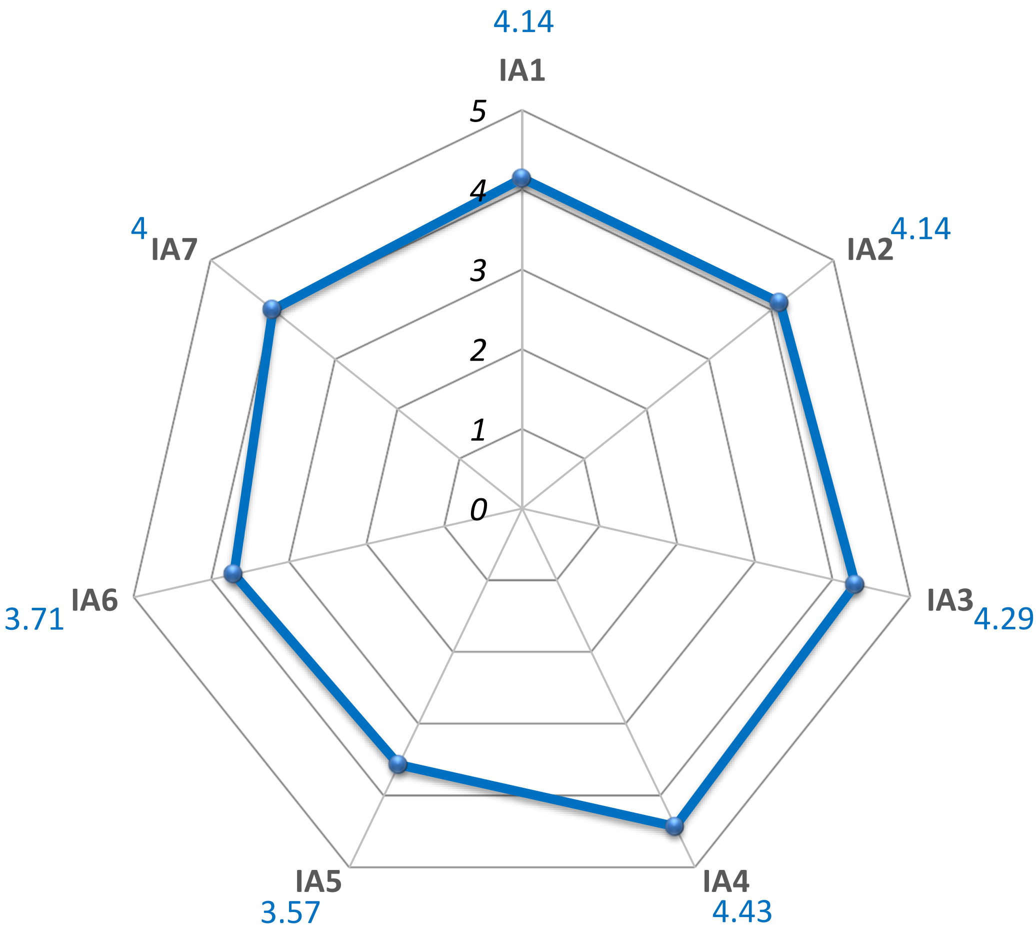


Value	Level of Feasibility & Validity
5	Highly Feasible & Valid
4	Feasible & Valid
3	Neutral
2	Infeasibly & Invalid
1	Very Infeasibly & Invalid

Figure 7.4: Average Index Radar Chart of Level of Feasibility and Validity for BIM Framework for BIM Syllabus - BIM Inter-Disciplinary Design Studio

Figure 7.4 summarises the findings of W.A.I analysis on the feasibility and validity of implementing the third segment of the framework for BIM syllabus which refers to the BIM Inter-Disciplinary Design Studio. The results of the analysis show that all but one of the criteria within this framework manage to obtain the W.A.I value above 4.00, which is similar to the second segment of the framework. In this case, Criterion II7: Mode of Assessment is the only criterion that scores a W.A.I less than 4.00 with the exact value of 3.86. Nevertheless, a value of 3.86 is considered to be in close proximity to the value of 4.00, thus making the criterion acceptable due to its feasibility and validity. In addition, the interesting point to this finding is that all the HEIs seem to be strongly agree with the implementation of BIM in the inter-disciplinary design studio despite the fact that none of the HEIs are currently offering it to their students. Hence, this further signifies that all the HEIs are fully aware on the ever-increasing importance of collaborative practice as well as the needs to expose their students to the real working approach that reflects the real-life practice of today's architects. However, it is essential to take extra caution on the potential challenges that might come with the introduction of a collaborative design studio which include the lack of experience. Apart from that, it should be noted that an inter-disciplinary module demands streamlined effort and commitment from the students and staffs of other programmes.

7.5.3.4 BIM APPLIED MODULES



Value	Level of Feasibility & Validity
5	Highly Feasible & Valid
4	Feasible & Valid
3	Neutral
2	Infeasibly & Invalid
1	Very Infeasibly & Invalid

Figure 7.5: Average Index Radar Chart of Level of Feasibility and Validity for BIM Framework for BIM Syllabus - BIM Applied Course

Figure 7.5 summarises the findings of W.A.I analysis on the feasibility and validity of implementing the fourth segment of the framework for BIM syllabus which is known as BIM Applied Modules. The analysis for the final segment of this framework shows that all but two of the criteria manage to receive a W.A.I value of 4.00 and above which include IA1: Course Level and Placement, IA2: Course Approach, IA3: Aims and Objectives, IA4: Learning Outcome (LO), and IA7: Mode of Assessment. Meanwhile, the two criteria that receive a score below 4.00 are IA5: Course Outline and IA6: Mode of Delivery. In this case, it is interesting to note that this is the only segment of the framework that contains criteria which do not suggest any formal instruction, particularly referring to the two criteria with W.A.I value less than 4.00. A possible explanation of the two criteria not having any formal instruction might be that the Applied BIM Modules are existing core and/or elective modules that have their own syllabus outline and not directly or exclusively related to BIM per se, which further explains the absence of BIM teaching syllabus. However, these modules do require the students to utilise BIM as a medium to deliver the tasks and assignments given by the course instructor. Therefore, there is a possibility that some of the respondents might *simply* agree instead of *strongly* agree with the suggested approach for these two criteria based on the above points.

7.5.4 PRESENTATION OF FINAL FRAMEWORK

Overall, it is safe to conclude based on the validation analysis that the criteria for all four segments of the framework for BIM syllabus were feasible and valid as suggested by all the respondents. Therefore, no further refinement is required which makes the framework ready to be used by architecture schools in Malaysia as a guidance to integrate BIM into their current curriculum.

CHAPTER 8: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

8.1 INTRODUCTION

The final chapter of this thesis presents the discussion of the results obtained during the course of the research as well as the subsequent analysis performed in this study. In regard to this matter, the narrative draws upon the original aim and objectives of the research by also considering the possible implications, limitations, and original contributions to the body of the literature. The recommendations for further research are also presented with a predominant emphasis on the pedagogical design considerations that are significantly essential to the successful integration of BIM in the architecture undergraduate programmes in Malaysia.

8.2 DISCUSSION

Building Information Modelling (BIM) is rapidly turning into an industry standard for the architecture industry considering all the substantial changes that have been fulfilled by BIM in replacing the conventional method of delivering projects. In relation to this matter, ICT advancement and transformation has always been the key source of increased efficiency, competitiveness, and innovation (Piccoli and Pigni, 2016), while BIM is particularly regarded as one of the means that can help to overcome the traditional difficulties that have been plaguing the architecture industry for decades, especially in communications and information management. In addition, the latest tools built into BIM technology provide the ability to simulate and evaluate building designs, applied technologies, thermal properties, visual properties, energy use, and schedules of operations. On a more important note, these procedures can be performed without the need to physically construct the artefact being modelled; which is a distinctive feature that has inadvertently increased the industry's attention towards BIM in a reflection to the significant influence of the fast-growing awareness of sustainability development and green design in the industry within the last decade. Moreover, another function that differentiates BIM from the 'predecessor' technologies refers to its ability to model building elements and components inclusive of its functions, behaviour, and costing data, which is indicative in providing benefits to the facility management (FM) team for post-construction management, maintenance, and operation works. More importantly, the main attribute of BIM that have significantly contributed to the biggest change in the practice and culture of the AEC industry is its ability to function as a comprehensive collaborative tool that fully supports the Integrated Project Delivery (IPD) system, thus relatively changing the traditional roles and silos within the industry.

Nevertheless, Malaysia has failed to achieve similar results to those of developed nations such as the countries of North America, Western Europe, Scandinavia, and Oceania considering the fact that these countries have managed to show promising results in the implementation of BIM (McGraw-Hill, 2012a, McGraw-Hill, 2014a, Jung and Lee, 2015). As discussed earlier, it is undeniable that the lack of consistent approach as well as the peculiar cultural aspects of the Malaysian society have led to the low rate of BIM adoption. However, it is important to note that innovations and changes have been occurring on a global scale which seems to challenge the traditional working and thinking practices in Malaysia's architecture industry. Overall, it is safe to say that this does not only influence the industry, but also the tertiary education which is generally recognised as the main supply of compatible and competent workforce for the industry.

However, there is a growing need for the higher education, not just in Malaysia but globally, to step up with a better pace in ensuring that the industry are equipped with graduates that possess the appropriate set of skills and knowledge for the purpose of overcoming the struggle that has been faced by the AEC industry in keeping up with the global change (Khosrowshahi and Arayici, 2012, Herr and Fischer, 2017, Jacobsson et al., 2017). Hence, it is a good sign that most of the architecture schools are aware of this which has encouraged them to take the necessary steps to integrate BIM into their curriculum. Nonetheless, it appears that more effort is needed to integrate BIM because its integration is not as easy as the preceding technologies such as CAD due to the fact that BIM integration requires a holistic approach that is believed to affect a large chunk of the curriculum. Hence, this would result in half-baked integration of BIM into the curriculum, which eventually ensues the continuous usage of traditional CAD as the main digital application for design deliverables. Therefore, the new paradigm must be accumulated and developed in the pedagogical framework to create a comprehensive architecture programme with the purpose of accommodating the future requirements of the industry. In specific terms, the proposed framework developed by the current research will help to establish the suitable approach to integrate BIM into the current architecture curriculum, which will result in the development of a comprehensive curriculum that is able to adhere to the needs of the local architecture industry.

8.3 REVIEW OF RESEARCH AIMS, OBJECTIVES AND QUESTIONS

The original aim of this research was to propose a framework of recommendation that can support the integration of Building Information Modelling (BIM) into the LAM Part I and Part II architecture programmes in Malaysia. Apart from that, another purpose of this study is to help trigger and guide HEIs in ensuring their graduates are equipped with the appropriate skills, adequate knowledge and understanding, and enhanced way of thinking to enable them to carry out the duty of an architect that revolves around BIM usage. Therefore, the followings are the objectives of the current research to:

Objective 1

To explore, appraise, and synthesise relevant literature related to Building Information Modelling (BIM) from both international and local perspectives.

Objective 2

To explore, appraise, and synthesise relevant literature related to BIM by specifically focusing on the professional practice – architecture education relationship and the effects on each other.

Objective 3

To identify the current trends and practices among architectural firms in regard to their utilisation of digital technologies in performing project deliverables.

Objective 4

To evaluate the impact of BIM opportunities and challenges on design strategies, associated management structures, and cultures within architectural practices.

Objective 5

To explore how the HEIs equip their graduates with the capabilities to make the most out of digital technology in response to the latest market needs.

Objective 6

To identify the enablers and barriers in the implementation of BIM principles and concepts into architecture programmes in government-owned public HEIs in Malaysia.

Objective 7

To propose a framework that will facilitate the re-evaluation and re-formulation of the current curriculum syllabus for the purpose of incorporating BIM.

Research questions and research objectives are two fundamental components of research that are closely related to each other. In particular, research questions are described as the set of structured questions indicating the area of interest for the research, while the specific actions to answer these relevant questions are referred as the research objectives. The relevant questions were first acquired from the critical review of the literature prior to the process of developing the aims and objectives of this research, as can be referred in Chapter 2 and Chapter 3. The relevant questions are described as follows:

i. What are the type of digital technologies used by the architecture firms in the AEC industry in their work deliverables?

ii. How do the architecture firms utilise their digital technologies in their daily task?

iii. What is the adoption rate of BIM in the country's architecture industry?

iv. How are BIM opportunities impacting on the design strategies, associated management structures, and cultures within these architectural practices?

v. How does the architecture schools in Malaysia's public HEIs catch up with the evolution of BIM?

vi. How are these HEIs equipping their graduates with the capabilities to fully utilise digital technology in response to the market needs?

vii. What are the similarities and differences in regard to the perceptions and opinions on BIM between the architecture industry and the HEIs?

viii. How can a framework of recommendations support the integration of BIM into the LAM Part 1 and Part II architecture programmes in Malaysia?

8.4 REVIEW OF RESEARCH METHODS AND PROCESS

Chapter 4 described the mixed-methods approach adopted in the present study which consisted of the qualitative and quantitative techniques for the purpose of fulfilling the aims and objectives of the current research project. This particular approach was adopted despite the philosophical position of the research that leans towards being positivist as well as the theorizing direction that points towards a deductive approach. The purpose of choosing this approach was due to the circumstances of the research, particularly in regard to developing the instrument for data collection among the HEIs because it required a certain extent of exploration due to the scarce amount of credible literature. Hence, this literature-based research thesis aimed to fully comprehend the concepts related to the current topics prior to the process of primary data collection. On the other hand, the secondary data that are spread across two chapters was obtained from two different contexts, namely architecture industry and architecture education. Subsequently, the research adopted the primary research method to obtain the primary data in order to generate effective conclusions which are further described in the following subsections.

8.4.1 QUALITATIVE COMPARATIVE ANALYSIS

The Qualitative Comparative Analysis (QCA) was employed to establish logical conclusions for the data set supports. Moreover, this method was applied in Chapter 3 to generate a comparison analysis for numerous approaches employed by the national and international organisations in conducting the survey for BIM adoption in the AEC industry around the world. Subsequently, the QCA was adopted to compare various approaches employed by researchers and educationists in the survey of BIM adoption and experience, particularly in the context of academia. Therefore, this allowed the researcher to develop the relevant research questions that led to the development of a theoretical framework with the purpose of guiding the research process.

