

**ORGANISATIONAL READINESS TO IMPLEMENT
BUILDING INFORMATION MODELLING:
A FRAMEWORK FOR DESIGN CONSULTANTS IN
MALAYSIA**

AHMAD TARMIZI HARON

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AHMAD TARMIZI HARON

**School of the Built Environment
Faculty of Business, Law and the Built Environment
University of Salford Manchester, Salford, M5 4WT, U.K**

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ABSTRACT

Building Information Modelling (BIM) is defined as an approach to building design and construction through modelling technology, associated sets of processes and people to produce, communicate and analyse building information models. The implementation of BIM is expected to improve the delivery of design and construction through 3D visualisation, integrated and automated drawing production, intelligent documentation and information retrieval, consistent data and information, automated conflict detection and automated material take off.

Although the potential benefits of BIM are well documented, the implementation process requires proper strategic planning and a thoughtful review of many aspects to realise those benefits. One part of the strategic planning is the readiness assessment where it measures the current position of the organisation as compared to the targeted implementation requirements of the BIM system by using several categories and readiness criteria. Set against the background of the Malaysian construction industry, in the infancy stage of BIM implementation, however has raised the question about the categories and the readiness criteria that should be used to conduct the assessment. The lack of documented BIM implementation in a form of publicly available reports, best practice and guidelines has also escalated the situation.

The aim of this research was therefore set to support improvements in the design consultant practice by developing an organisational readiness framework for BIM implementation. The research explored and identified the readiness criteria as the main components of the framework. The research engaged a multiple-case-studies approach and four design consultant companies were selected for the primary data collection. Data from each company was analysed by using content analysis technique before it was cross analysed to determine the pattern of answer. After that, the findings were discussed and theoretically validated to produce a conceptual framework. The conceptual framework was later validated through a focus group workshop to produce the final framework.

As the research's main outcome, the readiness framework consists of four elements. The first readiness element is Process which has three categories residing within it, which are, Process Change Strategy, BIM Implementation Management, and Policy. The second readiness element is Management which includes the categories of Business Strategy, Management Competency, and Leadership. The third element is Technology which also has three categories residing within it, which are Hardware, Technical Support, and Software and the fourth element is People, which has four categories and they are, Roles and Responsibilities, Skill and Attitude, Training and Education and Work Environment. Meanwhile, the 38 readiness criteria that were identified and validated, resided accordingly within each readiness category. The readiness framework as the main outcome of the research can be used to assist the design consultant to identify the readiness gap of the company. The importance lies on informing the area of concern so the effort for BIM implementation can be prioritised. In addition, the individual case study report which had information rich data could help the industry to understand the BIM implementation issue within the context of Malaysia. The outcome of this research showed that the main problems that are preventing consultants from embracing BIM were rarely technical. They were related more to the management and people issues which underpin the capability of the company to successfully implement BIM.

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DECLARATION

This thesis is presented as an original contribution based on Doctorate of Philosophy research at University of Salford, Salford, United Kingdom and has not been previously submitted to meet requirements for an award at any higher education institution under my name or that of any other individuals. To the best of my knowledge and belief, the thesis contains no materials previously published or written by another person except where due reference is made.

.....(Signature)
Ahmad Tarmizi Bin Haron

..... (Date)

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LIST OF ABBREVIATION

2D	2 Dimensional
3D	3 Dimensional
4D	4 Dimensional
5D	5 Dimensional
n-D	n Dimensional
A.I	Average Index
AEC	Architectural, Engineering and Construction
AGC	The Associated General Contractors of America
AIA	The American Institute of Architects
BIM	Building Information Modelling
BIMMi	Building Information Maturity Index
BPNM	Business Process Notation Modelling
C&S	Civil and Structure
CAD	Computer Aided Design
CIB	International Council for Research and Innovation in Building and Construction
CIMP	Construction Industry Master Plan of Malaysia
CIDB	Construction Industry Development Board of Malaysia
CMM	Capability and Maturity Model
CMMi	Capability and Maturity Model integrated
CREAM	Construction Research Institute of Malaysia
CTS	Client's Technical Specification
DBM	Design Basis Memorandum
EPCC	Engineering, Procurement, Construction and Commissioning
EPU	Economy Planning Unit of Malaysia
GB	Gigabyte (1024 Megabyte)
GDP	Gross Domestic Product
GPIS	General Practitioner Information System
IBS	Industrialised Building System
ICT	Information & Communication Technology
i-CMM	Interactive Capability Maturity Model
IDC	Internal Document Check
IDEF	Integrated Definition Modelling
IFC	Industry Foundation Classes

IS	Information System
ISO	International Organisation for Standardisation
IT	Information Technology
IPD	Integrated Project Delivery
IDDS	Integrated Design and Delivery Solutions
KPKT	Ministry of Housing and Local Government
MEP	Mechanical, Electrical and Plumbing
MIMOS	Malaysian Institute of Microelectronic Systems
MTO	Material Taking Off
NBIMS	U.S National Building Information Standard
NeTI	National E-Tendering Initiatives
NIBS	National Institute of Building Science
OHSAS	International Occupational Health and Safety Management System
P&ID	Plant and Instrumentation Diagram
PDM	Project Data Management
PDMS	Plant Design Management System
PFD	Process Flow Diagram
PWD	Public Work Department of Malaysia
R&D	Research and Development
RAM	Random Access Memory
RICS	Royal Institution of Chartered Surveyor
RM	Ringgit Malaysia
SIRIM	Standards and Industrial Research Institute of Malaysia
SPICE	Standardised Process Improvement for Construction
SOP	Standard Operating Procedure
TRI	Technology Readiness Index
U.S	United States of America
U.K	United Kingdom
VDC	Virtual Design and Construction
VERDICT	Verify End-User e-Readiness

CHAPTER 1: INTRODUCTION TO THE RESEARCH

1.1 INTRODUCTION

The construction industry is generally known to be one of the most challenging industries in many countries. A low reliable rate of profitability, little investment in research and development, a crisis in training to replace aging people and the client's tendency of selecting the lowest price are among the issues raised by the Construction Task Force Report (1998). Meanwhile, improper planning, lack of control, subcontractor delays, and improper construction methods, have worsened the condition of the industry. According to AIA Guide (2007), many studies document inefficiencies and waste in the construction industry. For example, an *Economist* article from 2000 identified 30% waste in the US construction industry; an NIST study from 2004 targeted a lack of AEC software interoperability as costing the industry \$15.8B annually; and a US Bureau of Labour Statistics study showed construction alone, out of all non-farming industries, as decreasing in productivity since 1964. Meanwhile, all other non-farming industries have increased productivity by over 200% during the same period.

Within the context of Malaysia, although no quantitative data was ever recorded to depict the inefficiency of the construction industry, the issue is well recognised and addressed (CIMP, 2007). There are many interrelated contributing factors to the inefficiency of the industry such as low productivity, low quality of end product and projects time and cost overrun. The low productivity as identified by Kadir et al. (2005) was mainly caused by poor design constructability, coordination among project participants, rework due to construction error and strict government policy on recruitment of foreign workers. Meanwhile, the low quality of the end product is also caused by poor design and constructability in addition to ineffective supervision, lack of skilled manpower, inadequate and inappropriate technology utilisation for both design and construction stage, financial problems and lack of information at point of use (CIDB, 2008; CIDB, 2009 and CIMP, 2007). As for time and cost overruns, Alaghbari et al. (2007) and Sambasivan & Soon (2007) further identified among their other findings in their research that the most common form of compensable time delay is caused by inadequate drawings and specifications, the owner's failure to respond in a timely fashion to requests for information or shop drawings, owner's changes in design or materials, and owner's disruption and/or change in the sequence of the work. Among all the factors, fragmentation was identified as one of the biggest contributing factors for inefficiency in the Malaysian Construction Industry. Some of the problems caused by fragmentation are weak links in the team, inadequate planning, material shortage, variation in project objectives and inherited problems from the design

stage (Lim & Mohamed, 2000; Ibrahim et al., 2010). Nima et al. (2001) on the other hand, identified that fragmentation also inhibits the concept of constructability from being implemented within Malaysian construction projects since the construction personnel could not be brought together early enough in the design stage so that the information regarding construction could be incorporated. Meanwhile, the utilisation of ICT within the construction process is still limited to basic application which worsens the project implementation to reduce fragmentation problems (Jaafar, 2007; Ibrahim et al., 2010).

Consequently, together with other problems and a target for better improvement, Construction Industry Development Board of Malaysia has directed the national agenda by producing the Construction Industry Master Plan, CIMP. The development of CIMP is made by the industry and for the industry, with an emphasis on the target to increase construction contribution by increasing market size in new and unexplored developing foreign markets, and also to improve productivity, efficiency, and cost-effectiveness of the domestic construction industry in order to provide comparative advantage to the economy (CIMP 2007). There are seven strategic thrusts identified; the first strategic thrust is focusing on resolving the fragmentation issue by integrating the construction industry value chain to enhance productivity and efficiency while the sixth strategic thrust focuses on leveraging the information and communication technology in the construction industry (CIMP, 2007). Both strategic thrusts have opened some room for Building Information Modelling (BIM) to fit within the national agenda. In addition, the CIMP also discussed the importance of software interoperability and integration which is related to the current effort of BIM by many parties all over the world.

Some important features of Building Information Modelling are how it creates an object-oriented database that is made up of intelligent objects, the 3D representation of integrated information and a relational database that is interconnected (Eastman et al., 2008), which could possibly provide a better solution for the Malaysian construction industry. According to Eastman et al., (2008) and Smith & Tardif (2009), most of the information used on a construction project originates in the Computer Aided Design (CAD) drawings. However, these have limited capability to serve as a data repository, are labour intensive and time consuming to produce, check and ensure consistency and are un-computable where the personnel who receives the information is required to interpret, decode and re-enter the data manually for further use. Consequently, it sets up ineffective activities and creates much room for error in the information production and flow. In addition, its complexity has also amplified the disadvantage of CAD drawings where it was estimated 98% of the industry could not understand drawings accordingly (Lee et al., 2003). BIM as an approach to building design and

construction distinguishes it from other technologies. This lies not only on the advantages of 3D parametric modelling, but also the structured information that is organised, defined, and exchangeable. The structured information opens the door to more effective communication and collaboration at every critical juncture of project lifecycle (Smith & Tardif, 2009). The BIM approach can overcome most of the problems as discussed previously by increasing the design certainty, improving consistency and easing the coordination of design production and providing a seamless information flow and communication. As for tackling the fragmentation problems, BIM as the repository system has attracted many endeavours to expand the capability of BIM resulting in the introduction of a few concepts such as Integrated Project Delivery (IPD) by the American Institute of Architects (AIA), Integrated Design and Delivery Solutions by International Council for Research and Innovation in Building and Construction, CIB and nD modelling by the University of Salford which are aimed at integrating an *n*th number of design dimensions into a holistic model which would enable users to portray and visually project the building design over its complete lifecycle (Marshall-Ponting & Aouad, 2005).

Therefore, in August 2009, in the very first seminar of Building Information Modelling in Malaysia, Director of Public Work Department Malaysia (PWD), Datuk Seri Prof Judin Abdul Karim, in the keynote speech, urged construction companies to adopt ICT and stressed the importance of having an integrated software system and standardisation for obtaining effective workflow for the project development and implementation (Construction companies urged to adopt ICT, 2009). Aiming first at improving efficiency, a BIM pilot project has also been delivered by PWD on the National Cancer Institute building in Putrajaya, Malaysia where the results of the pilot project will be used to determine if BIM can be applied in the 10th Malaysia Plan development projects (Sani, 2010). The keynote speech has provided an early indicator of the government's commitment to implement BIM. It is worth mentioning that the PWD is the federal government department, under the Ministry of Works Malaysia, involved directly in the public project as the client's agent representing the client ministries. PWD is responsible for the implementation of the development projects which involves various aspects of design, construction, monitoring, and maintenance of public infrastructure in Malaysia.

1.2 PROBLEM STATEMENT AND RESEARCH JUSTIFICATION

ICT in the Malaysian construction industry has been recognised as the main catalyst for improvement. Many efforts have been driven especially by the government, focusing on IT in construction to realise the full benefits of IT implementation. At the strategic level, in the year 2009

the Economic Planning Unit (EPU) of Malaysia under the Prime Minister's Department published a two-year research effort entitled IT Strategy Plan for the Construction Sector. The study was led by the Standards and Industrial Research Institute of Malaysia (SIRIM), and it formulated a strategic plan for the holistic adoption of ICT to enhance productivity and competitiveness of the construction industry. The study encompasses the industry's supply chain partners and current use of ICT. For the record, SIRIM is a corporate organisation owned wholly by the Malaysian Government, under the Minister of Finance Incorporated. It has been entrusted by the Malaysian Government to be the national organisation for standards and quality, and as a promoter of technological excellence in the Malaysian industry in general (EPU, 2009; SIRIM, 2009). In fact, the sixth strategic thrust of CIMP, which has been discussed previously, was also developed in line with the IT Strategy Plan for the Construction Sector.

Despite many initiatives that were conducted strategically to embrace the benefits of ICT, the implementation of ICT by the Malaysian construction players is still relatively low. Findings from a survey of internet usage by the Malaysian construction industry conducted by Mui et al. (2002), shows that although the construction players recognised the importance of the internet and indicated that there is an increase in efficiency and cost savings from the use of internet, the full potential of the internet is however not utilised by the firms where the implementation is still limited to basic applications such as email and information search. This is in agreement with Ibrahim et al. (2010). Although 8 years have passed between the time Mui et al. (2002) and Ibrahim et al. (2010) conducted their studies, ICT implementation seems to have progressed very slowly. Meanwhile, a study conducted by Jaafar et al. (2007) on the technology readiness among managers of Malaysian contractors, found that the technology readiness index (TRI) scored a median value of 3.18 which indicates that the managers are moderate in terms of their technology readiness, whereas bigger firms were found to be more optimistic compared to smaller firms but with no significant difference in the overall TRI.

The absence of proper strategic planning on implementing the new technology is another factor that many construction industry players are still unable to gain the benefits from. Li et al. (2000) and Mui at al. (2002) believed many companies invest in technology advancement because they simply followed others who successfully implemented ICT without doing feasibility studies, and the majority of companies adopt and implement ICT in an ad-hoc manner and without planning and evaluation. They are not aware of the potential problems, the right strategies and why they need that technology, while Yusuf & Othman (2008) added, they are lacking in training, and it is limited to expert users in the area of ICT in construction industry, which worsens the current situation.

Meanwhile, Wade & Hulland (2004) argues that some organisations failed to adopt and adapt to the rapid changing of ICT technologies, practices, processes, and expertise in their organisational processes. Alshawi (2007) and Peppard & Peppard (2007) believed that benefits from utilisation of ICT do not come automatically because some of the benefits require more time to mature and involve the process of evolving from the current practice into an ‘unknown environment’, therefore, there is a time gap between the early investment and income.

As for BIM as part of ICT, it is being identified as essential to improve the construction. The implementation process requires proper strategic planning and a thoughtful review of many aspects. Many factors need to be considered and most importantly the readiness of the organisation needs to be assessed. According to Alshawi (2007) and Ward & Peppard (2002), the strategic planning for implementing new ICT technologies follows a sequence of activities and one of the critical activities is to assess the readiness level of the organisation. Smith & Tardif (2009) also strengthened the need to evaluate the organisation’s readiness as the first step to implement BIM to realise the real value of BIM investment. The readiness assessment concept measures the current position of the organisation as compared to the targeted implementation requirements of the proposed system using several categories, and the targeted implementation requirement is referred to as readiness criteria, according to Alshawi (2007). The question however, arises about the categories and the readiness criteria that should be used to carry out the assessment of the proposed system implementation when BIM is placed in to the business process. This research therefore attempts to answer these questions by generating an organisational readiness framework for BIM implementation. The framework outlines comprehensive readiness criteria which covers the elements of people, process, technology, and management for the design consultant organisation within a Malaysian context. On the other hand, in the same context of Malaysia, the implementation of BIM has not yet been documented in the form of publicly available reports such as best practice, implementation guide, or framework. The absence of these documents thus drives the need to carry forward the exploration to identify the current status of implementation of BIM before the readiness criteria can be identified. Another issue relating to the Building Information Modelling which also strengthens the need for exploring the current implementation is variation of BIM use between organisations throughout the entire construction life cycle. According to The Computer Integrated Construction Research Group (2009), there are twenty-five uses of BIM for consideration on a project lifecycle. As Eastman et al. (2008) summarised based on the 10 case studies, the BIM implementation varies from one organisation to another and no single project has yet realised all or even a majority of BIM’s potential benefits. This strengthens the need for studying the implementation of BIM by the organisations within their business process before the readiness criteria can be identified.

1.3 AIM AND OBJECTIVES

The aim of this research is to support improvements in the design consultants practice through their implementation and use of BIM. Therefore, the development of an organisational readiness framework for BIM implementation is proposed for Malaysian design consultants. By having the readiness framework, the design consultants are able to evaluate and understand their readiness in term of the BIM implementation requirement that need to be satisfied and their current readiness gap. To achieve the aim, several objectives were identified:

- 1) To explore, appraise and synthesise relevant literature related to BIM with specific focus to the concept, usage, evolution, implementation requirement, and success factors.
- 2) To explore, appraise and synthesise relevant literature related to readiness assessment with specific focus to the concept, currently available model and its component.
- 3) To explore the current implementation of BIM within the business process by the organisation.
- 4) To identify the readiness criteria for implementing the achieved BIM status.
- 5) To develop a conceptual framework by utilising the emerging findings in objective 4, and to cross reference the finding with the literature review.
- 6) To finalise the framework by validating and refining the conceptual framework in objective 5 into organisational readiness framework for BIM implementation.

1.4 SCOPE OF THE RESEARCH

The main justification of having a research scope is to narrow down the research area and also to set boundaries to what should be investigated. Limitation of scope is further discussed as follows:

Construction Project Lifecycle: Design stage

In product development of the construction industry, regardless of what type of project delivery, generally there are four phases involved which are planning, design, construction, and operation. This research however, has been limited to BIM implementation within the design stage with the focus directed on the design consultant. According to Latham (1994) and Egan (1998), although the design process itself constitutes just 5% of the cost associated with a typical construction project, its success affects the remaining 95% of building cost and the quality. A similar effect of the design stage is also supported by AIA (2007) by using the MacLeamy Curve which can be referred to on page 34. On the other hand, according to Smith & Tardif (2009) the concept of Building Information Modelling is to build a building virtually, prior to building it physically, in order to work out problems and simulate and analyse potential impacts. Within the construction lifecycle, much of the virtual analysis of a

building takes place during the design stage as compared with other stages (Elvin, 2007; Jernigan, 2007; Eastman et al., 2008). Therefore it justifies the need for carrying out this research within this phase of the construction lifecycle.

Context of Research: Design consultant types of organisation

The focus of this research concentrates on the organisations rather than the project. The justification lies on the nature of BIM investments which requires a long-term investment and could only justify the return on investment through a series of projects implementation and thus requires a long-term effort by the organisation. The long-term investment covers the needs for training and education, hardware and software deployment and cultural and process flow change (Smith & Tardif, 2007; Aranda-Mena, 2009). The organisation is the design consultant type organisation. However, whether the design consultant is an architectural, structural, mechanical, electrical, or an integrated design consultant, they are not set to provide a bigger pool of potential cases. The nature of the business process however has been recorded so the context of BIM implementation could be understood and any bias on the data collection could be informed.

Technology Application: 3D parametric tools

Within the context of technology used in Building Information Modelling, this research focuses on the uptake of 3D parametric BIM as a primary tool. Either it is engaged as design authoring tools or application tools. This scope will set a boundary so it is not confused with 2D/3D vector-based means of creating objects and 3D surface modelling tools used for the purpose of visualisation only, which carries no attribute to the element.

Respondent: Middle level management and top level management

This research collects two primary data sets concerned with the level of BIM implementation within the organisational business process and readiness criteria of the achieved level of BIM implementation. For the purpose of exploring the level of BIM implementation, the data is collected to reflect the operational level. The justification is that most BIM activities are taking place within this level in terms of organisation interaction, data and information sharing and communication. Therefore, it requires a respondent who has the capability of understanding the whole process within the operational level. Thus, middle level managers are proposed. Examples of middle level management posts are the design manager or project manager. On the other hand, in studying the readiness criteria of the achieved level, the top level managers are selected as the respondents. As Smith & Tardif (2007) and Hardin (2008) suggest, the successful investment of BIM is much more of a business decision than a technical one. Furthermore, the top level management has the authority to change the policy, direction, and target of the company. The view of the top level management on the currently implemented BIM is therefore important to be explored in the form of readiness criteria.

Area of exploration: People, Process, Technology, and Management: Conceptually, this research engaged the readiness concept by identifying the readiness criteria, set by the organisation when implementing BIM. By comparing the available model, instead of proposing the readiness criteria to be tested, this research has identified 4 elements, and 17 categorised to be explored in developing the readiness framework. These elements and categories are used as a guideline to data collection for identifying the readiness criteria. As suggested by the Software Engineering Institute (2009), Alshawi (2007) and Smith & Tardif (2009), Kunz & Fischer (2009), the implementation of IT systems in general and BIM specifically are interrelated with people, process and technology. It is therefore crucial to study each element and the relationships that may exist. On the other hand, as this research is focused on the organisation, the management elements are also proposed, justifying the authority and decision making power to dictate BIM implementation.

1.5 RESEARCH METHODOLOGY

This research approach was qualitative in nature as the inductive approach drove the order of data collection. It started by conducting the first stage of the literature review. It is important to note that this research engaged two stages of literature reviews. The first stage of the review carried two purposes as following:

- a) As a starting point of the research, the first stage literature review was conducted to form knowledge of the current issues in construction industry and subsequently identifying the research problems and forming the research aim and objective as discussed earlier in this chapter.
- b) After the aim and objectives were identified, a more detailed literature review was conducted on the subject matter to form knowledge regarding BIM and the readiness assessment model, which concentrated on the theoretical and fundamental concept. It was directed to develop a theoretical framework for organisational readiness for BIM implementation as can be referred to in chapter 2.

Meanwhile, the second stage of the literature review concentrated on making sense, justifying, and theoretically validating the research findings. Therefore, it was reasonable to be conducted after the data collection and analysis were made for each individual company, as can be seen in chapter 4. The second stage of the literature review was included therefore in chapter 5. Chapter 4 discussed the findings of each individual case study by concentrating on the evidence and the identification of each readiness criterion. Meanwhile, chapter 5 focused on developing the BIM readiness framework and thus it required justifications to be made for the readiness criteria before they could be populated into

the framework. Therefore, that chapter discussed the cross analysis of the findings in chapter 4 and the literature review that were used to make sense and support the justifications and arguments for each readiness criterion. As a result, a conceptual framework was proposed within the chapter.

In the first stage of the literature review, the purpose of developing the theoretical framework was to set out the area of exploration in which it was important to guide the researcher on the line of research inquiry. Eight readiness models which are applicable to the construction industry were reviewed and as a result, four readiness elements and 17 readiness categories (which resided accordingly in each readiness element) were identified. The first readiness element is Process which has three categories residing within it, which are Process Change Strategy, BIM Implementation Management, and Policy. The second readiness element is Management which includes the categories of Business Strategy, Management Competency, and Leadership. The third element is Technology which also has three categories residing within it which are Hardware, Technical Support, and Software. And finally, the fourth element is People, which has four categories and they are Roles and Responsibilities, Skill and Attitude, Training and Education and Work Environment. The entire readiness categories set out the exploratory area to guide research inquiries in identifying the readiness criteria inductively through the case study data collection. The framework was then developed further to be used to define the interview questions and the data collection strategy. The detail of the theoretical framework is shown in Table 2.5 on page 50.