8.4.2 SURVEY QUESTIONNAIRES

The main instrument adopted to gather the primary data for the present study was the survey questionnaires considering that survey based research has been widely agreed as one of the most established, popular, and commonly used techniques in obtaining primary data (Rovai et al., 2013, Vir, 2015, Bryman, 2015). On a more important note, two surveys were carried out on two different set of samples with different numbers and background, namely Survey A and Survey B due to the fact that the current research seeks answers from two different contexts. Unfortunately, the researcher discovered at this stage that the literature on the local HEIs were not adequate to offer supportive data in developing a fully quantitative set of questionnaires for Survey B, which explains the need of including the qualitative approach for the survey. On the other hand, the survey questionnaires for Survey A were constructed of quantitative questions.

8.5 LIMITATION OF STUDY

With regard to the research methods, two limitations need to be acknowledged. The first limitation refers to the lack of literature on the current topic. BIM is still a relatively new subject, and though it could be said that literature on BIM in general have increased over the recent years, the same could not be said for *BIM in education*, more specifically *BIM in architecture education*. The available literature managed to form knowledge on the current issues and challenges related to the development of BIM, and subsequently build research questions that lead to the formation of the aims and objectives of the current research. Apart from that, the QCA performed on the literature was deemed sufficient to be utilised in developing the survey questionnaires for Survey A. In relation to this matter, the limited amount of literature on BIM in regard to education particularly in the context of the local background has led the researcher to adopt a mixed quantitative-qualitative approach in developing the survey questionnaires for Survey B; an approach that is often used for exploration of pure subjectivity and leans towards *subjectivism*. The second limitation occurred during the primary data collection when the return response rate for Survey A was limited to 26%, which is a relatively low rate that could restrict the potential for the generalisability of the findings. However, the survey was developed with the main purpose of providing an insight into the topic in the context of the country rather than generalising it out rightly considering that this survey was the first BIM survey to be conducted in Malaysia. Nevertheless, the pragmatic approach of subsequently counter analysing the findings from both Survey A and Survey B was able to provide efficient data in the effort of understanding the current practice, general perceptions, and expectations between the industry and the HEIs.

8.6 CONCLUSIONS OF MAIN FINDINGS

The aim of the current research was to guide academic institutions in ensuring that the graduates are equipped with the appropriate skills, adequate understanding, and enhanced way of thinking which will enable them to carry out the duty of an architect in response to the growing trends of BIM utilisation. Therefore, a comprehensive framework of recommendations that is capable of supporting the integration of Building Information Modelling (BIM) principles into the Lam Part I and Part II architecture programmes in Malaysia was developed in order to achieve the aim. As research aim is achieved upon the accomplishment of its subsidiary set of objectives, it is therefore important to perlustrate the attainment of the current research objectives.

To demonstrate the evolution of the framework from theoretical to final, the research objectives are herewith appended with the discussion of the research's main findings.

Objective 1: *To explore, appraise, and synthesise relevant literature related to Building Information Modelling (BIM) from both international and local perspectives*.

The findings for objective 1 have been discussed and argued in Chapter 2 and Chapter 3 which make up the Literature Review of this research. In this case, the researcher started by amassing the key literature in the form of books, journal articles, conference proceedings, government and non-governmental reports, magazine articles, web portals, publications by news agencies, and online forums that are related to digital technologies in general, followed by BIM in particular. In relation to this matter, it is deemed very crucial to explore and evaluate the literature on BIM for the purpose of identifying the issues and concerns that are relevant to BIM. The process was further continued by narrowing the literature down to a particular issue of commendable significance that will act as the base of this subject inquiry, with the hope of providing a clearer picture that can shape the direction of the current research. One of the crucial issues of BIM refers to the slow adoption of the technology despite the claim that states BIM as a technology can bring a paradigm shift to the industry. The main reasons that led to this particular circumstance is described by the lack of BIM training and skilled staff in the industry, which subsequently brings the attention to the role of HEIs as the traditional main source of skilled workforce. In regard to this matter, HEIs are touted to be capable of providing the solution that can equip the graduates with BIM skills, thus further rendering the needs of the industry to carry all the burden by itself in ensuring that the staff are capable of handling BIM. Apart from that, the literature also presented a lack of systematic approach by the HEIs in the integration of BIM into their curriculum, which poses a threat that the BIM skills provided by the HEIs may not be sufficient for the use of the industry. On a similar note, the deeper perspective seems to suggest that BIM might not be holistically integrated into the overall design thinking of architecture when in fact the architecture design process tends to evolve as a result of BIM utilisation. Hence, this generates the questions for the present study and provides the foundation of the current research.

On another note, the researcher discovered that the amount of literature on BIM within the context of Malaysia is considerably low compared to those of overseas despite the fact that there is already a lack of research on the matter even among the developed nations when compared to other fields of research. This can be proven based on a quick search of the topic on the internet that shows that most of the established research publications pertaining to BIM comes from developed countries, particularly from North America and Western Europe. In addition, established BIM related organizations and developers are mostly based in developed countries and not in developing countries. Therefore, the above factors in tangent with the fact that the researcher is a native of Malaysia and employed by Universiti Kebangsaan Malaysia (UKM) clearly explained why Malaysia was chosen as the context of the current research.

The literature described in Chapter 1 and Chapter 2 have paved the way to a step by step justification of the understanding of the research which can be seen below:

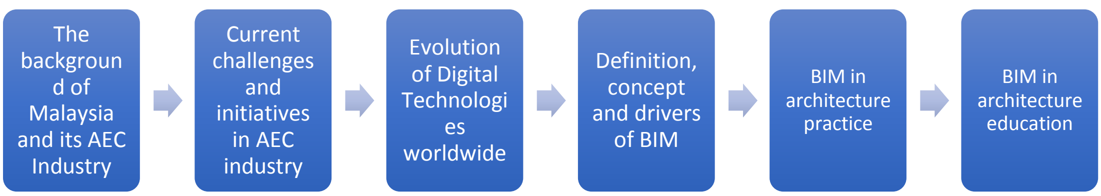


Figure 8.1: Process of developing understanding of the research.

Objective 2: *To explore, appraise, and synthesise relevant literature related to BIM by focusing specifically on the professional practice – architecture education relationship and the effects on each other.*

Objective 2 narrows down the research and establishes the context of the research that lies between the architecture industry and tertiary architecture education in Malaysia. In addition, this objective was built up within the literature reviews presented in Chapter 2 and Chapter 3 but most particularly in the latter. As has been mentioned, the focus of objective 1 revolves around identifying and understanding the current development and key issues on BIM implementation within the architecture industry and academia at both global and local contexts; which subsequently lead to how the context of this research is developed. Meanwhile, objective 2 sets out to explore the industry-academia relationship in addition to further establishing the context of the research.

In relation to this matter, it is important to note the significant differences in technology implementation between the developed countries and developing countries in the effort of understanding the reasons behind establishing Malaysia as the context of this research, specifically focusing on technologies that are produced by developed countries such as BIM. First, it should be acknowledged that developed countries tend to produce a relatively higher income per capita and higher currency values compared to developing countries, which clearly explains the reason behind the slow purchase and adoption of a new technology such as BIM at a mass scale because it is deemed more challenging to a developing country like Malaysia. Second, the differences in the working cultures have been found to contribute to the case considering the fact that employers in developing countries like Malaysia are generally lacking in their willingness to invest in the new '*unproven'* efforts which include technologies and training, thus causing them to remain with the 'proven' conservative methods. Hence, this clearly shows why the industry seemed to be less enthusiastic in investing and adopting new technologies, especially without external support. Overall, this leads to the notion that the HEIs are significantly responsible as the traditional resource of workforce supply by providing its graduates with the appropriate skills and knowledge that will eventually be able to support the architecture industry in Malaysia in adopting new technologies and methods of working.

The current research proceeds with developing the strategies to execute the inquiry after the establishment of the focus and context of the research. A considerable amount of studies and research on the strategies to integrate BIM into the architecture programme and curriculum have been appraised and synthesised together with existing surveys conducted by other researchers and bodies on BIM adoption. Overall, a total of four strategies in developing BIM curriculum have been identified from various studies and reports that predominantly came from developed countries considering the scarce information available in the context of Malaysia. The first strategy is the most common method employed where the HEIs develop in-house BIM modules without engaging with the industry or any external academicians alike. Moreover, this process is often carried out by the course co-ordinators themselves. The second strategy in developing BIM modules by the HEIs refers to the need of engaging industry stakeholders through focus group discussions or surveys for the purpose of obtaining opinions and thoughts on what is needed or deemed necessary for graduates that will be the future workforce. Next, the third strategy involves the process of engaging opinions and thoughts of fellow academicians from the academic world rather than stakeholders from the industry, similarly by focusing on group discussions or surveys, that will later be used to help develop the BIM modules. The fourth strategy by the HEIs involves the engagement of the industry or external academicians only after the in-house BIM modules are developed with the purpose of providing opinions and feedback on the already created and implemented BIM modules. Hence, it is safe to say that HEIs tend to engage only one party, either the industry or academicians rather than including both parties. However, none of the HEIs have reported to engage with both the HEIs and industry stakeholders at a national level prior to the development and construction of the BIM modules. Even though some of the above methods may provide insight into the discourse of developing a new curriculum, but to do it effectively, both the industry and HEIs are recommended to engage from the very beginning in making sure that the new curriculum be tailored to suit both ends of the profession; balancing the industry's needs with academic expertise and aspirations. This research strategy is formed and established to engage both parties; the local industry as the end receiver, and the local HEIs as the provider, with the purpose of attaining the necessary thoughts and opinions in developing a BIM curriculum that suits to the local context. As discussed in Chapter 1, this is crucial because the curriculums for architecture degree programmes are already known to be dense; hence, any future changes or additions should be minimal yet effective, practical, and tailored to the needs of the Malaysian architecture industry, which technologies applications have found to be not as advanced and progressive as those in advanced countries. The strategy to focus on both parties in tandem to BIM understanding later led to the development of the theoretical framework for this research, which is used to develop the questionnaires for both surveys, namely Survey A and Survey B. The method to perform this strategy has been discussed and elaborated in Chapter 4 known as the Research Methodology.

Objective 3: *To identify the current trends and practices among architectural firms in utilising digital technologies to perform project deliverables.*

This research requires input from two parties from the same field but with different backgrounds, namely the industry and the HEIs. The method employed in this study for data collection purposes has been discussed and elaborated in Chapter 4, known as the "Research Methodology". The methodology that was developed is based on the above contexts and led to the decision to apply a dual-track survey method as the main instrument for primary data collection, which requires both surveys on both the industry and HEIs to be carried out at the same time with a substantial percentage of similar questions. *Objective 3* is concerned with the first set of survey questions from the dual-track survey, which is referred to as Survey A. This set of survey questionnaires were distributed to all the architecture firms in the country with the purpose of identifying the current trends and practices of digital technologies among these firms, particularly in regard to BIM. Due to the abundance of architecture related software applications available to the market, it is therefore crucial to firstly identify the applications that are current industry standards, applications that play supporting roles, and applications that are perceived to have a significant potential in the eyes of the industry. The findings to this inquiry that were analysed in Chapter 5 found that the architecture industry have been sluggish in the adoption of BIM, whereby only an approximate of 20% of the architecture firms have been reported to use it for project deliverables. Hence, this further explains why CAD remains as the industry standard for digital technology, including the users of BIM who are still actively using CAD. The important findings from this is that CAD is still an industry standard software for project deliverables and therefore shall continue to exist in architecture education despite the continuous growth of BIM within the industry.

Objective 4: *To evaluate the impact of BIM opportunities and challenges on design strategies, associated management structures, and cultures within architectural practices.*

Objective 4 is part of the primary data that were collected through Survey A. The current research went further to study how BIM are affecting these firms after identifying the take up of BIM among the architecture firms in the industry by putting more focus on design strategies, associated management structures and procedures, and work cultures. These insights have brought substantial significance to the research considering that BIM is a new holistic technology that works differently from CAD and widely reported to be affecting architecture practice in one way or another. The survey findings in regard to this objective revealed that BIM does require extra attention in terms of design strategies, associated management structures, and cultures within architectural practices that may be affected to a certain degree. However, this has not gone to the alarming stage, but concerns regarding this matter need to be addressed using the best possible way. The findings from objective 3 and 4 provide the research with the insights to one spectrum of the inquiry, which refers to the industry. However, these findings need to be cross analysed with the findings from the trends of the other side of the spectrum which refers to the architecture education for the purpose of cognising the supply and demand aspects of BIM in the profession. Therefore, this brings the research to the next objective.

Objective 5: *To explore how the HEIs equip their graduates with the capabilities to make the most out of digital technology in response to the latest market needs.*

Objective 3 and objective 4 set out to explore BIM uptake and effects within the industry; meanwhile, the aim of objective 5 is to bring the current research into the other end of the spectrum with the purpose of exploring the trends of BIM among the architecture schools in the country. This is deemed crucial to the development of the proposed framework of recommendations considering that the framework is constructed on the basis that there should be a balance between the desire of the industry with staff expertise, while also focusing on the need to maintain the core syllabus of architecture principles required by LAM. Objective 5 similarly requires the collection of primary data using the same method that was discussed in great detail as presented in Chapter 4, particularly the second part of the dual-track survey used for this research known as Survey B. On a similar note, Survey B also started its inquiries towards the HEIs by first studying their selection of digital application software as well as identifying the software that are most widely used among the HEIs, software that play supporting roles, and software that are perceived to be potentially significant in the eyes of the HEIs.

The findings of this objective which are part of the analyses results of Survey B have been discussed in detail in Chapter 6. In regard to this matter, it should be noted that the trends among the HEIs are slightly different compared to the trends within the industry. All but one of the HEIs have already started to implement BIM despite the fact that CAD is still actively being taught to the undergraduate students by all of these HEIs. Contrary to the industry, the HEIs seem to be more aware of the current global trends and have already taken the steps to champion BIM usage. At this point, the HEIs have been observed to be on the right track and direction towards the global change. Nevertheless, it is on a positive note that the HEIs are still retaining CAD as part of its curriculum based on the acknowledgement that CAD is still high on demand within the industry. Overall, it is safe to say that the most important thing at this point is that the research has managed to identify how BIM has been used in both contexts.