After defining the interview questions and the data collection strategy, the research progressed into the data collection stage. The stage was initiated by first identifying potential companies and interviewees. The identification was done by reviewing the local job advertisements on the internet and in newspapers that offered BIM related posts, direct communication with BIM tools providers, direct contact with participants and speakers in a local BIM seminar and attachment and collaboration with Construction Research Institute of Malaysia (CREAM), the research arm for Construction Industry and Development Board of Malaysia (CIDB). As a result, four companies were identified and agreed to participate in the case study research. The data collection was first started by piloting a case study. The pilot study was conducted to help refine data collection plans with respect to both the content of the data and the procedure to be followed. Afterwards, the multiple case studies research was delivered to collect the primary data of the research, which are the readiness criteria. The main techniques that were used to collect the primary data were semi-structured interviews and direct observation at each organisation. Each interview was audio recorded using a Dictaphone. As for analysing the data, it was firstly transcribed into an interview script before content analysis was conducted. The findings from each company were then cross analysed in a table of matrix form to

determine the pattern of answers. After that, the second stage literature review was conducted to make sense, justify, and theoretically validate the research findings. The outcome of this was a conceptual framework consisting of 38 readiness criteria which resided accordingly within each readiness category. The detail of each readiness criterion can be referred to in Appendix 3.0. At this stage, as the conceptual framework was developed based on a limited number of four case studies data, the framework suffered from a limited application. In addition, the theoretical validation and researcher's interpretation to make sense of and justify the readiness criteria has also modified the findings. Therefore, a validation of the conceptual framework was needed to generalise and verify the findings, and was achieved through a focus group workshop.

Similar to primary data collection, the validation process was qualitative in nature by engaging a focus group workshop, attended by seventeen participants. Early before the workshop started, each participant was given a questionnaire to fill in. The use of the questionnaire was needed to ease capturing the workshop participant's view as the researcher had a time constraint of around 2 hours to conduct the workshop. The questionnaire form was developed based on the conceptual framework aimed to determine the level of importance of the 38 readiness criteria. In the workshop, the seventeen workshop participants were divided into three groups and within their groups, they were all required to discuss their justification of importance for each readiness criterion, prepare the presentation slides and present their discussion findings at the end of the workshop session. In addition, the group discussions and presentations were all audio recorded using a Dictaphone. The qualitative data of the workshop was analysed using content analysis whereas the quantitative data was analysed with Average Index and frequency analysis. The findings from the validation exercise have helped to refine and validate the conceptual framework into the final framework. The process flow of the research is described in chapter 3, Research Methodology in Figure 3.2, Research Process Flow, as can be referred to page 56.

1.6 CONTRIBUTION TO KNOWLEDGE

The contribution to knowledge of this research can be organised into two contexts which are theoretical and practical. Within the theoretical context, the main deliverable of this study which is the organisation readiness framework, will contribute to the current body of knowledge. Since the approach that was engaged is qualitative in nature, the readiness framework is expected to be informative and more understandable to refer. Meanwhile, within the practical context, since the readiness framework was developed based on the practical application within the Malaysian construction industry, it could be used as a comparative guide or readiness assessment tool to

evaluate the investment of BIM. The framework is expected to be used by the design consultants and it can assist in informing the organisation on the expected target needed to be achieved so strategy can be formulated. Additionally, the comprehensive investigation which covers People, Process, Technology, and Management will also provide a documentation of reference for BIM practice in Malaysia.

1.7 STRUCTURE OF THE THESIS

The thesis write-up is divided into seven chapters to create a flow. The structure of the thesis is therefore summarised as following:

Chapter 1 explains the background of the research. It provides the introduction to guide the reader into the research topic. The problem statement, research questions, aims, objectives, and outline of the thesis are included in this chapter.

Chapter 2 describes the literature review that was conducted on the background of Malaysian construction industry to provide a better understanding of the research industrial context. In addition, the chapter also discusses Building Information Modelling with specific focus on the concept, usage, evolution, implementation requirement and success factors and readiness assessment model with specific focus on the concept, currently available model and its component. At the end of the chapter, a theoretical framework was proposed to guide the researcher on the line of research inquiry as can be seen in Table 2.5 on page 50.

Chapter 3 presents the research design and methodology. Drawing on the literature review and guided by philosophical considerations, the research aims and objectives are defined. They lead to the selection of the case study as a research approach for data collection and workshop for framework validation. The chapter also explains the technique used in the analysis and issues related to data collection.

Chapter 4 presents and discusses the results of the case study findings with the design consultants. The data was analysed by using a content analysis and pattern matching technique and presented in a standard individual report for each organisation.

Chapter 5 discusses the case study findings in a cross examination between the organisations and is supported with a theoretical review for validation. This leads to the development and formulation of the conceptual framework.

Chapter 6 reports the results of framework validation with the industry focus group. This is to further validate the draft framework for the purpose of cross triangulation of methodologies. The final framework is developed and discussed in this chapter.

Finally **Chapter 7** revisits and discusses the summary of the research, the research objectives, and the research questions, presents the conclusions derived from the research, highlights the contributions, points out the limitations of the study and suggests recommendations for future research. References and appendices are presented at the end of the thesis.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

The main aim of this chapter is to provide several discussions regarding the main area of literature review. The first area is the background of the research themes where the issues related to the Malaysian construction industry and the need of Information and Communication Technology to address these issues, are discussed. The common challenges associated to the industry such as fragmented nature, low productivity rate, and quality, and time and cost overrun were first discussed, and later on highlight the initiative made by the Malaysian government to address the issues. The Malaysian vision 2020 to become a developed country and the development of Construction Industry Master Plan (CIMP) as a response of the construction industry to support the vision, are also discussed to highlight the position of ICT within the strategic direction of the nation. Within the CIMP, strategic thrust 6 focuses on leveraging the information and communication technology. The importance of ICT is therefore discussed to include the readiness of the industry to embrace the ICT and the position of BIM within the strategic direction.

The second area of the literature is to explore, appraise, and synthesise relevant literature related to Building Information Modelling (BIM) with specific focus to the concept, usage, evolution, implementation requirement, and success factors. Therefore, the process flow, the requirement of people, the benefits, and technology are all discussed to form a fundamental knowledge to support the research objective and to clarify the research scope, especially on the use of 3D parametric tools as an important feature of BIM. Meanwhile, the third area of literature discusses the readiness assessment with specific focus on the concept, currently available model and its component. The critics on NBIMS Capability and Maturity Model are also prepared to position this research on the current knowledge area. After that, seven readiness models were reviewed to form a fundamental knowledge of readiness assessment.

This chapter is important with respect to the framework as it provides the secondary data for the development of a theoretical framework. The theoretical framework was used in the research to guide the research inquiry and to develop interview questions where it set the area of exploration to determine the readiness criteria during the case study research. The framework has served as the baseline framework which was later populated with the readiness criteria that were identified in the case studies, and can be referred to in chapters 4 and 5.

2.2 THE BACKGROUND OF MALAYSIA

Malaysia is a country of federal constitutional monarchy in South East Asia which consists of thirteen states and three Federal Territories, with a total landmass of 329,845 square kilometres. The capital city is Kuala Lumpur while Putrajaya, located 25 kilometres south of Kuala Lumpur, serves as the federal administrative centre of Malaysia (CIMP, 2007). In 2010, according to the Department of Statistics Malaysia, the population stood at 28.59 million with the approximate distribution of ethnic groups recorded for Malay (50%), Chinese (22%), Indian (6%), and other ethnic groups (22%). The country is separated by the South China Sea into two regions, Peninsular Malaysia and East Malaysia. Malaysia borders Thailand, Indonesia, Singapore, and Brunei. In 2008, GDP per capita (PPP) of Malaysia stood at USD 14,215, ranking 48th in the world and 2nd in South East Asia, lagging behind neighbouring Singapore which had a GDP per capita (PPP) of USD 49,288, ranking 3rd in the world (CIDB, 2009). By comparison, Thailand has a per capita income of USD 7,703 (ranked 81st) and Indonesia with USD 3,975 (ranked 106th) (CIDB, 2009).

Table 2.1: Growth of gross domestic product (GDP) Malaysia from 2004 to 2008 at constant price 2000 (percentage) (Central Bank of Malaysia, 2009, p.2)

Sector	2005	2006	2007	2008				
				Q1	Q2	Q3	Q4	Average
Agriculture, Forestry, Fishery	2.6	5.2	1.4	6.5	6.3	3.3	0.5	4.0
Mining and Quarrying	-0.4	-1.0	2.0	3.6	-0.5	-0.3	-5.7	-0.8
Manufacturing	5.2	6.7	3.1	7.0	5.6	1.8	-8.8	1.3
Services	7.2	7.4	9.6	8.4	7.9	7.1	5.7	7.2
Construction	-1.5	-0.3	4.7	5.3	3.9	1.2	-1.6	2.1
GDP	5.3	5.8	6.3	7.4	6.6	4.8	0.1	4.6

By referring to Table 2.1 (Central Bank of Malaysia, 2009, p.2), between 2005 and 2008, Malaysia had registered a moderate growth rate of GDP although it was a slight decline against the rising trend recorded between 2007 and 2008. According to CIDB (2009), in 2008, the Malaysian economy registered a growth of 4.6% amidst the international financial turmoil and sharp deterioration in the global economic environment. Robust domestic demand, in particular sustained private consumption and strong public spending, supported growth during the year. While external demand was strong in the first half of 2008, the sharp and rapid deterioration in global economic conditions as well as major correction in commodity prices in the second half led to a contraction in Malaysia's export performance in the second half of the year. The contraction in export adversely affected income and

domestic demand. Private investment activities and private consumption moderated significantly in the fourth quarter of 2008.

Carrying a status of a developing country, Malaysia's government has set a vision to become a fully developed country by the year 2020. The vision, which is known as "Vision 2020," was unveiled by the former and fourth Prime Minister of Malaysia; Tun Dr. Mahathir Mohamad at the inaugural meeting of the Malaysian Business Council on 28th February 1991, and in December 1991, the Malaysian cabinet approved the vision unanimously after an immediate national conference (Islam, 2010). Since then, the vision has formally become Malaysia's National Vision. The essence of this vision is to have Malaysia functioning as a fully developed country by the year 2020 and according to Kassim (1993), the focus of the vision goes beyond the purely economic aspects of development by considering other aspects such as social justice, quality of life, moral and ethical values, and work ethics, evidenced in the specific objectives that were set as following:

- a) To have sufficient food and shelter with easy access to health and basic essentials
- b) To reduce the present level of poverty
- c) To remove the identification of race with major economic functions and to have a fair distribution with regard to the control, management and ownership of the modern economy
- d) To maintain annual population growth rate of 2.5%
- e) To double real GDP every ten years between 1990 and 2020
- f) To have a balanced growth in all sectors namely: industry, agro forestry, energy, transport, tourism and communications, and banking, that is technologically proficient, fully able to adapt, innovative, coupled with a view to always moving to higher levels of technology

2.2.1 THE BACKGROUND OF MALAYSIAN CONSTRUCTION INDUSTRY

In Malaysia, under definition in the Act 520 (CIDB, 2003), the construction industry is the industry that concerns construction works including construction, installation, repair, maintenance, renewal, removal, renovation, alteration dismantling or demolition of:

- a) Any building, erection, edifice, structure, wall, fence or chimney, whether constructed wholly or partly or below ground level
- b) Any road, harbour, railway, cable way, canal or aerodrome
- c) Any drainage, irrigation, or river control work

- d) Any electrical, mechanical, water, gas, petrochemical, or telecommunication
- e) Any bridge, viaduct, dam, reservoir, earthwork, pipeline, sewer, aqueduct, culvert, driveshaft, tunnel, and reclamation work

Historically, construction in Malaysia began in the early days, together with the formation of various states in the country. It started in around the 5th century with the development of *Gangga Negara*, an ancient kingdom in Kedah, a state of Malaysia located in the north-western part of Peninsular Malaysia. The construction evolved through the establishment of Malay architecture in the 14th and 15th century. The Chinese and Indian settlements, on the other hand, introduced their traditional elements in Malaysian construction and architecture in this country; followed by colonial influence in the 16th century by the Portuguese, in the 17th century by the Dutch and the 18th and 19th centuries by the British in the construction of buildings, and has become an industry in progression. Construction in the post-independent Malaysia (formerly known as Malaya) had geared up towards developing better infrastructure and housing for the people (CIDB, 2007).

Similar to USA, UK, and other countries, the construction industry is considered to be a major productive sector in Malaysia, evidenced from the output of the construction sector which hovered around RM15.33 billion and RM15.66 billion respectively in the year 2007 and 2008 (Central Bank of Malaysia, 2009). By referring to Table 2.1 (CIDB, 2009a, P.54), the construction industry is among the top three of the major economic sectors that contribute to the national gross domestic product (GDP), which is important for the achievement of vision 2020. In 2007, the contribution to GDP by services, construction, and manufacturing sector was 9.6%, 4.7%, and 3.1% respectively. In the succeeding year, the construction industry recorded a decline of GDP growth to 2.1%, and dropped a position at third place where the agricultural, forestry and fishery sector sat at the second rank to contribute to the growth of GDP with the value of 4.0%. The Services sector, although recording a significant decline of GDP contribution to 7.2%, still topped at first place in 2008. According to CIDB (2009), the drop in the construction sectors caused by the rise in oil and diesel prices, dramatically influenced the rise of raw materials during the second quarter of 2008. This in turn generated a negative impact on the growth of the Construction Sector which registered a decline during the fourth quarter of the year (Q4: -1.6%). The civil engineering sub-sector registered higher growth during the first half of 2008. This was due to the implementation of projects under the Ninth Malaysia Plan where the Federal Government expenditure was increased to 23.5% to facilitate the funding of new construction projects and improvements of infrastructure. The growth of the civil engineering sub-sector was adversely affected by the sudden rise in building materials, especially steel and cement. In addition, according to Ibrahim et al. (2010), as Malaysia is in the process of

industrialisation, the construction industry is crucial to provide the economic and social infrastructure for industrial production and reproduction. Basic amenities and also infrastructure, for example residential space, roads, airports, railways, ports, power electricity, communication utilities, and also the other basic infrastructure needed in a country, are just some of the basic developments required for the society to improve in social living standards and also for all other sectors to develop and grow.

Meanwhile, towards the achievement of vision 2020, the government has invested heavily in modernising the infrastructure of Malaysia. The modernisation is designed to propel Malaysia into the digital age and position it as a hub for high technology businesses in Southeast Asia. Meanwhile, the government has initiated some mega projects in the hope of propelling the economy to the best level since 1991 (Ibrahim et al., 2010). As far as expenditure is concerned, from 1991 to 2005, Malaysia has spent well over RM45 billion on infrastructure projects such as the Kuala Lumpur International Airport (KLIA), Petronas Twin Towers, Putrajaya, and the Multimedia Super Corridor Malaysia. KLIA cost RM8.7 billion and was built to resemble a cluster of Arabian tents. The RM4.8 billion Petronas Twin Towers in Kuala Lumpur, which consist of Islamic motifs with the soaring lines of New York’s Chrysler building, are the world’s tallest twin skyscrapers. The new city of Putrajaya, which is the seat of the federal government, was built at a cost of RM30.80 billion with a dominant domed prime minister’s office building, known as the Perdana Putra Building which was designed after a mosque. The city was built to relieve overcrowding in Kuala Lumpur. Meanwhile, the Multimedia Super Corridor Malaysia is an intricate project that transformed a 15x40 kilometre area stretching south from Kuala Lumpur into Asia’s version of Silicon Valley. The project has a value of RM20.10 million (CIDB, 2009a).

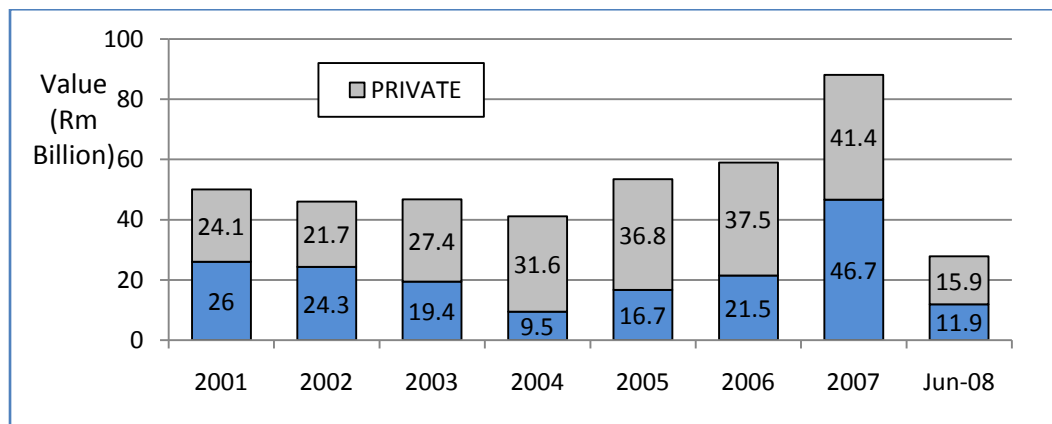


Figure 2.1: Value of public and private projects awarded in RM billion (2001 to June 2008) (CIDB, 2009a, p.54)

According to Chan (2009), the Malaysian construction industry has largely been supported by substantial public spending to fund the construction of basic infrastructure in order to enhance economic activities and to provide affordable public housing. Owing to a decline in public spending in 2003 and 2004, the construction sector value dropped 0.9%, 1.5%, and 0.3% in 2004, 2005 and 2006 respectively. In the Ninth Malaysia Plan a sum of RM200 billion, or RM40 billion per year in construction project value has been allocated (EPU, 2006). The total value of public and private contracts awarded in 2006 increased to RM59 billion followed by a further increase to RM88 billion in 2007 as can be seen in Figure 2.1. In the figure, the value of public and private projects between 2001 and June 2008 can help us understand the monetary project value of the Malaysian Construction Industry.

Today, the Malaysian Construction Industry plays an important role in generating wealth to the country and the development of social and economic infrastructure and buildings. The industry provides job opportunities for 800,000 people, representing 8% of the total workforce (CIMP, 2007). Data in Table 2.1 (Central Bank of Malaysia, 2009, p.2) on page 14 shows that the construction sector contributed 4.7% and 2.1% respectively in 2007 and 2008 to the total Gross Domestic Product (GDP) of Malaysia. Meanwhile, the global market offers ample opportunities for Malaysian construction players to tap into. Taking advantage of global opportunities will allow the Malaysian construction industry to reduce the effects of congested domestic market conditions and have greater control over its own development. As for the international market, since 2002, a total of 116 projects in excess of RM18 billion have been completed, mainly in India, the Middle East and ASEAN regions (CIMP, 2007).

2.2.2 THE CHALLENGES IN MALAYSIAN CONSTRUCTION INDUSTRY

Despite its growth and healthy contribution to GDP, the Malaysian Construction Industry is under constant pressure to improve its performance. The Malaysian Construction Industry has been characterised as adversarial and inefficient and in need of structural and cultural reform (CIMP, 2007). The national agenda for achieving the vision 2020 would be affected if the productivity, quality, safety, and technology utilisation of the industry is not improving. The improvements are challenged by fragmentation among parties, failure to complete the construction project within the time period and cost and lack of innovation and automation.

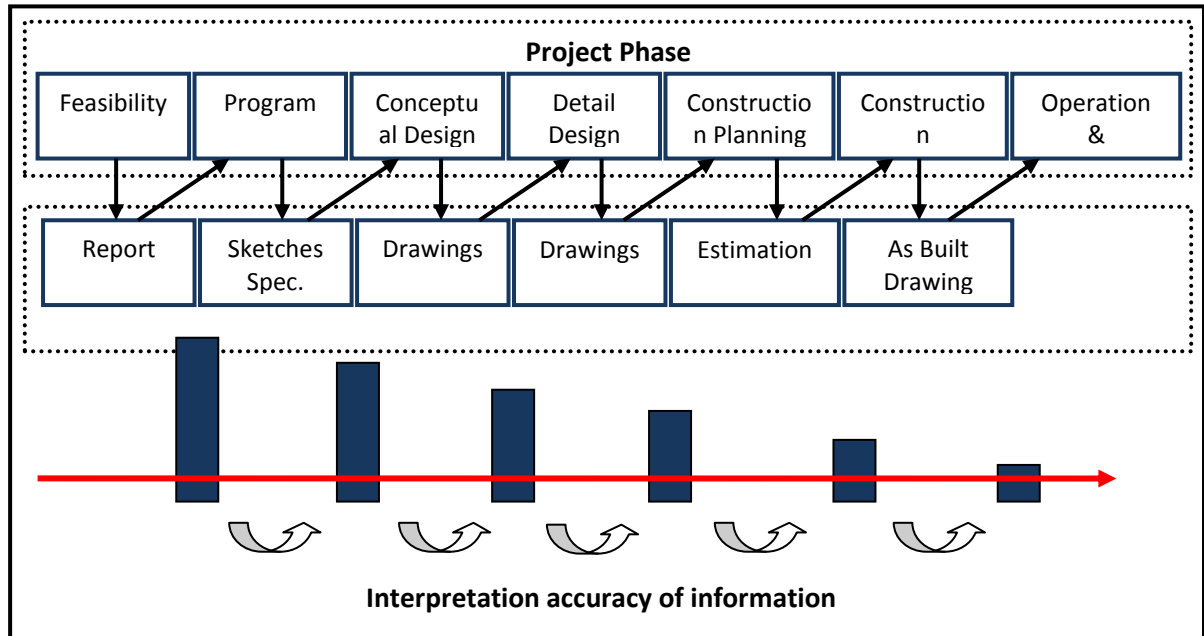


Figure 2.2: Interpretation accuracy of information in project's life cycle (CIDB, 2003, p.18)

As identified by CIDB, fragmentation is the main problem in the Malaysian Construction Industry. By referring to Figure 2.2 (CIDB, 2003, p.18), in the project's life cycle, the project participants exchange information among them in a sequential and fragmented approach and CIDB (2003) found that the interpretation accuracy of information decreases from one phase to another across the project's life cycle. Consequently, the overall success of the project is reduced due to the information misinterpretation. In addition, the fragmentation also causes weak links in the team, inadequate planning, material shortage, variation in project objectives and inherited problems from the design stage as further identified by Lim & Mohamed, 2000 and Ibrahim et al. 2010. Nima et al. (2001) also identified that fragmentation inhibits the concept of constructability to be implemented within Malaysian construction projects since the construction personnel could not be brought together early in the design stage to incorporate the information regarding the construction. According to Anumba & Evbuomwan (1997), fragmentation in construction has created inter alia: an adversarial culture and information with data generated at one stage that could not be automatically available for re-use downstream and lack of real life cycle analysis. Also, it creates difficulties in changing and adapting design, planning and cost estimate (McKinney & Fischer, 1998; Aouad et al., 2003), over the brick wall effect (Aouad et al., 2007) and failure to link impacts of design to construction decisions (McKinney & Fischer, 1998). Additionally, it has also caused poor coordination as mentioned in research by Rad (1979), Hensy (1993), Lee & Sexton (2007) and Succar (2008), difficulties in promoting a collaborative environment (Heesom & Mahdjoubi, 2004; Marshall-Ponting, 2006) and ineffective communication (Marshall-Ponting, 2006; Lee & Sexton, 2007; David & Mahdjoubi,

2004; Hensy, 1993). To make it worse, similar to findings from the CIDB (2003), Marshall-Ponting (2006) also identified that fragmentation would cause information wastage, repetition and long lead times, together with redundant and replicated work at different interfaces between departments and slow product development and process improvement.

Although Malaysian construction industry is very competitive, practices in the industry have resulted in relatively low productivity as compared with other sectors, with the GDP per worker about half that of other industries. The productivity of the construction industry has been stagnant since the 1980s. The productivity level of the industry is worth RM 20 511, with an increase of around 1.52% from 2007 to 2008. Nonetheless, this growth is relatively low as compared to other sectors in Malaysia (MPC, 2009). The ineffectiveness and low productivity are caused by the failure of the industry to utilise a new as well as other relevant labour-reducing technologies (CIMP 2007). Meanwhile, a study conducted by Kadir et al. (2005) on factors affecting construction labour productivity for Malaysian construction residential projects, found that the top five most important factors were, material shortage at site, non-payment to suppliers causing the stoppage of material delivery to site, change of order by consultants, late issuance of construction drawing by consultants, and incapability of contractors' site management to organise site activities. In addition, other factors not ranked in the top five, recorded a high Importance Index value which sits between the answer of Strongly Important and Important. The factors are poor constructability of design, coordination problems with supplier, subcontractor, client and consultant, rework due to construction error, and strict government policy on recruitment of foreign workers.