Objective 6: *To identify the enablers and barriers in the implementation of BIM principles and concepts into architecture programmes in government-owned public HEIs in Malaysia.*

Objective 6 has been partly discussed in Chapter 3, Chapter 6, and Chapter 7. Part of Survey B seek the opinions of HEIs in regard to the aspects that has driven the integration of BIM into the architecture curriculum of the architecture programmes. Hence, the top three drivers of BIM adoption among the HEIs as summarized from the elaborated analysis written in Chapter 6 are in the following order; (1) industry demands, (2) research needs, and (3) global trends and reputation of the technology. Nevertheless, the HEIs quoted ‘industry demands’ as the biggest influence to adopt any technology including BIM despite the absence of national wide survey on BIM adoption in the country prior to this research. This is a very positive indication which further proves that the HEIs are actually ‘looking’ and ‘listening’ to industry leaders and players; possibly through the occasional engagement that have been conducted between the HEIs and the industry such as the invitation to practising architects from the HEIs for critique sessions, talks, seminars, and supervision; events and discourse carried out by PAM, LAM, and NGOs involving both practising architects and academicians; or any form of colloquium that often happens between the HEIs and the industry players. Therefore, it is reasonable to believe that such events are able to provide awareness to the HEIs in regard to the need of the industry, including BIM. Overall, this clearly explains the importance of a nation-wide survey that engages both parties in order to grasp in detail the needs of majority in the industry as well as the capabilities of HEIs, which subsequently justifies the importance of this research.

Apart from the enablers of BIM, it is equally crucial to identify the barriers of BIM. In fact, it is undeniably more important to know the latter because removing the hindrance will at least pave the way wide open for the adoption of the technology. According to USM which is the only HEI that have not implemented BIM, there are three main barriers that hinder the adoption of BIM that are described as follows: (1) lack of qualified teaching staff, (2) lack of teaching assistant support, and (3) the high cost of the BIM software application. It is undeniable that all of these points are expected of something new to the scene such as BIM, including the demand of an early bird which involves high investment not just in terms of monetary, but also time and effort. Nevertheless, USM have originally acknowledged that demands by the industry have driven them to venture into any new technology despite the fact that they have not implemented BIM. Therefore, the current research that gathers formal inputs from the industry can very well be the key to convince HEIs such as USM to implement BIM.

Objective 7: *To propose a framework that will facilitate the re-evaluation and re-formulation of the current curriculum syllabus for the purpose of incorporating BIM.*

The build up towards the final product which refers to the proposed framework of recommendations for BIM integration was performed by crossed checking and analysing the trends in the industry and HEIs that managed to be gathered through Survey A and Survey B with the accreditation requirements by LAM and MQA. Chapter 7 has successfully discussed and elaborated the findings of objective 7. Therefore, the framework of recommendations is presented as follows:

<u>An Introduction to BIM – Beginner's Level</u>

Table 8.1: Framework for BIM Syllabus – Introduction to BIM.

DIGITAL GRAPHICS IN ARCHITECTURE		
1	Course level & placement	Beginner Year 1 *or* Year 2 – B.Sc. (Arch) (LAM Part I)
2	Course approach	BIM Integrated Module (BIM to be integrated into existing core module i.e. Digital Graphics or CAD)
3	Aims and objectives	4) To provide conceptual understanding on the principles and key concepts of using design software application in architecture; i.e. drafting, conventional modelling, parametric modelling, image editing, visual communication, collaboration and simulation. 5) To provide basic procedural/technical skills of computer software applications for 2D drafting, 3D modelling and image editing purposes, which acts as part of visual communication in architecture. 6) To provide simple understanding of the interoperability between various software applications.

4	Learning outcome (LO)	6) Recognise the importance of the above technology applications. 7) Understand how the technology applications work within the architecture practice and education. 8) Understand the process of using basic tools and features of the application. 9) Able to produce and represent a design project in relation to design studio project. 10) Able to cross transfer models from CAD to BIM and vis-à-vis; and at the same time able to address interoperability function.
5	Course outline (CO)	A semester of 14 weeks is divided into: CAD - 4 weeks BIM - 5 weeks Image editing – 3 weeks Quizzes and lab works- 2 weeks
6	Mode of delivery	Lectures Tutorials
7	Mode of assessment	Lab based assignments Projects - integrated into Construction Drawings module and Design Studio. Final project involves producing Design Studio's final project representation using the taught software application.

BIM Technology – Intermediate Level

Table 8.2: Framework for BIM Syllabus – BIM Technology.

BUILDING INFORMATION MODELLING		
1	Course level & placement	Intermediate Year 3 – B.Sc. (Arch) (LAM Part I)
2	Course approach	BIM Standalone Module (Elective Module)
3	Aims and objectives	6) To address the principles and key concepts of BIM in a deeper level. 7) To provide understanding of the classes and categories of BIM tools. 8) To provide intermediate level of procedural/technical skills of BIM for the purpose of 2D drafting, parametric 3D modelling, visualisation and rendering. 9) To introduce the functions and tools of BIM for collaboration and integrated practice. 10) To introduce BIM features and tools for constructability purpose.
4	Learning outcome (LO)	7) Understand the phased structure of a BIM project. 8) Understand the classes and categories of BIM tools. 9) Able to use BIM features to model conceptual massing, building elements, interiors, circulation and detailing. 10) Able to use BIM for visualization and renderings of design models. 11) Understand how BIM can be used for collaboration and integrated practice. 12) Understand how BIM can be used to understand the constructability aspect of a design.
5	Course outline (CO)	Each week shall consist of one single session of 3 *contact hours* and 4-6 *individual learning* hours. A semester of 14 weeks is divided into: Introduction - 1 week Modelling tools - 6 weeks Components and Families/Libraries – 1 week

		Collaboration/Integrated practice – 1 week Materials, Lighting and Rendering – 2 weeks Constructability and analysis – 1 week Quizzes and lab works- 2 weeks
6	Mode of delivery	Lectures Tutorials
7	Mode of assessment	Lab based assignments Projects – integrated into Design Studio. (i.e. the presentations for Design Studio's final project be produced by using BIM).

BIM Inter-Disciplinary Design Studio – Intermediate Level

Table 8.3: Framework for BIM Syllabus – Inter-Disciplinary Design Studio.

INTER-DISCIPLINARY STUDIO		
1	Course level & placement	Intermediate Year 4 – B. Arch (LAM Part II) *or* Year 1 – M. Arch (LAM Part II)
2	Course approach	BIM Inter-Disciplinary Collaborative Module * potential inclusion of students from i) Architecture ii) Landscape Architecture iii) Civil/Structural Engineering iv) Mechanical and Electrical Engineering v) Construction Management (Design Studio - Core Module)
3	Aims and objectives	6) To expose students with real-life collaboration and Integrated Project Delivery (IPD). 7) To develop the ability to effectively communicate both verbally and with digital graphic programs i.e. BIM 8) To develop the understanding on the roles and responsibility of team players in conjunction of using BIM. 9) To provide skills in using BIM tools that will enable the development and inspection of the constructability aspects. 10) To provide skills in using BIM tools for design performance simulation.
4	Learning outcome (LO)	8) Able to interact, collaborate and function on multi-disciplinary teams. 9) Able to understand the different roles and functions of individuals in the team.

		10) Able to effectively communicate both verbally and with digital graphic programmes i.e. BIM 11) Able to demonstrate understanding on the aspects of constructability by using BIM. 12) Able to utilise the design/energy performance simulation in developing design. 13) Able to co-ordinate various simulation by other team players into the design. 14) Able to co-ordinate design changes using BIM throughout the design development process.
5	Course outline (CO)	A semester of 14 weeks is divided into: Introduction – 1 week Theoretical Input and Planning – 2 weeks Schematic Design Stage – 2 weeks Design Development & Simulation – 6 weeks Documenting – 3 weeks
6	Mode of delivery	Concurrent studio periods (all disciplines) Lectures by internal staff and invited industry stakeholders Tutorials by internal staff and invited industry stakeholders Field trips and investigations Studio discussion and collaboration
7	Mode of assessment	Active participation and team involvement – 20% Project work – 80%

<u>BIM Applied Modules</u>

Table 8.4: Framework for BIM Syllabus –BIM Applied Module.

TECHNOLOGY RELATED MODULES i.e. *advanced building technology, advanced building construction* **DRAFTING AND TECHNICAL DRAWINGS RELATED MODULES** i.e. *technical drawings, measured drawings*		
1	Course level & placement	Intermediate Year 2-3 - B.Sc. (Arch) (LAM Part I) *and* B.Arch or M.Arch (LAM Part II)
2	Course approach	BIM Applied Module (Part of existing Core Modules i.e. i) Technology related modules i.e. *Advanced Building Technology, Advanced Building Construction* ii) Drafting and technical drawings related modules i.e. *Technical/Construction Drawings, Measured Drawings*)
3	Aims and objectives	3) To allow students to use BIM as a medium to develop and accomplish tasks. 4) To allow BIM to be used as a medium to convey tasks intent by means of representations.
4	Learning outcome (LO)	4) Able to develop and accomplish tasks by using BIM, which is one of the various possible methods allowed by the module. 5) Able to describe or explain the technicality aspects of the tasks by using design software i.e. BIM. 6) Able to use BIM, as one of the various digital methods allowed, to represent tasks intent.
5	Course outline (CO)	Not relevant – *BIM only used as assisting tool/medium.*
6	Mode of delivery	Not relevant – *BIM only used as assisting tool/medium.*

7	Mode of assessment	The *Assessment Rubrics* or *Marking Sheets* for assignments and projects to contain an unsubstantial percentage dedicated for BIM usage.

8.7 RECOMMENDATIONFOR FUTURE RESEARCH

The framework of recommendations developed for the integration of BIM into LAM Part I and Part II architecture programme proposes that BIM syllabus is originally structured into four modes of delivery, whereby one of them is described as the multi-disciplinary design studio. As has been mentioned earlier in Chapter 7, the decision to integrate BIM into the design studio for a single semester at Part II level was made considering that the introduction of BIM at an earlier level may hinder the creative development of design thinking among the new architecture students. Apart from that, the multi-disciplinary studio tends to focus on the collaborative works among students from various backgrounds, which is deemed suitable only for students of senior year that possess a certain level of proficiency on construction and technical understanding of designs. In relation to this matter, an increasing number of researchers in advanced countries in America and Europe have posited that after many years of implementing BIM, HEIs should now look into the prospect of integrating BIM into the conventional design studio at an earlier stage (Ambrose, 2012, Sharag-Eldin and Nawari, 2010, Barison and Santos, 2010a). According to them, this is to enable the students to gain more experience working with BIM and be better prepared to work in a BIM-centred environment once they graduated and started working. Therefore, it is possible for future research to formulate the best method to implement BIM in design studios across the architecture programme by taking the above matter into consideration, which will make it possible to achieve the benefit of BIM's rigour quantitative processes without having to sacrifice the comprehensive nature of design thinking.

Second, the recommended framework has only been centred on the development of BIM syllabus for the architecture curriculum, but failed to provide assistance in the assessment of organisational readiness to implement BIM. According to Smith and Tardif (2012), it is definitely important for organisations to first evaluate their level of readiness prior to the implementation of new technology such as BIM. In this case, it is highly recommended for HEIs to look into the availability of expertise and facilities for the purpose of ensuring that the teaching staffs are equipped with a certain amount of knowledge on BIM with the hope of realising a smooth and effective implementation. Apart from that, this may not only include BIM instructors, but also other staffs that may be responsible in overseeing the usage of BIM in design studios and architecture supporting modules such as *architecture technology*, *construction*, and *measured drawings*. Hence, it is important for each studio to be equipped with the necessary facilities if BIM were to be introduced into design studios with the hope that it can facilitate full BIM usage in the studio, which at the moment is not the case in most design studios in the local HEIs. Therefore, further works should be carried out to explore the need of appropriate tools that are required to assess the organisational readiness of BIM implementation among HEIs.

Third, it is suggested that further research should be conducted to evaluate the effectiveness of the framework considering that the recommended framework has not yet been put into practice by architecture programmes in Malaysia. This notion can be realised by embracing the qualitative and anthropological evaluation approach, whereby the effects and outcomes of the adopted approach can be practically evaluated from a holistic perspective based on the recommendation of the framework. In addition, this should collectively be done at all the HEIs and a detailed comparison must be made considering that modifications might take place from one HEI to another based on the fact that HEIs possess their own autonomy to carve their own curriculum design to a certain degree as long as it meets LAM's accreditation provisions.

Finally, as discussed earlier in the *limitation of the research* in Chapter 1, there is a possibility that several researchers may posit that the framework of recommendations is not able to be generalised within the Malaysian context due to its limited number of samples for Survey A; albeit that it is not the case for Survey B which managed to be fully completed by all required parties. On another note, the methods and process in developing the framework are deemed comprehensive and well-detailed, thus allowing for the same research framework and data collection instruments to be adopted in future studies for the purpose of upgrading the framework of recommendations with updated data provided that the amount of response is sufficient to enable the generalisation of research data.

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APPENDICES

APPENDIX A: QUESTIONNAIRES FOR SURVEY A

Universiti Kebangsaan Malaysia
National University of Malaysia

University of Strathclyde Glasgow

abatan Seni Bina *Department of Architecture*

18 March 2013

Dear Tan Sri/Datuk/Professor/Ar./ Mr./Ms.,

You are kindly invited to participate in a research survey titled "**The Development of Digital Architecture Modeling in the Architecture, Engineering and Construction (AEC) Industry in Malaysia**". This study is a joint research by *University of Strathclyde* and *Universiti Kebangsaan Malaysia*. The purpose of this study is to find out the development of digital technologies in Malaysia, with the focus being **Building Information Modeling (BIM)**.

The completion of this research would depend very much on getting adequate number of respondents from the sample population. As such, we are appealing for your good self to help us complete the attached questionnaire.

Here is a link to the survey:

https://www.surveymonkey.com/s/buildinginformationmodelingacademic

We owe a debt of gratitude to you for your time and cooperation. We thank you very much for taking the time to assist us and your contribution is very much appreciated.

Sincerely,

MUHAMMAD FARIHAN IRFAN MOHD NOR
Doctoral Candidate,
University of Strathclyde.

DR. MICHAEL GRANT
Supervisor,
Department of Architecture,
University of Strathclyde,
Glasgow, United Kingdom.

Segment 1

Basic data of employer/employee

Q.1 Please select your age band..

18-24 / 25-34 / 35-44 / 45-54 / 55+

Q.2 Your Job Title is..

Principal Architect - Architect - Production/ Draftsman - Graphic designer – Management

Q.3 Including yourself, approximately how many people...

- are employed in your firm?

  1-10 / 11-25 / 26-50 / 51- 100/ >100

- in your firm are directly involved in drawing & building documentation?

  1-10 / 11-25 / 26-50 / 51- 100/ >100

Q4. The majority of your projects are..

Private projects / Public-Government projects / Historic conservation / Renovation works / Other

Q5. Value of all active projects (current and completed projects within the last 12 months)

RM100,000- RM1 million / RM2 million-RM10 million / RM11 million-RM50 million / RM51 million-RM100million / > RM100 million

Segment 2

Usage of digital technologies at establishment.

Q6. When producing CAD drawings, which of the following software do you mainly use?

Autodesk AutoCAD / Autodesk Architectural Desktop / Autodesk Revit / Bentley Microstation / Bentley Building Suite / Sketchup / Graphisoft ArchiCAD / Nemetschek Allplan / Nemetschek Vectorworks / Other (please specify)

Q7. Which other software do you also use at your workplace?

Autodesk AutoCAD / Autodesk Architectural Desktop / Autodesk Revit / Autodesk Ecotect / Autodesk Green Building Studio / eQuest / Bentley Microstation / Bentley Building Suite / Sketchup / 3D Studio Max / Graphisoft ArchiCAD / Graphisoft EcoDesigner / Nemetschek Allplan / Nemetschek Vectorworks / IES / Other (please specify)

Q8. For each of the following statements, how would you describe your firm's use of CAD?

(For all projects / For most projects / For some projects / Never / Don't know)

- We use our CAD models to produce *2D drawings*
- We use our CAD models to produce *3D visualisations*
- We generate *schedules* directly from our CAD models
- We generate *bills of quantity* directly from our CAD models
- We carry out *building performance analysis* on our CAD models
- We perform *clash detection* by collaborating with others through the use of CAD models
- We need to have access to a wide range of generic CAD objects, not just manufacturer's objects
- We keep a *library* of CAD objects we create for reuse

Q9. The main factor that drives you to adopt new software/technologies would be..

(*Strongly agree/Slightly agree/Neither agree nor disagree/Slightly disagree/Strongly disagree)*

- Sales Pressure by suppliers and vendors
- Clients' needs
- Project Team's needs

- Organization (e.g *Pertubuhan Arkitek Malaysia*)
- Types of skills graduate posses
- As a marketing tool for your organization

Segment 3

Awareness and BIM experience

Q10. Had you ever heard of BIM (Building Information Modelling) before taking this survey?

Yes / No / Don't know

Q11. Does your firm currently use BIM for its projects? (‘*No*’ brings to Q12b)

Yes / No / We Out-Source BIM works

Q12. Will your firm keep using BIM in the future?

Yes / No / Don't know

Q12b. Will your firm use BIM in the future? *(‘Yes’ brings to Q14. ‘No’ / ‘Don’t know’ brings to Q16a)*

Yes / No / Don't know

Q13. For how long has your firm implemented BIM?

<1 year / 1 year / 2 years / 3 years / 4 years / > 4 years

Q14. From your understanding of BIM, how strongly do you agree or disagree with the following statements?

(*Strongly agree/Slightly agree/Neither agree nor disagree/Slightly disagree/Strongly disagree)*

- You hear more often of BIM these days
- BIM is all about software and nothing more
- BIM is used to produce 3D CAD drawings only
- BIM is all about real time collaboration

- BIM is the future of project information
- BIM is the future of project management
- BIM is only for new build, not refurbishment or alteration
- BIM leads to bland and less creative design
- The industry does not fully understand what BIM is yet
- BIM is needed to design sustainable buildings

Q15. Based on your experience and involvement in using BIM, how strongly do you agree or disagree with the following statements? *(brings to Q16b)*

(*Strongly agree/Slightly agree/Neither agree nor disagree/Slightly disagree/Strongly disagree)*

- BIM has improved visualisation
- BIM has increased coordination of construction documents
- BIM has improved site logistics
- BIM has improved productivity
- BIM has increased speed of delivery
- BIM has brought cost efficiencies
- BIM has increased our profitability & return of investment (ROI)
- BIM has helped us in producing specifications
- BIM has helped us in producing bills of quantities
- BIM has required changes in roles and work scope
- BIM has required changes in our workflow, practices and procedures
- We have a BIM unit/division that handles/supports all BIM matters
- Clients has increasingly insist on us using BIM
- We have used BIM successfully
- We rather stick with CAD than adopt BIM

Segment 4

BIM in the future: Drivers and barriers

Q16a. How strongly do you agree or disagree of the following reasons for not using BIM at your organisation?

(Strongly agree/Slightly agree/Neither agree nor disagree/Slightly disagree/Strongly disagree)

- We believe that the approaches/systems we currently use are better
- The functionality of BIM doesn’t help much in what we do
- There are concerns about the liability for BIM models
- There are interoperability concerns between BIM and our CAD applications
- The availability of BIM-compatible content/libraries seems to be insufficient
- It is too difficult to use BIM software
- There is a lack of BIM skilled staff
- The training available for BIM is insufficient
- BIM software is too expensive
- There is not enough demand from clients and/or other project members
- BIM seems less efficient for smaller projects
- Introducing BIM in a project will result in unclear roles/change in roles of participants
- Issues concerning ownership and maintenance of the BIM model are still unresolved
- The current legal contracts do not adequately address BIM issues
- There are not enough research on BIM to support its usage
- We are interested in using BIM, but we don't know where to start

Q16b. How strongly do you agree or disagree that the followings would be strong drivers towards BIM adoption?

(Strongly agree/Slightly agree/Neither agree nor disagree/Slightly disagree/Strongly disagree)

- Mandating BIM on projects by Government

- Having credible accreditation process
- Availability of accredited trainers
- Having complete understanding and buy-in from all trades involved
- Availability of skilled professionals
- Availability of industry Standards
- Compatibility between BIM and CAD software
- Availability of in-depth research that covers all aspects of BIM

Segment 5

Skills and training

Q17. Architecture education has roles to play in keeping up with the development of digital technology, particularly in BIM. How strongly do you agree or disagree with the followings:

(Strongly agree/Slightly agree/Neither agree nor disagree/Slightly disagree/Strongly disagree)

- Academic institutions should produce more research on BIM.
- Academic institutions should lead the way in adopting and promoting BIM.
- It is expected for graduates to have adequate IT skills deemed by the organisation/company.
- Graduates leave universities with the right IT skills needed by the workforce.
- Graduates should be taught on the conceptual knowledge and understanding of BIM rather than the proficient skills with BIM software.
- Our organisation/company prefers staff to be trained in-house for IT skills rather than relying on skills taught during tertiary education.

Name of company/firm:

- End –

APPENDIX B: QUESTIONNAIRES FOR SURVEY B

Universiti Kebangsaan Malaysia
National University of Malaysia

University of Strathclyde Glasgow

Jabatan Seni Bina | Department of Architecture

15 March 2013

Jabatan Seni Bina,
Universiti Teknologi MARA,
Shah Alam, Selangor Darul Ehsan.

Dear Dr.,

RESEARCH SURVEY ON BUILDING INFORMATION MODELING (BIM)

You are kindly invited to participate in a research survey titled "**The Development of Digital Architecture Modeling in the Architecture, Engineering and Construction (AEC) Industry in Malaysia**". This study is a joint research by *University of Strathclyde* and *Universiti Kebangsaan Malaysia*, and it is the main focus of my PhD theses. The purpose of this study is to find out the development of digital technologies in Malaysia, with the focus being Building Information Modeling (BIM).

The completion of my PhD thesis would depend very much on getting adequate number of respondents from the sample population. As such, I am appealing to the honourable members of the academic such as your good self to help me complete the attached questionnaire. Please take a few minutes today to answer each question on the survey as completely and accurately as possible.

I owe a debt of gratitude to you for your time and cooperation. Without your kind assistance I would definitely fail to accomplish my research objectives and therefore rendering my PhD incomplete. In return, I am offering my hands to assist you in any other research projects or academic related matters to which I can be of assistance.

I thank you very much for taking the time to assist me in my educational endeavors and your contribution is very much appreciated. May God reward you for your kind assistance.

Sincerely,

MUHAMMAD FARIHAN IRFAN MOHD NOR
Doctoral Candidate,
University of Strathclyde.

DR. MICHAEL GRANT
Supervisor,
Department of Architecture,
University of Strathclyde,
Glasgow, United Kingdom.

Segment 1

Basic Profile

Name :

____

Position:

____

Department:

____

Institution:

____

Segment 2

CAD Usage

Q1. Which of the following tools are taught as part of the architecture program?

Autodesk AutoCAD / Autodesk Architectural Desktop / Autodesk Revit / Autodesk Ecotect / Autodesk Green Building Studio / eQuest / Bentley Microstation / Bentley Building Suite / Sketchup / 3D Studio Max / Graphisoft ArchiCAD / Graphisoft EcoDesigner / Nemetschek Allplan / Nemetschek Vectorworks / IES / others

Q2. The students are taught to use CAD to..

(all projects / most projects / some projects / Never / Don't know)

- Produce *3D visualisations* using our CAD models
- Produce *2D drawings* using our CAD models
- Generate *schedules* from our CAD models
- Generate *bills of quantity* from our CAD models
- Carry out *performance analysis* (energy consumption/structural/acoustic) on our CAD models

- Perform *clash detection* by collaborating with others through the use of CAD models
- We keep a *library* of CAD objects we create for reuse

Q3. The main factor that drives the program to adopt new kinds of software/technologies would be..

(*Strongly agree/Slightly agree/Neither agree nor disagree/Slightly disagree/Strongly disagree)*

- Sales Pressure by suppliers and vendors
- Demands by professional practices
- Driven by research needs
- Organization (e.g *Pertubuhan Arkitek Malaysia*)
- Demands by students
- Recommendations by other institutions
- Due to the software/technology's global reputation

Segment 3

BIM experience

Q4. Does the architectural program offer BIM or BIM related course? ('*No*' brings to Q12)

Yes / No / We Out-Source BIM works

Q5. Since when did BIM become part of the program?

before 2003 / 2003-2005 / 2006-2008 / 2009-2011 / 2012 onwards

Q6. The number of courses offered in the program that contains BIM elements are…

1 / 2-3 / 4-5 / 5-6 / more than 6

Q7. BIM is taught during..

1st year / 2nd- 3rd year / Final year / Masters / PhD

Q8. For undergraduate program, these courses are taught as..

core course / elective course / external course / others / irrelevant

Q9. For post-graduate program, these courses are taught as..

core course / elective course / external course / others / irrelevant

Q10. How do the following statements conform to the teachings of BIM in the architecture program?

(Yes / No, but maybe in the future / No, still undecided for the future / No, never / Not relevant)

- BIM is taught in specific single-course(s)
- BIM is taught intra-courses throughout the curriculum
- BIM is taught through interdisciplinary courses and distance collaboration
- We had a curriculum-wide coordination due to implementing BIM
- We have introduced BIM into our Design Studio courses
- We *train students to use BIM as the main collaborative tool in team projects.*
- We teach students to use BIM for 3D visualization purpose
- We teach students to use BIM for constructability purpose
- We teach students to use BIM to tie schedules to models
- We teach students to use BIM to tie estimates to the models
- We teach students to use BIM models for further energy simulation / operations analysis.
- We teach students to use BIM to perform clash detection on design projects.

Q11. From your experience of teaching BIM, how strongly do you agree or disagree with the following statements? *(brings to Q13)*

(Strongly agree / Slightly agree / Neither agree nor disagree / Slightly disagree / Strongly disagree)

- BIM has helped students to enhance design creativity
- BIM has helped students to improve visualisation
- BIM has helped students to improve productivity
- BIM has helped students to increase speed of delivery
- BIM has helped students to consider cost efficiencies in design
- BIM has helped in producing specifications
- BIM has helped in producing bills of quantities
- BIM has required changes in studio workflow and practices
- Students are happy in using BIM
- We have used BIM successfully
- We rather stick with CAD than adopt BIM

Q12. How strongly do you agree or disagree of the following reasons for not incorporating BIM into curriculum to this date. *(brings to Q14)*

(Strongly agree / Slightly agree / Neither agree nor disagree / Slightly disagree / Strongly disagree)

- We don't have anyone to teach it
- Lack of Teaching Assistant support
- Inadequate resources to make the curriculum change
- No room in curriculum
- Not an accreditation criterion
- BIM software are expensive
- Lack of familiarity with BIM
- Not considered important
- Insufficient student demand

Q13. "*It is important to focus in teaching students on the conceptual knowledge and understanding of BIM rather than on the proficient skills of BIM software".*

Do you agree or disagree? Please elaborate.

____

____

Q14. "*Keeping the curriculum in line with the needs of industry is an important challenge given that the AEC industry is poised for rapid transformation. However, AEC education should be setting the pace rather than keeping the pace with the industry*."

(Becerik-Gerber, Gerber et al. 2011)

Do you agree or disagree that Academic institutions should lead the way in adopting and promoting BIM? Please elaborate.

____

____

Segment 4

BIM Research

Q15. Research is needed to develop an awareness of the changes that BIM is having on the AEC industry. It plays an important role in justifying the investment and adoption of a new technology, moreover those that require big investments and those that result in core changes to the deliverable system. Please describe briefly on the university's Department of Architecture's involvement in BIM research based on the followings:

Number of overall projects (research grants)

Value of grants for the above research (in RM)

Research within the department

Inter disciplinary research across the university

Joint research with the industry

Joint research with foreign institutions/industry

- End -

APPENDIX C: ATTACHMENT OF VALIDATION SURVEY

10 April 2018

Jabatan Seni Bina,
Universiti Teknologi MARA,
Shah Alam, Selangor Darul Ehsan.

Research Information Statement for the PhD Project

ON THE INTEGRATION OF BUILDING INFORMATION MODELLING (BIM) IN ARCHITECTURE PROGRAMMES IN MALAYSIA

Dear Dr.,

My name is Muhammad Farihan Irfan Mohd Nor, faculty member of Universiti Kebangsaan Malaysia and currently undertaking PhD programme at the University of Strathclyde, United Kingdom under the supervision of Dr. Michael P. Grant and co-supervision of Dr. David Grierson.

Following the earlier survey entitled *The Development of Digital Architecture Modeling in the AEC Education in Malaysia* that you have taken in 2013, I am now kindly inviting your goodself to validate my research findings on my PhD research entitled On the Integration of Building Information Modelling (BIM) in Architecture Programmes in Malaysia. This research aims at developing a framework that is able to support the integration of Building Information Modelling (BIM) principles into the LAM Part I and Part 2 architecture programmes in Malaysia. Therefore, I am appealing for your kind cooperation in providing your time and expertise by completing the questionnaire through the link given below.