Meanwhile, the products of the construction industry are generally not of a high quality, both for the design deliverables and construction end products. Factors that contribute to a lack of quality in construction are poor design and constructability, ineffective supervision, lack of skilled manpower, inadequate and inappropriate technology utilisation for both design and construction stage, financial problems, and lack of information at point of use (CIDB, 2008; CIDB, 2009a; CIMP, 2007). According to Kadir et al. (2005) the low quality of design deliverable has caused a change in order due to design errors during the planning stage. The factor is a particularly irritating and costly problem if the work has been done, for example hacking of hardened concrete is time consuming and affects the workers' motivation and disrupts the work sequence due to rework. In addition, late issuance of construction drawings may cause man-hours to be lost due to workers idling. Often the late issuance of construction drawings is interrelated to coordination problems among consultants.

Besides the fragmentation and low productivity issues, time, and cost overrun in the Malaysian construction industry are the most prominent problems. Cost overrun can be defined as extra cost beyond the planned cost agreed during signing the contract, while time overrun can be interpreted as an extension of time beyond planned completion dates as agreed by both party's clients and contractors (Intan et al., 2005). According to Abdul-Rahman et al. (2006), Malaysia's delays in the completion dates during the construction phase is almost 45.9%, while Murali & Soon (2007) added about 17.3% of government contract projects in Malaysia were considered sick because of delays more than three months or abandoned due to various causes in the year 2005. Ministry of Housing and Local Government (KPKT) defines the project delay as projects which are experiencing delays in construction period where different gaps between the actual in-progress sites work compared to the work scheduled, which is between 10% to 30% (KPKT, 2010). Intan et al. (2005) found that only 46.8% and 37.2% of projects were completed within budget for the public and private sector respectively in Malaysia. These figures show the seriousness of the problems faced by the construction industry.

In response to identifying the cause of time overrun in the Malaysian construction industry, Alaghbari et al. (2007) and Sambasivan & Soon (2007) identified that the sources of time overrun comes from clients, contractors, consultants, suppliers, labour and subcontractors and the contractual relationship and external causes. Although the majority of factors of time overruns are caused by the contractors, the factors of delays which were caused by the clients and the consultants must also be addressed. According to Alaghbari (2005) the factors introduced a compensable delay and therefore the contractor is entitled to both monetary compensation and extension of time. As a consequence, the time and cost of the project will increase. Alaghbari et al. (2007) and Sambasivan & Soon (2007) further identified in their research that the most common forms of compensable delay are inadequate drawings and specifications, the owner's failure to respond in a timely fashion to requests for information or shop drawings, owner's changes in design or materials, and owner's disruption and/or change in the sequence of the work. In addition, based on the experience of managing 24 projects in the Universiti Teknologi Malaysia's 9th Malaysian Plan (RMK9), amounting close to RM1 billion worth of construction value, poor design quality, poor communication and poor planning and scheduling were identified as the main contribution of delay (Shah et al., 2009). The poor design quality has introduced design errors and discrepancies of details design between the consultants, inadequate breakdown in pricing and poor estimation of M&E works which lead to more time needed for adjustments and change in the design and scope of the M&E works. The poor design quality as they further identified was caused by poor design coordination and inability to understand the clients' needs precisely. Meanwhile, poor communication involves exchange of information among project

participants, the main ones being the client or owner, consultants, contractors, external approving authorities, sub-contractors and suppliers. It does not only concern communication between different parties but also within organizations. In the project, Shah et al., (2009) recognised that poor communication is generally reflected by the following:

- i. Poor coordination of data and information used in the design process between the consultants and project team members often leading to gross overdesign or errors in estimates requiring major adjustments to designs before and sometimes after procurement, and also changes in works during construction stage.
- ii. Varying interpretation of design standards and requirements between consultants causing discrepancies between different elements of the structures and fittings and systems.
- iii. Late decisions or finalization of designs and various approvals affecting critical activities and lowering morale of team members.
- iv. Poor coordination of data and information during construction stage causing unnecessary delays to allow for reworks or adjustments.

In classifying the delays caused by the consultants, Rahman & Berawi (2001) identified four main categories which are as following:

- i. Design error and inaccuracy
- ii. Ineffective process to correct design problems, communicating and distributing the new design details
- iii. Late review of shop drawings,
- iv. Delay in testing and inspections.

These factors can lead to delay in the construction phase where the consultants fail to give appropriate and complete details to the contractor to perform the work on time, the consequence being wrong interpretation of detail designs by the contractor. Meanwhile, a survey conducted by Rahman et al. (2006) reported that the satisfaction index of the contractor towards a consultant is low, where only 10.1% were satisfied with the consultants who submitted a complete set of final drawings at the right time. This survey revealed that consultants in Malaysia are still lacking in providing good services to the contractors and need an innovative approach to cater for this issue.

2.2.3 MALAYSIAN GOVERNMENT INITIATIVE

To achieve the Vision 2020, the construction industry has a significant role in assisting and supporting the government. All of the construction-related challenges need to be addressed and resolved with appropriate solutions. According to Zaini (2000) the construction industry needs an urgent shift of paradigm from using the traditional approach to a more innovative approach and at the same time, able to increase the operational performance of construction projects. The industry needs to evolve by upgrading the current construction approach, whether in terms of practice, management, or technology in order to meet the global standard, as since 1960, Malaysian Construction Industry has barely transformed in terms of technology or construction approach and still depends on the traditional approach.

In promoting, stimulating the development, improving and expanding the construction industry, the industry according to Chan (2009) is championed by the Construction Industry Development Board (CIDB) of Malaysia. The CIDB is a government agency which is established to represent the industry to the government and the private sector. Realising the need to resolve numerous challenges in the Malaysian Construction Industry, which has been discussed in the preceding subchapter, and to support the achievement of Vision 2020, CIDB in conjunction with the Ministry of Work Malaysia and Public Work Department, the relevant government departments and agencies, industry-players and organisations representing industry stakeholders, have sat together and collectively addressed the issues and successfully developed the first Construction Industry Master Plan (CIMP) in 2007. CIMP is aimed at transforming the construction industry in Malaysia to a higher level in terms of productivity, image, performance and capacity to become world-class, innovative, knowledgeable human capital and efficient (CIMP, 2007). The vision of the construction industry has been formulated in tandem with the objectives and goals of Vision 2020. This vision for the construction industry is intended to drive the development and implementation of all the strategies recommended in achieving its objectives. Therefore, the vision was set to transform the Malaysian Construction Industry into a world class, innovative and knowledgeable global solution provider. Meanwhile, the mission of the Malaysian Construction Industry is to initiate an industry-driven process change and reform that will convert the construction industry into one that is more sustainable, delivers higher quality products and related services, is performance-based oriented and has an improved image. It has the ambition to support and coordinate all the initiatives that will lead to realisation of the vision for the construction industry. The mission statement is set for the Malaysian Construction Industry to be a dynamic, productive, and resilient enabling sector, supporting sustainable wealth generation and value creation, driven by a technologically pervasive,

creative, and cohesive construction community. In order to achieve the vision and mission, seven strategic thrusts have been identified that form the basis for the CIMP as following:

- i. *Integrate the construction industry value chain to enhance productivity and efficiency.*
- ii. *Strengthen the construction industry's image.*
- iii. *Strive for the highest standard quality, occupational safety and health, and environmental practices.*
- iv. *Develop human resource capabilities and capacities in the construction industry.*
- v. *Innovate through research and development and adopt new construction methods.*
- vi. *Leverage on information and communication technology in the construction industry.*
- vii. *Benefit from globalization including the export of construction products and services.*

(CIMP, 2007, p.93)

2.2.4 ICT IN MALAYSIAN CONSTRUCTION INDUSTRY

ICT in the Malaysian Construction Industry has been recognised as the main enabler for improvement. Many efforts have been driven especially by the government, focusing on IT in construction to realise the full benefits of IT implementation. At the strategic level, in 2009, the Economic Planning Unit of Malaysia under the Prime Minister's Department has published a two-year research effort entitled "IT Strategy Plan for the Construction Sector." The study was led by Standards and Industrial Research Institute of Malaysia (SIRIM), and has formulated a strategic plan for the holistic adoption of ICT to enhance productivity and competitiveness of the construction industry. The study encompasses the industry's supply chain partners and current use of ICT. For the record, SIRIM is a corporate organisation owned wholly by the Malaysian Government, under the Minister of Finance Incorporated. It has been entrusted by the Malaysian Government to be the national organisation for standards and quality, and as a promoter of technological excellence in the Malaysian industry in general (EPU, 2009; SIRIM, 2009).

Meanwhile, in the Construction Industry Master Plan (CIMP), the 6th strategic thrust focused exclusively on ICT to leverage information and communication technology in the construction industry. The strategic thrust consists of two major recommendations, to encourage knowledge sharing for continuous improvement and to develop local construction software industry. The first recommendation requires the construction industry to have a single point of access to all information relevant to the industry and thus helps to develop a portal as a source of information to encourage knowledge sharing. As CIMP (2007) further recommends, the portal needs to be easily accessible to all its stakeholders, highlighting the need for it to be user friendly and free to a large extent.

Therefore, in order to realise the recommendation, an E-Construct online portal has been developed by CIDB E-Construct Services Sdn. Bhd. The portal offers a range of information such as tender information, recent projects awarded, information on registered contractors, market information, and articles on international projects. In addition, the portal provides a one-stop centre for intelligent information gathering and dissemination. Construction players along the supply chain will benefit from its endless repository of information, including best practices in construction from all over the world. The portal, which also serves as an online education tool is primarily aimed at educating the end users and consumers and empowering them to benefit from their construction investment (E-construct, 2009). For the record, CIDB E-Construct Services Sdn Bhd was incorporated in Malaysia on February 21, 2001 as a result of a joint-venture agreement between Construction Industry Development Board (CIDB) and Malaysian Institute of Microelectronic Systems (MIMOS). Subsequently CIDB acquired all of MIMOS's shares in this joint-venture making CIDB E-Construct Sdn Bhd a wholly owned subsidiary of CIDB (E-Construct, 2009).

Meanwhile, for the recommendation to develop the local construction software industry, it is targeted at ICT solutions which although are not commercially available but still stand as an urgent need to improve the construction. The recommendation requires the industry via CIDB to form joint working groups to raise awareness of IT in the construction industry, to promote the use of technology in the construction community, introduce and implement an online planning submission and building plan approval, and create an online tendering system for public sector projects. Consequently, E-Submission, which targeted on planning submission and building plan approval, and National E-Tendering Initiatives (NeTI), were initiated with the collaboration between CIDB, Public Work Department (PWD), and E-Construct Services Sdn. Bhd. (CIDB, 2009d). The NeTI system has four phases starting with advertisement, followed by downloading tender documents and submitting tender documents consecutively, and finally analysis of the tender document. The system was piloted in June 2008 before it was officially launched on 23rd March 2009.

Despite many initiatives conducted strategically to embrace the benefits of ICT, the implementation of ICT by the Malaysian construction players is still relatively low. Findings from a survey of internet usage by the Malaysian Construction Industry conducted by Mui et al. (2002) shows that although construction players recognised the importance of the internet and indicated that there is an increase in efficiency and cost savings from the use of the internet, the full potential of the internet is however not utilised by the firms where the implementation is still limited to basic applications such as email and information search, which also agrees with the study of Ibrahim et al. (2010). Meanwhile, another study conducted by Jaafar et al. (2007) on technology readiness among managers

of Malaysian contractors found that the technology readiness index (TRI) was moderate where bigger firms were found to be more optimistic compared to smaller firms but with no significant difference in the overall TRI. In the study, they adopted TRI approach to measure people's propensity to embrace and use technologies for accomplishing goals in home life and at work. A total of 96 responses were received from 400 questionnaires that were distributed to the contractors across the country.