I owe a debt of gratitude to you for your time and kind cooperation. In return, I am offering my hands to assist you in any other research projects or academic related matters to which I can be of assistance.

Thank you very much.

Privacy Protection
All responses to this questionnaire would be kept strictly confidential and will only be used for academic purposes only. Once an appropriate data collection be conducted, the questionnaire will be shredded away after use.

How will the information gained be used?
Unless requested, by default, once you have decided to participate, the data collected from your contributions may appear in the PhD dissertation and other related publications such as local and international journal. However, no personal details or details about the organisation will be disclosed.

Sincerely,

MUHAMMAD FARIHAN IRFAN MOHD NOR
Doctoral Candidate,
University of Strathclyde, U.K.

Framework for BIM Syllabus - Validation

1. Profile

* Name:

* Institution:

- Universiti Teknologi MARA (UiTM)
- Universiti Teknologi Malaysia (UTM)
- Universiti Sains Malaysia (USM)
- Universiti Malaya (UM)
- Universiti Putra Malaysia (UPM)
- International Islamic University Malaysia (IIUM)
- Universiti Sains Islam Malaysia (USIM)

Syllabus 1: Introduction to BIM – Beginner's level

Integrated BIM Courses

These are existing courses in the curriculum of the architecture Part I programme that has a certain percentage of the course content be replaced with BIM syllabus. There are 2 ways for this to happen, i) a certain percentage of the original content is removed and replaced with BIM syllabus, or ii) the original course content be compressed to make way for the inclusion of BIM syllabus.

For the level of feasibility and validness, please select the most appropriate answer by ticking one of the circles <u>for each criterion</u> (BI1-BI7) based on your opinion as an academician within the current context.

Highly feasible & valid	Feasible & valid	Neutral	Infeasible & invalid	Very Infeasible & invalid
○	○	○	○	○

IMPLEMENTATION CRITERIA		
VEL 1	BI1: COURSE LEVEL & PLACEMENT	Beginner Year 1 or Year 2 – B.Sc. (Arch) (LAM Part I)
	BI2: COURSE APPROACH	BIM Integrated Course (BIM to be integrated into existing core course i.e. Digital Graphics or CAD)
	BI3: AIMS AND OBJECTIVES	1) To provide conceptual understanding on the principles and key concepts of using design software application in architecture; i.e. drafting, conventional modelling, parametric modelling, image editing, visual communication, collaboration and simulation. 2) To provide basic procedural/technical skills of computer software applications for the purpose of 2D drafting, 3D modelling and image editing as part of visual communication in architecture. 3) To provide simple understanding on the interoperability between various software applications.

L E V	BI4: LEARNING OUTCOME (LO)	1) Recognise the importance of the above technology applications. 2) Understand how these technology applications work within the architecture practice and education. 3) Understand the process of using basic tools and features of the application. 4) Able to produce and represent a design project in relation to design studio project. 5) Able to cross transfer models from CAD to BIM and vis-à-vis; addressing interoperability function.
	BI5: COURSE OUTLINE (CO)	A semester of 14 weeks is divided into: CAD - 4 weeks BIM - 5 weeks Image editing – 3 weeks Quizzes and lab works- 2 weeks
	BI6: MODE OF DELIVERY	Lectures Tutorials
	BI7: MODE OF ASSESSMENT	Lab based assignments Projects - integrated into Construction Drawings course and Design Studio. Final project involves producing Design Studio's final project representation using the taught software application.

Syllabus 2: BIM Technology – Intermediate level

Standalone BIM Courses

This is a new course with course contents made up of only BIM syllabus. There are 2 ways for this to happen, 1) an existing standalone course (i.e. 3D Studio Max) is removed and replaced with BIM standalone course, or 2) to add an additional standalone course (BIM) into the current curriculum.

For the level of feasibility and validness, please select the most appropriate answer by ticking one of the circles for each criterion (IS1-IS7) based on your opinion as an academician within the current context.

Highly feasible & valid	Feasible & valid	Neutral	Infeasible & invalid	Very Infeasible & invalid
○	○	○	○	○

IMPLEMENTATION CRITERIA		
	IS1: COURSE LEVEL & PLACEMENT	Intermediate Year 3 – B.Sc. (Arch) (LAM Part I)
	IS2: COURSE APPROACH	BIM Standalone Course (Elective Course)

LEVEL 2	IS3: AIMS AND OBJECTIVES	1) To address the principles and key concepts of BIM in a deeper level. 2) To provide understanding on the classes and categories of BIM tools. 3) To provide intermediate level of procedural/technical skills of BIM for the purpose of 2D drafting, parametric 3D modelling, visualisation and rendering. 4) To introduce the functions and tools of BIM for collaboration and integrated practice. 5) To introduce BIM features and tools for constructability purpose.
	IS4: LEARNING OUTCOME (LO)	1) Understand the phased structure of a BIM project. 2) Understand the classes and categories of BIM tools. 3) Able to use BIM features to model conceptual massing, building elements, interiors, circulation and detailing. 4) Able to use BIM for visualization and renderings of design models. 5) Understand how BIM can be used for collaboration and integrated practice. 1) Understand how BIM can be used to understand the constructability aspect of a design.
	IS5: COURSE OUTLINE (CO)	A semester of 14 weeks is divided into: Introduction - 1 week Modelling tools - 6 weeks Components and Families/Libraries – 1 week Collaboration/Integrated practice – 1 week Materials, Lighting and Rendering – 2 weeks Constructability and analysis – 1 week Quizzes and lab works- 2 weeks
	IS6: MODE OF DELIVERY	Lectures Tutorials
	IS7: MODE OF ASSESSMENT	Lab based assignments Projects – integrated into Design Studio. (i.e. the presentations for Design Studio's final project be produced by using BIM).

Syllabus 3: BIM Inter-Disciplinary Studio – Intermediate level

<u>Inter-disciplinary Design Studio (BIM work-based)</u>

Design Studio based course that utilises Building Information Models (BIM) for the design of building projects with inter-disciplinary teams i.e. *Architecture, Landscape Architecture, Civil/Structural Engineering, Mechanical and Electrical Engineering, or Construction Management*. This studio, which is offered for a single semester, is based on the Integrated Project Delivery (IPD) process where formal collaboration between team members of different fields is at the centre of the process.

For the level of feasibility and validness, please select the most appropriate answer by ticking one of the circles <u>for each criterion</u> (II1-II7) based on your opinion as an academician within the current context.

Highly feasible & valid	Feasible & valid	Neutral	Infeasible & invalid	Very Infeasible & invalid
○	○	○	○	○

IMPLEMENTATION CRITERIA	
II1: COURSE LEVEL & PLACEMENT	Intermediate Year 4 – B.Arch (LAM Part II) *or* Year 1 – M.Arch (LAM Part II)
II2: COURSE APPROACH	BIM Inter-Disciplinary Collaborative Course * potential inclusion of students from i) Architecture ii) Landscape Architecture iii) Civil/Structural Engineering iv) Mechanical and Electrical Engineering v) Construction Management (Design Studio - Core Course)

LEVEL 2	II3: AIMS AND OBJECTIVES	1) To expose students with real-life collaboration and Integrated Project Delivery (IPD). 2) To develop the ability to effectively communicate both verbally and with digital graphic programs i.e. BIM 3) To develop understanding of the roles and responsibility of team players in conjunction of using BIM. 4) To provide skills in using BIM tools to develop and inspect constructability aspects. 5) To provide skills in using BIM tools for design performance simulation.
	II4: LEARNING OUTCOME (LO)	1) Able to interact, collaborate and function on multi-disciplinary teams. 2) Able to understand the different roles and functions of individuals in the team. 3) Able to effectively communicate both verbally and with digital graphic programmes i.e. BIM 4) To demonstrate understanding on the aspects of constructability by using BIM. 5) Capable of utilising and co-ordinating design/energy performance simulations in developing designs. 6) Able to co-ordinate design changes using BIM throughout the design development process.
	II5: COURSE OUTLINE (CO)	A semester of 14 weeks is divided into: Introduction – 1 week Theoretical Input and Planning – 2 weeks Schematic Design Stage – 2 weeks Design Development & Simulation – 6 weeks Documenting – 3 weeks
	II6: MODE OF DELIVERY	Concurrent studio periods (all disciplines) Lectures by internal staff and invited industry stakeholders Tutorials by internal staff and invited industry stakeholders Field trips and investigations Studio discussion and collaboration
	II7: MODE OF ASSESSMENT	Active participation and team involvement – 20% Project work – 80%

Syllabus 4: BIM Applied Courses – Intermediate level

<u>Applied Courses</u>

These are courses that may not contain formal BIM syllabus but require BIM to be used by students for certain tasks or projects. It is also possible that these applied courses are mapped together with the integrated or standalone courses of BIM where assessments are jointly made; contents of tasks are assessed by the former while techniques of delivering the tasks are assessed by the latter.

For the level of feasibility and validness, please select the most appropriate answer by ticking one of the circles <u>for each criterion</u> (IA1-IA7) based on your opinion as an academician within the current context.

Highly feasible & valid	Feasible & valid	Neutral	Infeasible & invalid	Very Infeasible & invalid
○	○	○	○	○

IMPLEMENTATION CRITERIA		
	IA1: COURSE LEVEL & PLACEMENT	Intermediate Year 2-3 - B.Sc. (Arch) (LAM Part I) *and* B.Arch or M.Arch (LAM Part II)
	IA2: COURSE APPROACH	BIM Applied Course (Part of existing Core Courses i.e. i) Design Studio ii) Technology related courses i.e. *Advanced Building Technology, Advanced Building Construction* iii) Drafting and technical drawings related courses i.e. *Technical/Construction Drawings, Measured Drawings*)

LEVEL 2	IA3: AIMS AND OBJECTIVES	1) To allow students to use BIM as a medium to develop and accomplish tasks. 2) To allow BIM be used as a medium to convey tasks intent by means of representations.
	IA4: LEARNING OUTCOME (LO)	1) Able to develop and accomplish tasks by using BIM, as one of the various possible methods allowed by the course. 2) Able to describe or explain the technicality aspects of the tasks by using design software i.e. BIM. 3) Able to use BIM, as one of the various digital methods allowed, to represent tasks intent.
	IA5: COURSE OUTLINE (CO)	Not relevant – *BIM only used as assisting tool/medium*.
	IA6: MODE OF DELIVERY	Not relevant – *BIM only used as assisting tool/medium*.
	IA7: MODE OF ASSESSMENT	The *Assessment Rubrics* or *Marking Sheets* for assignments and projects to contain an unsubstantial percentage dedicated for BIM usage.

APPENDIX D: RELATED PUBLICATION 1

Building Information Modelling (BIM) in the Malaysian Architecture Industry

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Abstract: - For the past quarter century, the architecture profession have seen tremendous developments in skills level, work processes and professional culture with the adoption of digital technologies. Investment in technology has always been to improve effectiveness in practice and increase performance in the design/build process that yields a return of investment at the end of the day. Today, more and more digital technologies have been developed and created to accommodate the high demands of the market over the years, including Building Information Modelling (BIM). This research paper aims to look into the insight of how architect firms in Malaysia are coping up with the introduction of BIM in the country. The main approach is by conducting a nationwide survey on all the architectural firms in Malaysia and the findings will be used as a foundation for further research on the matter. High quality research is needed to help justify the usage of this new technology within the country.

Key-Words: - Building Information Model (BIM), Computer Aided Design, Graphic Editor, Software, 2D Drafting, 3D Modeling and Rendering

1 Introduction

Digital technologies have been changing architects' life and way of working for the last few decades. At the start of the new millennium, research and development by the ever demanding market has led to the creation of an even more sophisticated technology that not only change the way architects design but also how the profession works. That technology is called Building Information Modeling (BIM) and Building Performance Simulation (BPS).

Today, BIM is centre-stage within the construction sector the world-over. It is seen as a means to overcome those age-old difficulties in communications and information management that have plagued the architecture industry for decades. Reports and research from around the world shows that BIM has now gained strong grounds and its numbers of users continue to grow from year to year.

The 2012 SmartMarket Report by McGraw Hill shows that the adoption rate of BIM in the United States has reached 72% [1]. Reports by the same publisher for the same year also states that the adoption rates in Korea is at 58% while the Middle East stands close to 25% [1]. According to a 2010 report, BIM usage in Western Europe has reached 38% [2]. The National Building Specification (NBS), a body owned by the Royal Institute of British Architects (RIBA), reported that the BIM adoption rate in the UK for 2012 stands at 31% [3]. On the Southern Hemisphere, a 2012 national report by Masterspec states that New Zealand has 34% users of BIM while Australia's adoption rate is at 19% [4].

Due to the benefits of BIM and its huge potential of improving the Architecture, Engineering and Construction (AEC) industry, governments of developed and developing countries around the world have also started to mandate the usage of BIM in their respective countries. In the United States, the General Services Administration (GSA) began requiring the use of BIM in all new projects in 2007 [5]. BIM has been compulsory in Finland since 2007 when it comes to the state enterprise Senate Properties that provides property services primarily to government customers [5]. Whereas in Norway, the civil state client *Statsbygg* decided to use BIM for the whole lifecycle of their buildings from 2005 onwards [6]. In 2007, Danish state clients such as the *Palaces & Properties Agency*, the *Danish University Property Agency* and the *Defence Construction Service* require BIM to be used for their projects [7]. The Dutch Ministry of Interior on the other hand, requires BIM to be used for large building maintenance projects in the Netherlands from 2012 onwards [6]. In Asia, where BIM was initially seen as slow to adopt BIM has now taken steps to catching up with the rest by mandating BIM use for public works. The Hong Kong Housing Authority will require BIM for all new projects from 2014 while the Public Procurement Service of Singapore made BIM compulsory for all projects over S$50 million and for all public sector projects by 2016 [8].

However, whilst BIM have shown promise elsewhere, it has not been the same in Malaysia. As to date, no government agencies or body has mandated the usage of BIM. Research in BIM is also at a low where none of the academic institutions have set up a unit or department that looks into BIM matters. While national scale reports or surveys on BIM usage has been conducted in many developed countries, it has not been the case with Malaysia.

2 Issue

When CAD was introduced to the architecture world about a quarter century ago, the architecture industry in Malaysia took its own time to adopt the new technology. This was probably due to the fact that the medium for the technology, the computer, was also a new technology altogether and a luxury to own such machine. Nevertheless, CAD technology is now used to the fullest by the majority of firms if not all. According to a survey done on Malaysian architecture firms in 2009, AutoCAD by Autodesk is a household item and used by all the respondents in the survey. It also revealed that high end 3D solid and surface modelers were used extensively by the industry [9].

However, BIM and BPS is a different game altogether compared to CAD, CAAD and CAM. It is not a tool that replaces pens and pencils. BIM is much more of a change for the industry than CAD/CAM/CAAD: it reorganizes the sequence, timing, and duration of the design process, ushers in a new model of constant, detailed communication, puts a geometrically larger amount of information into one place, and might even change the fundamental roles of each participating company [10]. A huge amount of investment is required to adopt this new system. Without data, guides and assist, few people can justify their adoption of BIM and those at the forefront of BIM technology may be moving in a direction that does not necessarily lead to success [11].

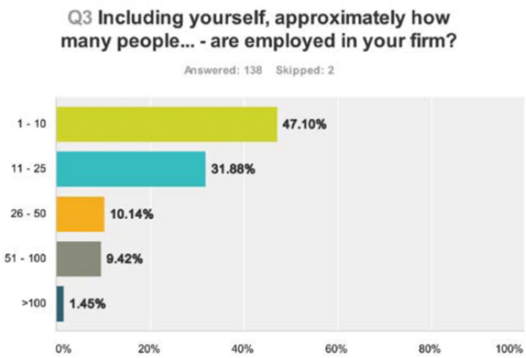
3 Methodology

Looking to the above matter, it is crucial that a report on the adoption and usage of BIM is produced at a national level as a first step towards developing the future roadmap towards full BIM implementation in the country. For this, a quantitative survey was done on all the architectural firms in Malaysia amounting to 535 firms. All of these firms are registered to the Malaysian Institute of Architects or *Pertubuhan Arkitek Malaysia* (PAM), the professional body for architects in Malaysia. The survey, which was distributed electronically through emails, was carried out from 18 March 2013 to 17 June 2013, a total period of three (3) months. From the survey, 140 firms responded, which gives a responds rate of 26%. From a demographic aspect, 61% of the responds came from Kuala Lumpur, Malaysia's capital and biggest city.

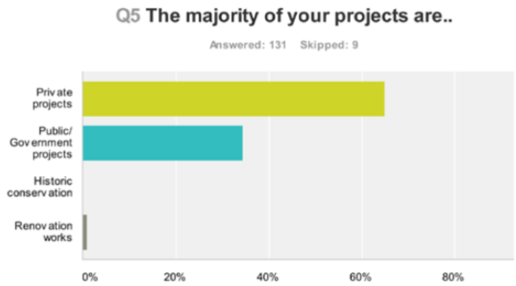
There are two (2) main objectives as to why the survey was carried out. The first objective was to find out the current use of digital technologies in practice. This includes the types of computer application used in offices and categorizing it into primary and secondary usage. The survey also gives insights into the impacts that these technologies are having on design strategies, associated management structures and cultures within the industry. The second objective of this survey was to explore the usage of BIM within the industry. This will also provide an insight into the impacts that BIM are having on design strategies, associated management structures and cultures among the firms.

The results obtained from this survey have provided the Malaysian Institute of Architects an insight which would help enable them to take further actions in promoting the adoption of BIM within the architecture industry in the country.

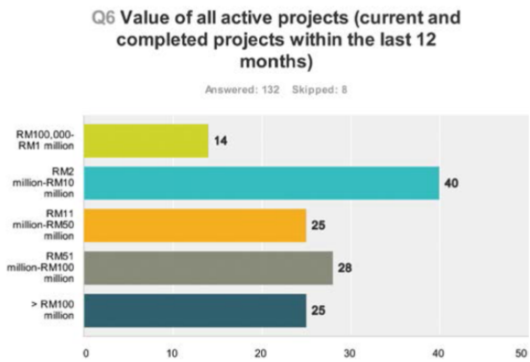
4 Findings and Analysis



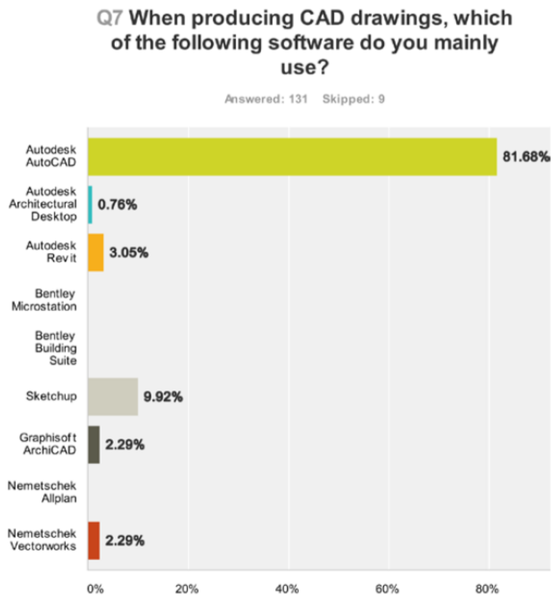
Firms with not more than 10 employees make up the majority at 47% of the sample, followed by firms with 11-25 employees at 32%, and firms with 26-50 employees at 10%. Bigger firms with 51 to 100 employees' makes up only 9% of the sample. Firms with the more than 100 employees made up the lowest respond rate at only 1.5%. With this, it shows a trend that the responds rate decreases as from smaller firms to bigger firms.



85 respondents reported that the majority of their projects come from the private sector whereas 45 respondents reported having public or government funded projects as their main source of projects. It is noticeable that only 1 respondent is concentrating on renovation projects while none from the sample are focusing on conservation works. This somehow shows that a young and developing country like Malaysia focuses more on new projects and unlike most European and North American countries, most of its buildings in the urban areas are less than 100 years old and considered not old enough to carry substantial heritage values.



The majority of respondents, which represent 30% of the sample, currently run projects worth between RM2-RM10 million. Other respondents above that category are equally distributed with each of the 3 other category having 25-28 respondents, or roughly 20% of the sample. This includes firms with active projects that cost more than RM100 million (£23 million). Even though small firms make up to nearly 60% of the respondents, the size and value of projects can be seen as being more equally distributed among the respondents.

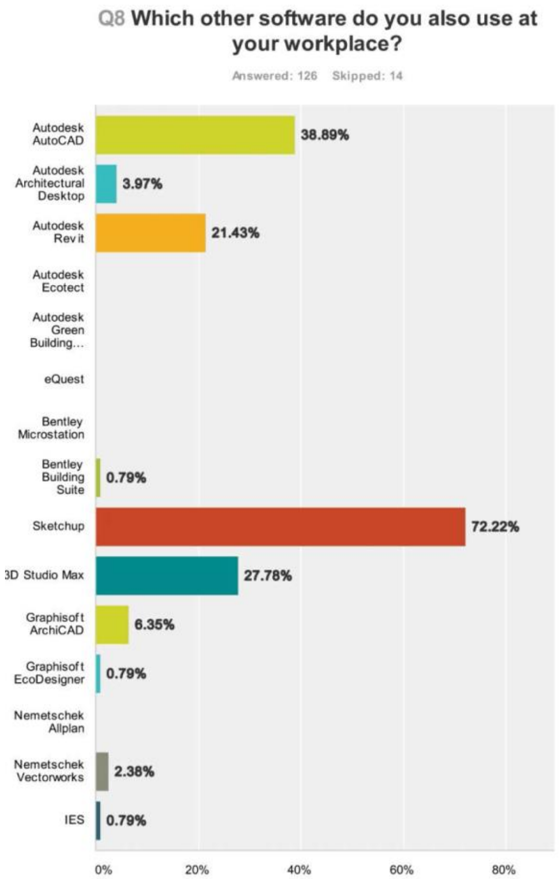


This question is one of the most important questions in the survey as the finding relatively answers the first objective of the research. The above figure shows the types of software applications that the architecture firms mainly used to produce CAD drawings. CAD drawings by definition means drawings used for construction and documentation purpose. Based on the responds, *AutoCAD* by *Autodesk* has the highest respondents with a total of 107, representing 82% of the sample. Next in second place is Sketchup with 13 respondents, 10% of the sample.

The huge difference on the nos. of users between *AutoCAD*, which sits at first place, and its closest rival shows that AutoCAD seems to be dominating the current CAD market and thus setting up a standard for the industry for 2D software. There may be a number of reasons as to why this happens. *AutoCAD*, a software traditionally used for the production of 2D drawings, was one of the first 2D drafting application introduced in the country. Therefore, being the earliest 2D drafting application, coupled with tremendous marketing effort during its introduction, the *AutoCAD* name has been synonymous to architects and draftsmen when it comes to 2D drafting [12].

Apart from that, the transfers of drawing files from one consultant to the other consultants in a construction project during the early years demanded all project team members to use the same software application. This was due to the fact that most software applications stands on its own platform and did not share the same format, making it unable to open and edit drawing files through other different applications. Due to this, AutoCAD, which was one of the earliest 2D drafting application to be introduced in the country, set an informal rule that any new office that intends to implement computer drafting has to have AutoCAD to be able to read AutoCAD drawings that comes from other senior or leading firms. Although this is no longer a problem as most software applications of today are able to read files from other applications, by the time this happens, AutoCAD has already been brought and used by most architect firms in the country.

Another revelation by this question was on the usage of Building Information Modeling (BIM). Software that uses BIM platform such as *Autodesk Revit* and *Graphisoft ArchiCAD* enables 2D drawings to be extracted directly from the main master model, thus making 2D software such as *AutoCAD* and *Microstation* redundant and irrelevant to architecture firms that adopt BIM. Based on this result, it is clear that 92% of the respondents may not yet adopt BIM, or at least have not made BIM their main platform for project deliverables.



An architecture firm can choose to use more than one type of digital media for its project deliverables. This may happen for firms that may have different employees with different skills and preferences for specific digital application even though they might all work on the same project. It may also happen that the different types of outputs an architecture firm produces such as 2D drawings, 3D drawings, montage images, virtual reality, simulations, video presentation and so on may result in the usage of different software application that offers different capabilities. An architecture firm that is replacing their main digital application with a new one might do that by first adopting the new technology as a secondary or supporting application before upgrading it to become their main digital application.

Based on the result, SketchUp by *Trimble Navigation Ltd*., which is a 3D software application, founds itself as the most popular secondary or supporting software in the Malaysian market. Although the software is considered relatively new, as its first release in the country was in late the 2000, its popularity rose sharply over the years as many consider its *Push/Pull* Technology (U.S patented 2003) has made it probably the easiest 3D software available on the market. However, as the application is meant for conceptual 3D modelling, as reflected by its name, SketchUp's popularity would most probably stays stagnant due to its inability to provide high-end 3D renderings. This is where 3D modelling and rendering software such as *Autodesk's* 3D Studio Max and Cinema4D by *Maxxon* comes in. Most SketchUp users end up having their 3D models rendered in these applications due to their high-end renderings ability.

Findings from this result also give an insight on Building Information Modeling, where 31% of the sample reported of adopting BIM technology. Among the BIM software, Revit by Autodesk seems to be the most popular with 27 respondents using it, and followed by ArchiCAD of Graphisoft, Vectorworks and Allplan, both by Nemetschek. Environmental software like IES, EcoDesigner, Ecotect, Green Building Studio, and eQuest, which offers building energy performance simulation, still have a very long way to go from becoming mainstream as only 2 respondents reported of using it.

Q10 The main factor that drives you to adopt new software/technologies would be..

Answered: 111 Skipped: 29

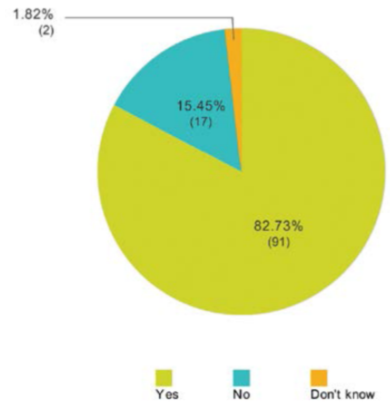
	Strongly agree	Slightly agree	Neither agree nor disagree	Slightly disagree	Strongly disagree	Total	Average Rating
Sales pressure by suppliers and vendors	8.18% 9	21.82% 24	26.36% 29	18.18% 20	25.45% 28	110	2.69
Clients' needs	30.91% 34	41.82% 46	16.36% 18	6.36% 7	4.55% 5	110	3.88
Project Team's needs	42.73% 47	40.91% 45	12.73% 14	0.91% 1	2.73% 3	110	4.20
Organization (e.g Pertubuhan Arkitek Malaysia)	12.84% 14	23.85% 26	42.20% 46	12.84% 14	8.26% 9	109	3.20
Types of skills graduate posses	39.64% 44	43.24% 48	13.51% 15	2.70% 3	0.90% 1	111	4.18
As a marketing tool for your organization	39.64% 44	39.64% 44	15.32% 17	1.80% 2	3.60% 4	111	4.10

From time to time it is important for business entities to upgrade and update their tools and technology in order for them to keep up the competitive edge that they should have in competing with other players. However, it is important to know what drives these entities to adopt new technologies so that we know which drivers give the best outcome. Based on the figure, adopting new technologies based on the project team's needs scored the highest rating of 4.2 out of a full rating of 5. This seems to be a very positive practice as it is done on a need-based basis.

One point that needs to be look upon with great concern is the fact that 82% of the respondents' decision to adopt new technology lies upon the types of skills graduate posses. This means that the direction of technological path the country goes upon is directly influenced to a certain extend by the HEI. The driver for new technology that received the lowest rating of 2.69 out of 5 is sales pressure by vendors. This is of course a positive sign as commercial marketing might not always be the best reference for a product.

Q11 Had you ever heard of BIM (Building Information Modelling) before taking this survey?

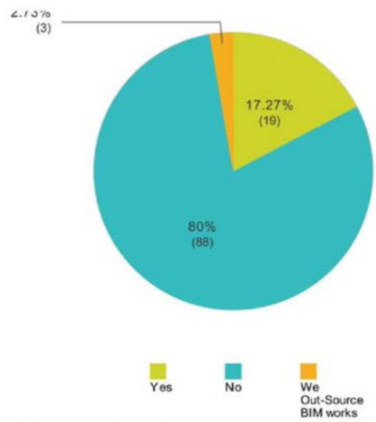
Answered: 110 Skipped: 30



By the time the survey reaches to this question, 30 respondents had opted out of the survey. However, closely to 90% opted to stay on course and continue with the survey through the third segment, which is the most important segment and where the research is centred. The response to this question was overwhelmingly positive whereby 83% of the sample reported as being fully aware of BIM and its capabilities.