Many factors contribute to slow adoption and implementation of ICT in the construction industry. The prominent factors of resistance to implement ICT in the construction industry are the people and the culture in the construction industry. Some organisations are reluctant to change their business process because they are afraid that by changing their business process at a cost, it will jeopardise their established process because they cannot accept the uncertainty. Also, some people in that organisation feel that the technology will take over their roles, resulting in great anxiety towards changes especially when it involves new technology (Gardner et al., 1993; Li et al., 2000; Davis & Songer, 2008). This shows that the level of readiness for change is still low and this contributes to the lag in adopting and implementing ICT in the construction industry.

Beside the factors of people and culture, the absence of proper planning on implementing the new technology is another factor that the majority of construction industry players are still unable to gain the benefits from. Li et al. (2000) and Mui et al. (2002) believed many companies invest in technology advancement because they simply followed other companies that successfully implemented ICT without doing feasibility studies and the majority of companies adopt and implement ICT in ad-hoc manner, without planning and evaluation. They are unaware of the problems that might arise, the right strategies to use, and why they need that technology, while Yusuf & Othman (2008) added that a lack of training and limited numbers of expert users in the area of ICT in construction industry, worsens the current situation. Meanwhile, Wade & Hulland (2004) viewed that some organisations failed to adopt and adapt to the rapid changing of ICT technologies, practices, process, and expertise in their organisational processes. Alshawi & Ingiringe (2003) and Peppard et al. (2007) believed that benefits from utilisation of ICT do not come automatically because some of the benefits required more time to mature and the process of evolving from their current practise into an 'unknown environment', therefore, there is a time gap between the early investment and income.

Despite the low level of IT readiness among the construction players, to realise the CIMP master plan and thus achieve the vision 2020, the Malaysian industry is probably in urgent need of implementing

Building Information Modelling (BIM) to resolve the construction challenges which have been discussed previously. Fragmentation, low productivity and time and cost overrun which is rooted at the change order, inadequate drawings and specifications, late issuance of construction drawings by consultants and the interrelated problem of coordination between consultants are among the issues that require BIM to be implemented effectively. The important features of Building Information Modelling are that it provides an object-oriented database that is made up of intelligent objects, the 3D representation of integrated information, and a relational database that is interconnected. This could possibly provide a better solution. In the following subchapter (subchapter 2.3), the concept of BIM is discussed in further detail. In addition, BIM also fits in the strategic thrust 1 and 6 of CIMP which is to integrate the construction industry value chain to enhance productivity and efficiency and leverage on information and communication technology in the construction industry respectively. Therefore, in August 2009, in the very first seminar of Building Information Modelling in Malaysia, Director of Public Work Department Malaysia (PWD), Datuk Seri Prof Judin Abdul Karim, in the keynote speech, urged construction companies to adopt ICT and stressed on the importance of having an integrated software system and standardisation for obtaining effective workflow for the project development and implementation (Construction companies urged to adopt ICT, 2009). Targeting first at improving efficiency, a BIM pilot project has also been delivered by PWD in 2010 on National Cancer Institute building in Putrajaya, Malaysia. The results of the pilot project will be used to determine if BIM can be applied in 10th Malaysia Plan development projects (Sani, 2010). The keynote speech has opened up an early indicator of the government's commitment to implement BIM. It is worth mentioning that while CIDB is responsible for the development of the construction industry as a whole, the PWD is responsible for the implementation of the development projects which involves various aspects of design, construction, monitoring, and maintenance of public infrastructure in Malaysia. The PWD is the federal government department which is involved directly with the public project as the client's agent representing the client ministries. Both the CIDB and PWD are agencies under the Ministry of Works Malaysia.

2.3 BUILDING INFORMATION MODELLING

This subchapter discusses related literature reviews regarding Building Information Modelling to form the fundamental knowledge area. The literature review was done to satisfy the scope of the research and the achievement of objective one which is to explore, appraise, and synthesise the definition, concept, and use of BIM in the whole project life cycle, the design benefits of BIM and the evolution of BIM. The details of the objectives and the scope of the research can be referred in section 1.3 and 1.4 respectively in chapter 1.

2.3.1 DEFINITION OF BUILDING INFORMATION MODEL, MODELLING

According to Aranda-Mena et al. (2009), BIM is an ambiguous term that carries different definitions to different professionals. Confirmed by empirical results from their research, BIM is not only defined in various ways according to particular professions but some confusion exists at three different levels where some professionals define BIM as a low level software application, while for some it is a process for designing and documenting building information. Yet others define BIM to the level where it is a whole new approach to practice and advancing the profession which requires the implementation of new policies, contracts, and relationships amongst project stakeholders. In addition, currently available research publications, academia and professional bodies also carry a number of views to what constitute BIM. Therefore, to suit the context of this research, it is important to define BIM accordingly.

According to the National Institute of Building Science (2007:12) Building Information Modelling (BIM) is defined as “a *digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle.*” The definition however, appears to be generic to include any digital technology as long as it could contribute to form information on a facility. As further explained by Onuma in Smith & Tardif (2009), a spread sheet of spatial data is a building information model and if the use of alphanumeric data contained in the spread sheet is to simulate an actual business process in the life cycle of a building, then a Building Information Modelling is engaged. The generic definition of Building Information Modelling is also supported by Jernigan (2007) by pointing out that the interactions of spread sheets with the complexity and an interrelationship of organisation is also Building Information Modelling.

This research however, needs to set a boundary to differentiate between Building Information Modelling with other modelling technologies such as 2D/3D vector based means of creating objects, and 3D surface modelling which is used for the purpose of visualisation only, which carries no attribute to the element. Therefore, the philosophical stand adapts the definition by Eastman et al. (2008) that Building Information Modelling is defined as an approach to building design and construction through modelling technology, an associated set of processes and people to produce, communicate and analyse building information models. On the other hand, the building information model, agreed by Kymmel (2008) and National Institute of Building Science (2007), is defined as a digital representation of physical and functional characteristics of a facility where the information is contained or attached to the component of the model.

In both definitions, modelling technology used in this context of research is the 3D parametric object technology which according to Eastman et al. (2008) has the following characteristics:

- a. *Consisting of a geometric definition and associated data and rules;*
- b. *Geometry is integrated non-redundantly and allows for no inconsistencies. When an object is shown in 3D, the shape cannot be represented internally redundantly, for example as multiple 2D views. A plan and elevation of a given object must always be consistent. Dimensions cannot be fudged.*
- c. *Parametric rules for objects automatically modify associated geometries when inserted into a building model or when changes are made to associated objects. For example, a door will fit automatically into a wall, a light switch will automatically locate next to the proper side of the door, a wall will automatically resize itself to automatically butt to a ceiling or roof, etc.*
- d. *Objects can be defined at different levels of aggregation, so the user can define a wall as well as its related components. Objects can be defined and managed at any number of hierarchy levels. For example, if the weight of a wall subcomponent changes, the weight of the wall should also change.*
- e. *Object rules can identify when a particular change violates object feasibility regarding size, manufacturability, etc.*
- f. *Objects have the ability to link to or receive, broadcast or export sets of attributes, e.g. structural materials, acoustic data, energy data, etc. to other applications and models.*

(Eastman et al., 2008, p. 14)

BIM Application	Feasibility	Conceptual Design	Detail Design	Procurement	Manufacture	Construct	Handover
Architecture Design Authoring		Revit Architecture, Bentley Architecture, Graphisoft ArchiCAD					
Architecture CAD/CAM Authoring		Gehry Digital Project,					
Authoring Structural Design		Revit Structure, Bentley Structural, Steel Design Data SDS/2, SeCAD					
Structural CAD/CAM Authoring		Tekla Structure	Tekla Structure, BOCAD, AceCAD StruCAD				
MEP Design Authoring		Revit MEP, Bentley MEP					
MEP CAD/CAM Authoring		Integrph PDS, Aveva PDMS, MAP CAD-Duct, CADPIPE, Hevacomp					
Material Taking off & Construction		VICO Virtual Construction, Innovaya Composer,					
Structural Analysis & Design		Robobat, SAP200, ETABS, Oasys GSA, STAAD-Pro, RAM, Esteem, Lusas, SACS					
Building Performance Analysis		Energy Plus, DOE-2, Apache, ESP-r, Ecotect, IES VE-Ware, SAP					
Mechanical Equipment Simulation		TRNSYS, Carrier E20-II					
Model and Design checking		Naviswork, EDM Model Checker, Solibri Model Checker					

Figure 2.3: BIM Software map across project lifecycle (Eastman et al., 2008; Smith & Tardif, 2009; BuildingSmart, 2009 and Elvin, 2007),

Therefore, to conduct the data collection for the research, it is important to investigate the type of software used by the organisation in compliance with the characteristics of 3D parametric modelling that was defined by Eastman et al. (2008). Among the 3D parametric tools as highlighted in a blue colour in Figure 2.3, this research focuses on the use of BIM authoring tools as according to Smith & Tardif (2009), an authoring tool is the large and robust application that is used to create and compile most of the information contained in the building information model. For the design organisation, the authoring tools are identified as prerequisite for BIM implementation (Smith & Tardif, 2009; Eastman et al., 2008; Elvin 2007). By combining the findings from Eastman et al. (2008), Smith & Tardif (2009), BuildingSmart (2009) and Elvin (2007), the identification of commercially available BIM technology across the project life-cycle is simplified in Figure 2.3.

2.3.2 THE CONCEPT OF BUILDING INFORMATION MODELLING

According to Smith & Tardif (2009) the concept of Building Information Modelling is to build a building virtually, prior to building it physically, in order to work out problems and simulate and analyse potential impacts. The heart of Building Information Modelling lies in an authoritative building information model.

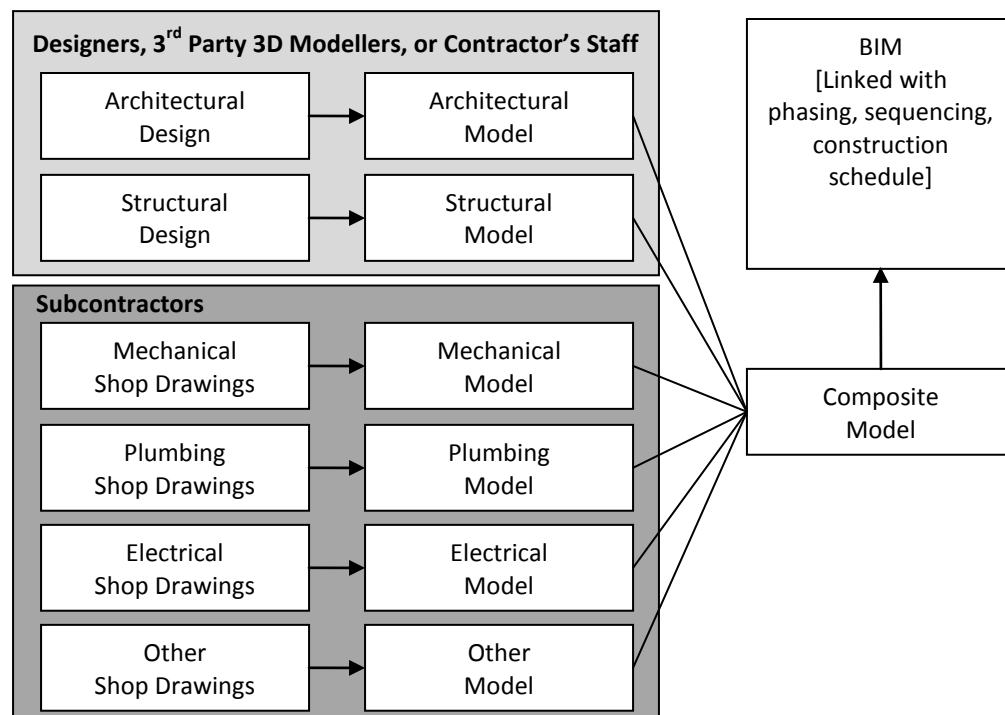


Figure 2.4: Multiple Models in Implementing Building Information Modelling for a Single Project (AGC, 2006, p.5)

By referring to Figure 2.4, at its core, according to AGC (2006), BIM software is a database where its application to a process requires that the database be initially populated and then maintained as the project progresses. The information contribution from each team member which consists of architect, civil and structural consultant, mechanical and electrical consultant, contractor and subcontractor, becomes crucial. This mode of information sharing requires the team member to be working on the building information model instead of paper based documents. Therefore, instead of providing information in 2D drawings to represent 3D reality, each team develops their own model to represent their information.