Q12 Does your firm currently use BIM for its projects?

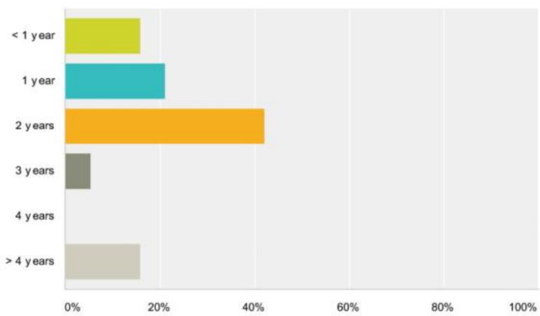
Answered: 110 Skipped: 30



This question is relatively the biggest and the most important question of the survey. The response to this question was also a revelation and a concern that needs to be looked and acted upon carefully and effectively. Based on the above figure, while 83% of the sample reported of being aware of BIM, only 20% are actually adopting it in their project deliverables. Needless to say that 14% from those who use BIM opted to out-source BIM works rather than adopting the technology in-house. This figure is a concern if one would compare it to some other parts of the world where the US has nearly 70% of their architects and Europe has 34% of players using BIM. It is also obscure as to why so many people choose not to use it while acknowledging the technology and its qualities.

Q13 For how long has your firm implemented BIM?

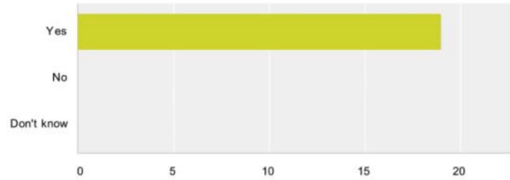
Answered: 19 Skipped: 121



The responds show us that BIM is still very much new to the architecture industry in Malaysia. Most of the users have been using BIM for not more than 2 years. This indicates that most BIM users in Malaysia are still at a very early stage of implementation. Only 16% of BIM users have used it for more than 4 years.

Q14 Will your firm keep using BIM in the future?

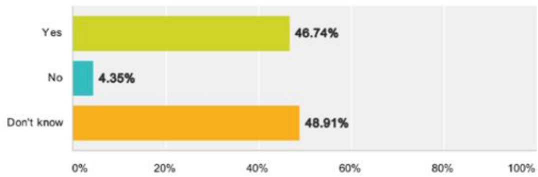
Answered: 19 Skipped: 121



All 19 respondents had indicated that they would keep on using BIM in the future for their project deliverables. This gives an indication that BIM has given benefits to these architecture firms and that they are content to continue with the adoption of the technology.

Q15 Will your firm use BIM in the future?

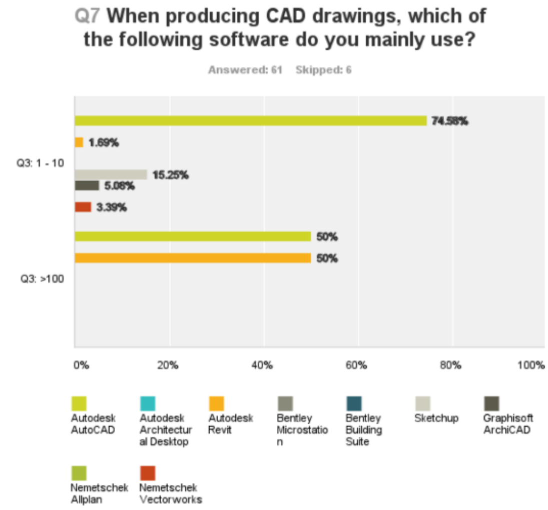
Answered: 92 Skipped: 48



This question reverts back to non-BIM users, which with 92 respondents, forms the majority of the survey's respondents. With 83% of respondents having full awareness of BIM, it is important to know how many of them are seriously planning to take the crucial step of adopting the new technology. Based on the above figure, nearly half of the non-users indicate that they will adopt the technology in the future. However, the same amount of respondents replied that they are still undecided over the implementation of BIM. Though this may not seem overwhelmingly positive, there is a chance that there could be a positive change of thought in the future. Only a mere 4% have clearly decided against the usage of BIM in the future.

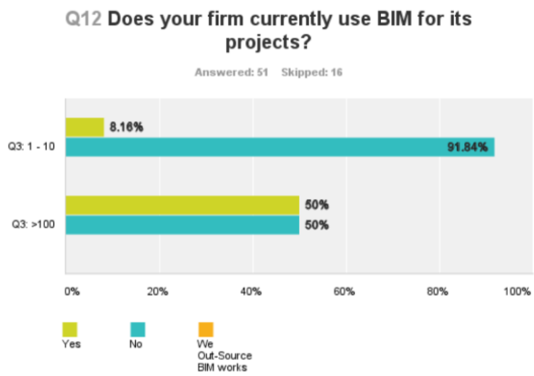
5 Cross Tabulation

For this survey, cross tabulation analyses were carried out as to examine the correlation and connection between different attributes. The holding attributes include size and income of architecture firms, types of software used and experience in BIM.



Software selection (Q7) and (Q8). Based on the software used by the respondents, it is clear that big firms with more staff have used BIM technology more than the small firms. Half of the big firms are using BIM software as their main software for CAD drawings, which is in stark contrast to the small firms where only 2% of them are using BIM software for the production of CAD drawings.

Based on the above figure, the majority of big firms seem to use BIM software as their second most used software, while small firms have Sketchup as their second most used software. This shows that the big firms have started to invest and adopt BIM while the small firms are still using traditional drafting software such as AutoCAD and conventional 3D software such as Sketchup.



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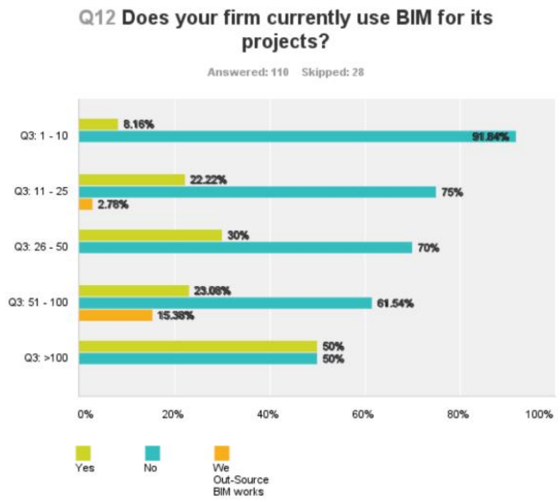

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BIM usage continues to grow around the world and many more high profile construction projects are seen to be using BIM throughout the design, construction and operation phase. It is a positive sign that more than 80% of the architecture firms in Malaysia are aware of BIM and its benefits. However, it trails behind many other developed countries in terms of adoption as only 20% of the architects firms in Malaysia are currently using the technology.

The findings from the survey shows that the BIM trend in Malaysia in general is not very different from earlier reports of BIM trends from other parts of the world. In regards to this, the architecture industry in Malaysia has an advantage of learning how America and Europe in particular has developed their strategies and roadmaps towards full implementation of BIM. The architecture industry in Malaysia can also avoid the mistakes and mishaps that had happen in those countries and try to strategize for a better roadmap towards full BIM implementation. For this to happen, all parties including government institutions, agencies, organizations and education institutions must participate and work together to achieve this target.

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APPENDIX E: RELATED PUBLICATION 2

The Development of Digital Architecture Modeling in the Malaysian Architecture Industry

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Abstract: - For the past 25 years, the architecture profession have seen great shifts in skills level, work processes and professional culture with the adoption of digital technologies. Investment in technology has always been to improve effectiveness in practice and increase performance in the design/build process that yields a return of investment at the end of the day.Today, more and more digital technologies have been developed and created to accommodate the high demands of the market over the years, including Building Information Modelling (BIM) and Building Performance Simulation (BPS). This research aims to look into the insight of how architect firms in Malaysia are coping up with the introduction with BIM and BPS. The main approach is by conducting a nationwide survey on all the architectural firms in Malaysia and the findings will be used as a base for further research on the matter.

*Key-Words: -*Building Information Model (BIM), Computer Aided Design, Graphic Editor, Software, 2D Drafting, 3D Modeling and Rendering

1 Introduction

Digital technologies have been changing architects' life and way of working for the last few decades.At the start of the new millennium, research and development by the ever demanding market has led to the creation of an even more sophisticated technology that not only change the way architects design but also how the profession works. That technology is called Building Information Modeling (BIM) and Building Performance Simulation (BPS).

Today, BIM is centre-stage within the construction sector the world-over. It is seen as a means to overcome those age-old difficulties in communications and information management that have plagued the architecture industry for decades. Reports and research from around the world shows that BIM has now gained strong grounds and its numbers of users continue to grow from year to year.

The 2012 SmartMarket Report by McGraw Hill shows that the adoption rate of BIM in the United States has reached 72% [1]. Reports by the same publisher for the same year also states that the adoption rates in Korea is at 58% while the Middle East stands close to 25% [1]. According to a 2010 report, BIM usage in Western Europe has reached 38%[2]. The National Building Specification (NBS), a body owned by the Royal Institute of British Architects (RIBA), reported that the BIM adoption rate in the UK for 2012 stands at 31%[3]. On the Southern Hemisphere, a 2012 national report by Masterspec states that New Zealand has 34% users of BIM while Australia's adoption rate is at 19%[4].

Due to the benefits of BIM and its huge potential of improving the Architecture, Engineering and Construction (AEC) industry, governments of developed and developing countries around the world have also started to mandate the usage of BIM in their respective countries. In the United States, the General Services Administration (GSA) began requiring the use of BIM in all new projects in 2007[5].BIM has been compulsory in Finland since 2007 when it comes to the state enterprise Senate Properties that provides property services primarily to government customers[5]. Whereas in Norway, the civil state client *Statsbygg* decided to use BIM for the whole lifecycle of their buildings from 2005 onwards [6]. In 2007, Danish state clients such as the *Palaces & Properties Agency*, the *Danish University Property Agency* and the *Defence Construction Service* require BIM to be used for their projects[7]. The Dutch Ministry of Interior on the other hand, requires BIM to be used for large building maintenance projects in the Netherlands from 2012 onwards[6]. In Asia, where BIM was initially seen as slow to adopt BIM has now taken steps to catching up with the rest by mandating BIM use for public works. The Hong Kong Housing Authority will require BIM for all new projects from 2014 while the Public Procurement Service of Singapore made BIM compulsory for all projects over S$50 million and for all public sector projects by 2016 [8].

However, whilst BIM have shown promise elsewhere, it has not been the same in Malaysia. As to date, no government agencies or body has mandated the usage of BIM. Research in BIM is also at a low where none of the academic institutions have set up a unit or department that looks into BIM matters.While national scale reports or surveys on BIM usage has been conducted in many developed countries, it has not been the case with Malaysia.

2 Issue

When CAD was introduced to the architecture world about a quarter century ago, the architecture industry in Malaysia took its own time to adopt the new technology. This was probably due to the fact that the medium for the technology, the computer, was also a new technology altogether and a luxury to own such machine. Nevertheless, CAD technology is now used to the fullest by the majority of firms if not all. According to a survey done on Malaysian architecture firms in 2009, AutoCAD by Autodesk is a household item and used by all the respondents in the survey. It also revealed that high end 3D solid and surfacemodelers were used extensively by the industry[9].

However, BIM and BPS is a different game altogether compared to CAD, CAAD and CAM. It is not a tool that replaces pens and pencils. BIM is much more of a change for the industry than CAD/CAM/CAAD: it reorganizes the sequence, timing, and duration of the design process, ushers in a new model of constant, detailed communication, puts a geometrically larger amount of information into one place, and might even change the fundamental roles of each participating company [10]. A huge amount of investment is required to adopt this new system. Without data, guides and assist, few people can justify their adoption of BIM and those at the forefront of BIM technology may be moving in a direction that does not necessarily lead to success [11].

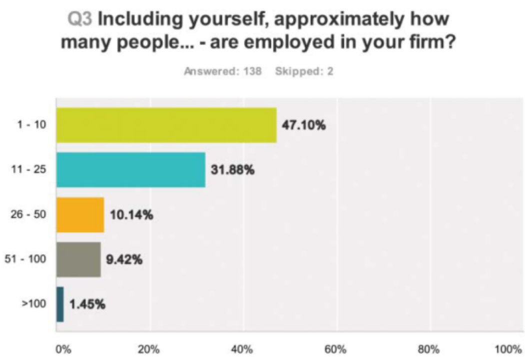
3 Methodology

Looking to the above matter, it is crucial that a report on the adoption and usage of BIM is produced at a national level as a first step towards developing the future roadmap towards full BIM implementation in the country. For this, a quantitative survey was done on allthe architectural firms in Malaysia amounting to 535 firms. All of these firms are registered to the Malaysian Institute of Architects or *PertubuhanArkitek Malaysia* (PAM), the professional body for architects in Malaysia. The survey, which was distributed electronically through emails, was carried out from 18 March 2013 to 17 June 2013, a total period of three (3) months. From the survey, 140 firms responded, which gives a responds rate of 26%. From a demographic aspect, 61% of the responds came from Kuala Lumpur, Malaysia's capital and biggest city.

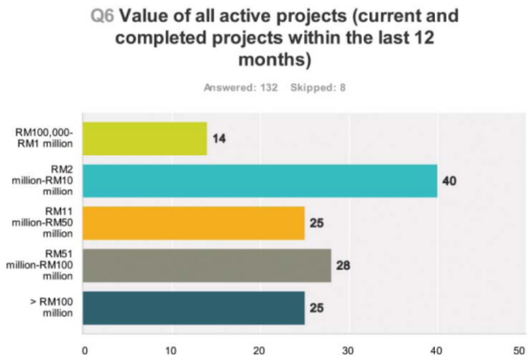
There are two (2) main objectives as to why the survey was carried out. The first objective was to find out the current use of digital technologies in practice. This includes the types of computer application used in offices and categorizing it into primary and secondary usage. The survey also gives insights into the impacts that these technologies are having on design strategies, associated management structures and cultures within the industry. The second objective of this survey was to explore the usage of BIM within the industry. This will also provide an insight into the impacts that BIM are having on design strategies, associated management structures and cultures among the firms.

The results obtained from this survey have provided the Malaysian Institute of Architects an insight which would help enable them to take further actions in promoting the adoption of BIM within the architecture industry in the country.

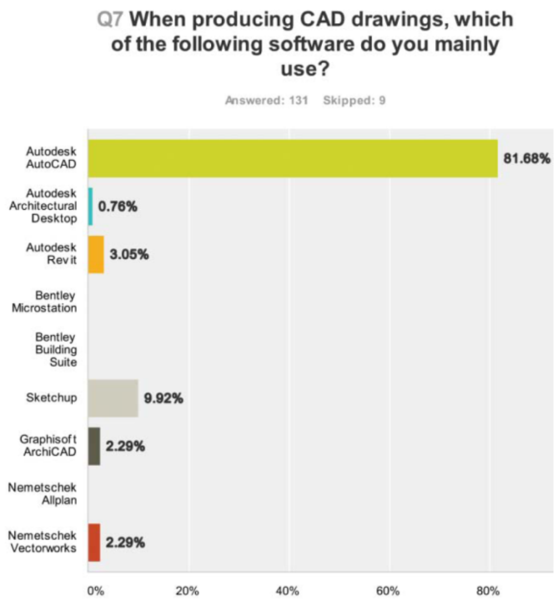
4 Findings and Analysis



Firms with not more than 10 employees make up the majority at 47% of the sample, followed by firms with 11-25 employees at 32%, and firms with 26-50 employees at 10%. Bigger firms with 51 to 100 employees' makes up only 9% of the sample. Firms with the more than 100 employees made up the lowest respond rate at only 1.5%. With this, it shows a trend that the responds rate decreases as from smaller firms to bigger firms.



The majority of respondents, which represent 30% of the sample, currently run projects worth between RM2-RM10 million. Other respondents above that category are equally distributed with each of the 3 other category having 25-28 respondents, or roughly 20% of the sample. This includes firms with active projects that cost more than RM100 million (£23 million). Even though small firms make up to nearly 60% of the respondents, the size and value of projects can be seen as being more equally distributed among the respondents.

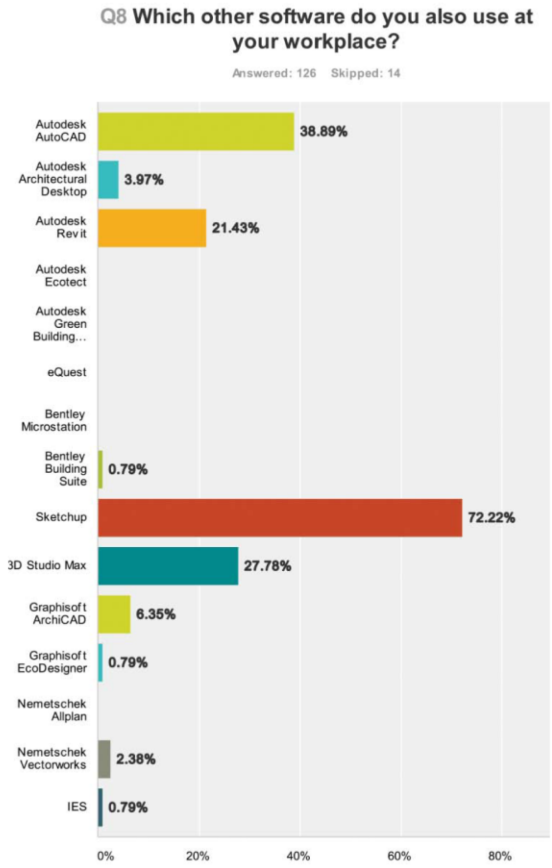


Based on the responds, *AutoCAD* by *Autodesk* has the highest respondents with a total of 107, representing 82% of the sample. Next in second place is Sketchup with 13 respondents, 10% of the sample.

The huge difference on the nos. of users between *AutoCAD*, which sits at first place, and its closest rival shows that AutoCAD seems to be dominating the current CAD market and thus setting up a standard for the industry for 2D software. There may be a number of reasons as to why this happens. *AutoCAD*, a software traditionally used for the production of 2D drawings, was one of the first 2D drafting application introduced in the country. Therefore, being the earliest 2D drafting application, coupled with tremendous marketing effort during its introduction, the *AutoCAD* name has been synonymous to architects and draftsmen when it comes to 2D drafting [12].

Apart from that, the transfers of drawing files from one consultant to the other consultants in a construction project during the early years demanded all project team members to use the same software application. This was due to the fact that most software applications stands on its own platform and did not share the same format, making it unable to open and edit drawing files through other different applications. Due to this, AutoCAD, which was one of the earliest 2D drafting application to be introduced in the country, set an informal rule that any new office that intends to implement computer drafting has to have AutoCAD to be able to read AutoCAD drawings that comes from other senior or leading firms. Although this is no longer a problem as most software applications of today are able to read files from other applications, by the time this happens, AutoCAD has already been brought and used by most architect firms in the country.

Another revelation by this question was on the usage of Building Information Modeling (BIM). Software that uses BIM platform such as *Autodesk Revit* and *GraphisoftArchiCAD* enables 2D drawings to be extracted directly from the main master model, thus making 2D software such as *AutoCAD* and *Microstation* redundant and irrelevant to architecture firms that adopt BIM. Based on this result, it is clear that 92% of the respondents may not yet adopt BIM, or at least have not made BIM their main platform for project deliverables.



Based on the result, SketchUp by *Trimble Navigation Ltd.*, which is a 3D software application, founds itself as the most popular secondary or supporting software in the Malaysian market. Although the software is considered relatively new, as its first release in the country was in late the 2000, its popularity rose sharply over the years as many consider its*Push/Pull* Technology (U.S patented 2003) has made it probably the easiest 3D software available on the market. However, as the application is meant for conceptual 3D modelling, as reflected by its name,

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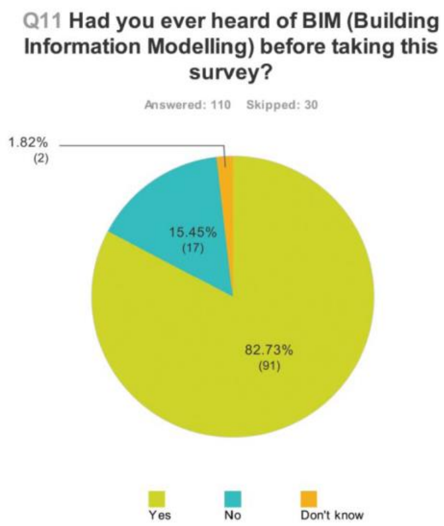
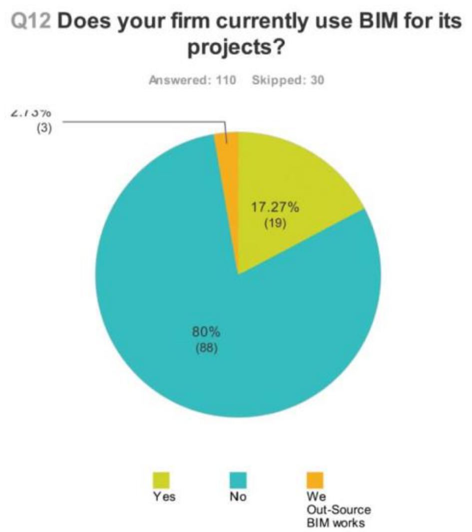
SketchUp'spopularity would most probably stays stagnant due to its inability to provide high-end 3D renderings. This is where 3D modelling and rendering software such as *Autodesk's* 3D Studio Max and Cinema4D by *Maxxon* comes in. Most SketchUp users end up having their 3D models rendered in these applications due to their high-end renderings ability.

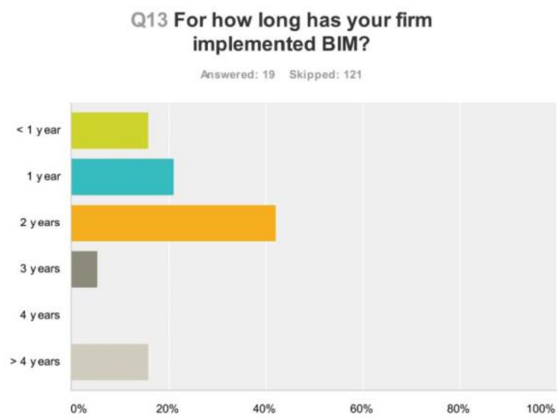
Findings from this result also give an insight on Building Information Modeling, where 31% of the sample reported of adopting BIM technology. Among the BIM software, Revit by Autodesk seems to be the most popular with 27 respondents using it, and followed by ArchiCAD of Graphisoft, Vectorworks and Allplan, both by Nemetschek. Environmental software like IES, EcoDesigner, Ecotect, Green Building Studio, and eQuest, which offers building energy performance simulation, still have a very long way to go from becoming mainstream as only 2 respondents reported of using it.



By the time the survey reaches to this question, 30 respondents had opted out of the survey. However, closely to 90% opted to stay on course and continue with the survey through the third segment, which is the most important segment and where the research is centred. The response to this question was overwhelmingly positive whereby 83% of the sample reported as being fully aware of BIM.



This question is relatively the biggest and the most important question of the survey. The response to this question was also a revelation and a concern that needs to be looked and acted upon carefully and effectively. Based on the above figure, while 83% of the sample reported of being aware of BIM, only 20% are actually adopting it in their project deliverables. Needless to say that 14% from those who use BIM opted to out-source BIM works rather than adopting the technology in-house. This figure is a concern if one would compare it to some other parts of the world where the US has nearly 70% of their architects and Europe has 34% of players using BIM. It is also obscure as to why so many people choose not to use it while acknowledging the technology and its qualities.



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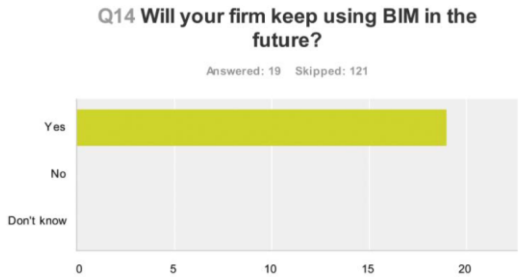
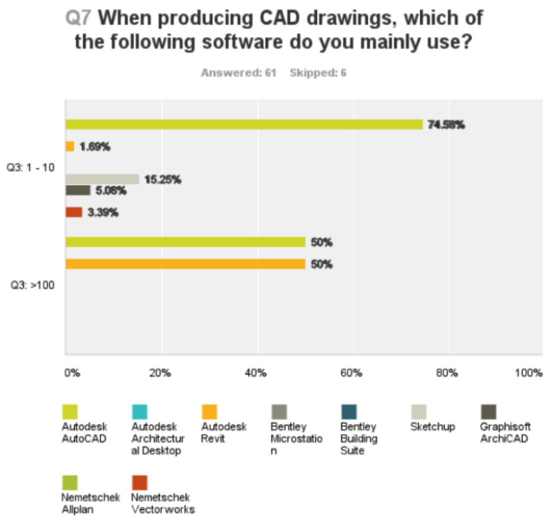
The responds show us that BIM is still very much new to the architecture industry in Malaysia. Most of the users have been using BIM for not more than 2 years. This indicates that most BIM users in Malaysia is still at a very early stage of implementation. Only 16% of BIM users have used it for more than 4 years.

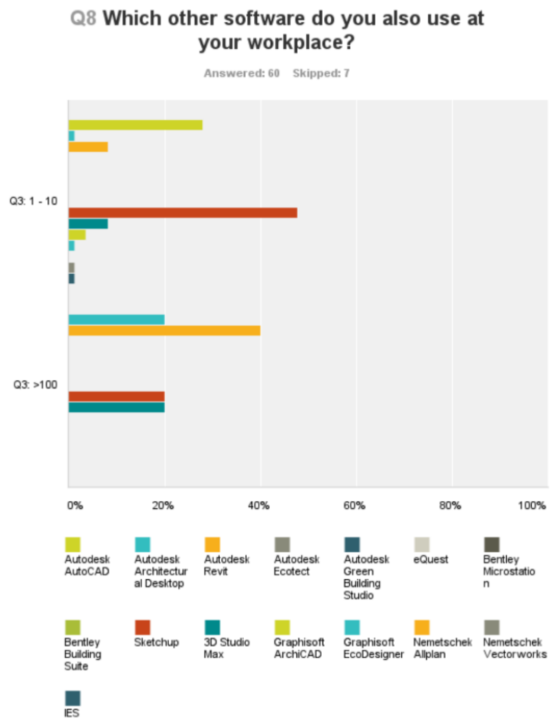


All 19 respondents had indicated that they would keep on using BIM in the future for their project deliverables. This gives an indication that BIM has given benefits to these architecture firms and that they are content to continue with the adoption of the technology.

5 Cross Tabulation

For this survey, cross tabulation analyses were carried out as to examine the correlation and connection between different attributes. The holding attributes include size and income of architecture firms, types of software used and experience in BIM.





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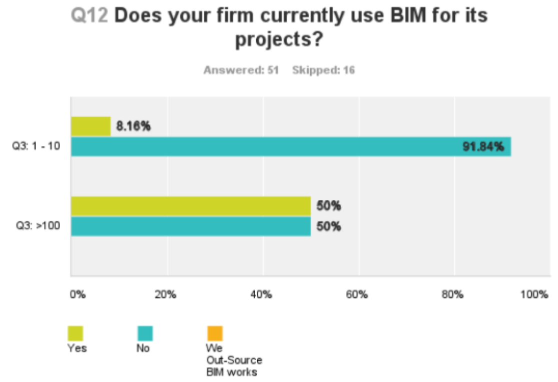

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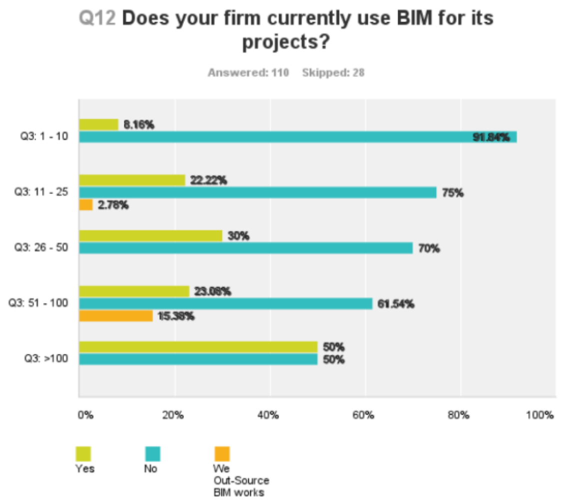

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