According to Kymmell (2008) virtual building implies that it is possible to practice construction, to experiment and to make adjustments in the project before it is constructed. Virtual mistakes generally do not have serious consequences provided that they are identified and addressed early enough so that they can be avoided in the actual construction of the project. When a project is planned and built virtually, most of its relevant aspects can be considered and communicated before the instructions for construction are finalized. It is like running a simulation of a construction project by considering all aspects of the construction life cycle.

In terms of the types of information or data that can be derived within a Building Information Model, generally, Elvin (2007) and Hardin (2008) explained that a Building Information Model could provide 2-D and 3D drawing with non-graphical information including specifications, cost data, scope data, and schedules. Kymmell (2008) on the other hand, categorised several types of information within Building Information Model based on the nature of the link between information and the model. This pertains to all information that is part of, or connected to, the components as well as the physical information inherent in the model itself such as size, location, etc. It is important that all information required in making an actual analysis be available from the BIM. The categories of information, as can be summarised from Kymmell (2008) is as follows:

- a) **Component Information**
Component information is the basic information contained in the 3D model file where it provides visual information and resides in the nature of the model part itself. Components in a 3D model also have specific locations in relation to an origin and to one another. An example of component information is a wall with material information or quantitative information such as part numbers.
- b) **Parametric Information**
Parametric Information is information contained in the parametric object which can be edited. It is embedded in the object and the model. Some of this information can be graphical, while much of it can also be intellectual, such as area, volume or material-

related qualities, such as density (providing weight based on the geometry of the object), *R* value, etc.

c) **Linked Information**

Linked Information refers to information that is actually not part of the model, but is connected to the model through external links. Visible links can be “flags” that will open a window or file when clicked to display that file. Invisible links could be, for example, connections to a database with cost information. When two files are linked, changes in one will result in adaptations in the other linked file, and vice versa.

d) **External Information**

External Information refers to information that is generated separate from the BIM, such as manufacturers’ specifications of products. External information may be linked to the model or remain autonomous. It is possible to provide a reference to a catalogue without creating a link to an electronic file. Since not all information will be available in a compatible format it may be necessary to keep it accessible in printed form such as an external reference.

Elvin (2007) further added that another important feature of Building Information Modelling is how it creates an object-oriented database, meaning that it is made up of intelligent objects, for example representation of doors, windows, and walls which are capable of storing both quantitative and qualitative information about the project. So while a door represented in a 2D CAD drawing is just a collection of lines, in BIM it is an intelligent object containing information on its size, cost, manufacturer, schedule and more. But BIM goes further by creating a relational database. This means that all information in the BIM is interconnected, and when a change is made to an object in the database, all other affected areas and objects are immediately updated. For example, if a wall is deleted, doors and windows within the wall are also deleted and all data on project scope are instantly adjusted.

To extend the application of Building Information Modelling to integrated practice in construction, according to Eastman et al. (2008), the building information model should be used as a building model repository. A building model repository is a database system whose schema is based on an object based format. It is different from existing Project Document Management (PDM) systems and web-based project management systems in that the PDM systems are file based and carry CAD and analysis package project files. Building model repositories are object based, allowing query, transfer, updating and management of individual project objects from a potentially heterogeneous set of applications. In this context, the integration occurs at the level of data and could also integrate with other dimensions such as the time dimension (schedule) and cost dimension, which are known as 4D and 5D modelling respectively (Zhou et al., 2009; Koo & Fischer, 2000, Dawood & Sikka, 2007;

Fischer & Kam, 2001). This application would allow construction phases to be analysed early in the design phase which as a result could support early involvement of the contractors in design development.

2.3.3 THE USE OF BIM IN CONSTRUCTION LIFECYCLE

In developing the readiness framework, the implementation of BIM within the lifecycle of project delivery is important to be reviewed since it affects the experience of the respondents working within it. In the context of the whole construction life cycle, the Building Information Modelling can be used in every single phase, regardless of the type of project delivery (AIA, 2007; AGC, 2006; Eastman et al 2008). The use of collaborative project delivery such as design and build or integrated project delivery however, could be advantageous where it could increase the efficiency of BIM uptake within a construction project (Eastman et al., 2008; AIA, 2007; Elvin, 2007). Furthermore, it could also assist delivery of Integrated Practice in the construction industry. Figure 2.5 outlines the use of BIM within the construction lifecycle.

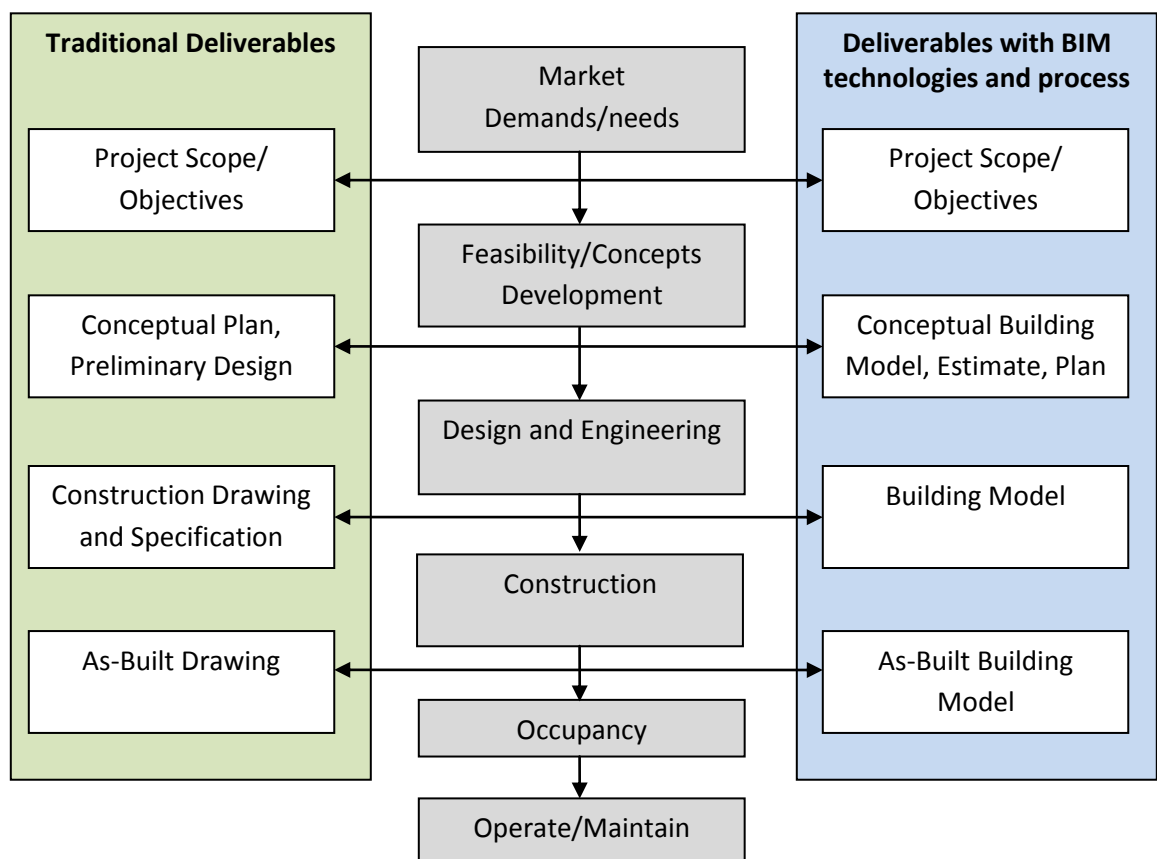


Figure 2.5: Typical contract deliverables as a function of the traditional design-bid-build process compared to the types of deliverables that result from collaborative BIM-based process (Eastman et al., 2008, p.140)

This research focuses on BIM implementation by the organisation involved during the design phase which is the design consultant. According to Eastman et al. (2008), design stage involves design activity where a major part of the information about a project is produced. Most of the information about a project originates with the design consultant which consists of the architect consultant, civil and structural engineering consultant and MEP consultant as the major design consultants. Since the majority of production of the building information is delivered by the design consultant, therefore it justifies the need to conduct the research on them.

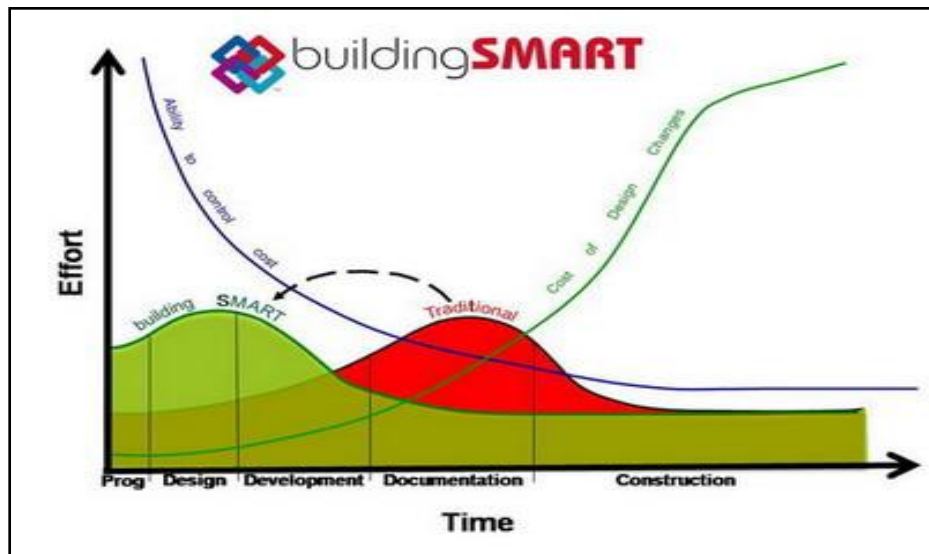


Figure 2.6: The Mcleamy curve of design effort, the ability to control cost and cost of design change (Eastman et al., 2008, p.153)

In addition, by referring to Figure 2.6, during the design stage, the ability to impact cost and functional capabilities is at the highest. Also, Smith & Tardif (2009) strengthened the argument by stating that an estimated 80% of the cost of a building is determined in the first 20% of the design process. By implementing BIM, according to Elvin (2007), the peak of design effort could be moved back behind the intersection of the cost changes and ability to control costs curves, thus producing better design solutions. Meanwhile, the focus of this research concentrates on the organisations rather than the project. The justification lies in the nature of BIM investments which require long-term investments and could only justify the return on investment through a series of projects implementation and thus requires a long-term effort by the organisation. The long-term investment covers the needs for training and education, hardware and software deployment and cultural and process flow change (Smith & Tardif, 2007; Aranda-Mena, 2009).

According to Eastman et al., (2008), the role and process of BIM used in the design phase can be categorised in four points of view depending on their level of information development. The first point of view addresses the conceptual design which involves generating the basic building plan, its massing and general appearance, determining the building's placement and orientation, the structure, and how the project will realise the basic building program. The second point of view addresses the use of BIM for detailed design and analysis of the building system. Analysis from this view point refers to the operations to measure the fluctuation of physical parameters that can be expected in the real building. The third point of view addresses the use of BIM in developing construction-level information which expedites the generation of standard construction documents, and lastly the fourth viewpoint involves design and construction integration which emphasises the growing use of a building model for direct use in construction and generating initial input for fabrication-level modelling. The application of BIM within the design phase is summarised in Table 2.2 (Kymmell, 2008; Eastman et al., 2008; Smith & Tardif, 2009; Elvin, 2007).

Table 2.2: BIM use within design phase

(Note: Data from Kymmell, 2008; Eastman et al., 2008; Smith & Tardif, 2009; Elvin, 2007)

Point view	BIM use
Conceptual Design	Massing and sketching Space planning Environmental Analysis Site development
Design and Analysis	Structural Analysis Energy Analysis Mechanical Equipment Simulation Lighting Analysis Acoustic Analysis Air Flow/CFD Building Function Analysis/Clash Detection Cost Estimation Improving Building Performance Experimental Design Option
Construction level Documentation	Building System Layout Drawing and document production Specification Bill of quantity
Design and Construction Integration	Collaboration between design and construction Early identification of long lead-time item and shortening procurement schedule Value engineering Constructability analysis Construction Sequencing/4D analysis 5D analysis

2.3.4 THE DESIGN BENEFITS OF BIM

The benefits of BIM need to be discussed to inform the research on the organisational motivation of BIM implementation, which in turn affects the level and context of the implementation. Many organisations encountered problems inherited with CAD design complexity and drafting errors as identified by Kaner et al. (2007), which led to low productivity and low cycle times for design review. By understanding the BIM benefits, the organisations could possibly strategize their action plan for BIM implementation to suit their needs. As for this research, the advantage of BIM assists in understanding the justification and the context of BIM implementation for the organisation, essential during the data collection of the case study as it may impose different criteria in the organisation's capability.

According to Kiviniemi et al. (2008), the use of BIM depends on the roles of the company and for the design consultant, the purpose normally concentrates on consistent drawings production, reuse of data for visualisation and improving communication which resulting in the reduction of design error. As Kaner et al. (2007) and Eastman et al. (2008) recognised in their case study, BIM has reduced the number of requests for information and change order on a project and thus improves the productivity as the problems which are rooted at the change order, inadequate drawings and specifications and late issuance of construction drawings, are minimised. In addition, labour productivity as according to Eastman et al. (2008), the total cost in terms of labour hours and salaries to realise the task, are often under-applied considerations for design firms. According to Kaner et al. (2007), research in the productivity gain for producing structural engineering drawings with rebar detailing has yielded gains of between 21% and 59%, depending on the size, complexity, and repetitiveness of the structures. Both of the organisations involved in the case study cited that the productivity and improved quality of design and documentation as primary advantages drives the implementation of BIM, besides being aware of the time consuming element, to achieve productivity enhancement.

The use of 3D parametric modelling tools in BIM also improves the clarity of representation of the design intent and consistent drawings production. Mismatch or internal contradictions in the content of any individual document or related sets of documents are eliminated and the increase in clarity and consistency leads to a much more efficient design production process within the organisations and improves the interaction and communication between parties in the construction projects (Kaner et al., 2007; Khanzode et al., 2008; Staub-French & Fischer, 2001). In the three case studies conducted by Bouchlaghem et al. (2005), they found that the visualisation could be benefited across entire project life. Similarly to the aforementioned researchers, in the design stage, visualisation helped the

designers to work collaboratively and communicate design ideas more efficiently as each project participants shared the same 3D design view. In addition, for housing development stage, site layout models can be used as a marketing tool with clients or for planning consultations with planners and improved design types that were developed by the design team. While during construction stage, the visualisation could bridge the gap between team designer and site to workout constructability issues.

Meanwhile, the use of BIM as the repository has identified potential to achieve the collaboration required for integrated practice, vital for resolving the fragmentation problems, which have been discussed previously in the challenges of the Malaysian construction industry. Integrated Project Delivery (IPD) which has been introduced by the American Institute of Architects (AIA) stated that to assist effective delivery of IPD, the utilisation of BIM is very important, and full benefits of both BIM and IPD are achieved only when they are used together (AIA, 2007). On the other hand, a well-known association, International Council for Research and Innovation in Building and Construction, CIB, is also supporting integrated practice in the construction industry by launching Integrated Design and Delivery Solution (IDDS, 2011) as a priority theme of CIB. The theme “Improving Construction and Use through IDDS,” aims to speed up the adaptation of techniques and practices that guide the traditional document-based work methods towards the use of Integrated Building Information Modelling. Meanwhile, the potential use of BIM as a tool has also been explored further to integrate the dimension beyond 3D geometry. The work that has been carried out by the University of Salford, “From 3D to nD Modelling Project” aimed to integrate an n th number of design dimensions into a holistic model which would enable users to portray and visually project the building design over its complete lifecycle. In the project, the additional dimensions that have been incorporated into the model were whole-lifecycle costing, acoustic, environmental impact data, crime analysis, and accessibility. The work enabled the what-if analysis to be carried out before the real construction takes place; for instance what are the knock-on effects for time, cost, maintainability, etc. of widening a door to allow for wheelchair access (Marshall-Ponting & Aouad, 2005).

At the downstream level, the other BIM benefits, as can be simplified from Eastman et al. (2008), are as follows:

- a) Easy Verification of consistency to the design intent.

BIM provides earlier 3D visualizations and quantifies the area of spaces and other material quantities, allowing for earlier and more accurate cost estimates. For technical buildings (labs, hospitals, and the like), the design intent is often defined quantitatively, and this allows a building model to be used to check for

these requirements. For qualitative requirements the 3D model also can support automatic evaluations.

b) Extraction of cost estimates during the design stage.

At any stage of the design, BIM technology can extract an bill of quantities and spaces that can be used for cost estimation. In the early stages of a design, cost estimates are based either on formulas that are keyed to significant project quantities, for example, number of parking spaces, square feet of office areas of various types, or unit costs per square foot. As the design progresses, more detailed quantities are available and can be used for more accurate and detailed cost estimates. It is possible to keep all parties aware of the cost implications associated with a given design before it progresses to the level of detailing required of construction bids. At the final stage of design, an estimate based on the quantities for all the objects contained within the model allows for the preparation of a more accurate final cost estimate. As a result, it is possible to make better-informed design decisions regarding costs using BIM rather than a paper-based system.

c) Automatic low-level corrections when changes are made to design.

If the objects used in the design are controlled by parametric rules that ensure proper alignment, then the 3D model will be free of geometry, alignment, and spatial coordination errors. This reduces the user's need to manage design.

d) Generation of accurate and consistent 2D drawings at any stage of the design.

Accurate and consistent drawings can be extracted for any set of objects or specified view of the project. This significantly reduces the amount of time and number of errors associated with generating construction drawings for all design disciplines. When changes to the design are required, fully consistent drawings can be generated as soon as the design modifications are entered.

e) Earlier collaboration of multiple design discipline.

BIM technology facilitates simultaneous work by multiple design disciplines. While collaboration with drawings is also possible, it is inherently more difficult and time consuming than working with one or more coordinated 3D models in which change control can be well managed. This shortens the design time and significantly reduces design errors and omissions. It also gives earlier insight into design problems and presents opportunities for a design to be continuously improved. This is much more cost-effective than waiting until a design is nearly

complete and then applying value engineering only after the major design decisions have been made.

2.3.5 THE EVOLUTION OF BIM

As previously discussed in the introduction, there are many problems caused by fragmentation in the construction industry which drives the need for developing an integrated solution. Generally in any product development, the main domains involved are people, processes and technology, and each domain is interrelated. Integrated practice, on the other hand, could focus on each domain, across 2 domains, or even involving 3 domains as a total solution. In the context of Building Information Modelling, from the perspectives of technology domain, Eastman et.al (2008) explained that there are at least four ways to integrate the different functionality needed in BIM technology:

- a) A single application is developed that covers all the functionality which could be similar to nD modelling technology (Aouad et al., 2007)
- b) A suite of integrated applications developed based on a business plan that is mutually beneficial to various companies (using a set of direct translators or plug-ins)
- c) The application supports a neutral public standard exchange interface (such as IFC) and relies on it to support integration. For the record, IFC stands for Industry Foundation Classes and is defined as a common and neutral data schema that makes it possible to hold and exchange relevant data between different software applications. The data schema comprises interdisciplinary building information as used throughout its lifecycle.
- d) BIM authoring tools expand their capabilities.

Kunz & Fischer (2009), using the concept of Virtual Design and Construction (VDC), found that the implementation of VDC takes place in 3 different phases which has its own value proposition, strategy and costs. The organisation proceeds sequentially through the steps of maturity encompassing Visualisation and Metrics, Integration, and finally Automation. In this context, the use of Building Information Modelling is identified as useful but the BIM alone is not enough to complement the VDC since it involves management issues and interaction of building, organisation, and process.

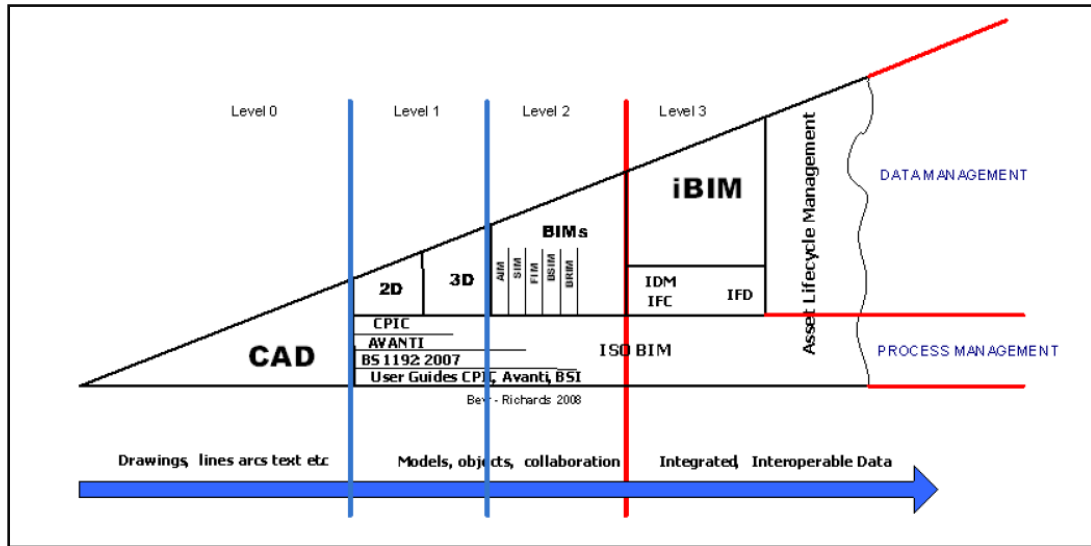


Figure 2.7: BIM evolutionary ramp from construction perspective (Bew & Richard, 2008 in Bew et al., 2008)

By referring to Figure 2.7, Bew et al., (2008) suggested that using the lenses of data and process sets, the evolution of BIM progresses in four levels and each level requires different capabilities of people, process, and technology. Each level is further discussed as follows:

Level 0 is the use of unmanaged CAD,

Level 1 is Managed CAD in 2D or 3D format where the company engaged industry standard within the process such as BS1192 with commercial data is managed by stand-alone finance and a cost management package,

Level 2 is Managed 3D environment held in separate discipline tools with parametric data and commercial data and managed by Enterprise Resource Planning. During this stage, integration occurs on the basis of proprietary interface or bespoke middleware,

Level 3 is a fully open interoperable process and data integration enabled by IFC. Named as integrated BIM, the data and information are managed by a collaborative model server.

Similarly, Succar (2008) suggests that the evolution of Building Information Modelling takes place in 4 major milestones that need to be reached by a team or an organisation as it implements BIM technologies and concepts towards the achievement of Integrated Design and Delivery Solution (IDDS), or even a target beyond that. The stages are object-based modelling, model-based collaboration, network-based integration, and finally IDDS. The stages are defined by their minimum requirements. As an example, for an organisation to be considered at BIM Capability Stage 1, it needs to have deployed an object-based modelling software tool, and the application of BIM takes

place in an isolated condition within the organisation. Similarly for BIM Capability Stage 2, an organisation needs to be part of a multidisciplinary model-based collaborative project. While to be considered at BIM Capability Stage 3, an organisation must be using a network-based solution like a model server to share object-based models with at least two other disciplines.

The evolution of BIM being noticeably towards integrated practice, informs this research that different stages of implementation pose different sets of capability to explore the implementation requirements. For instance, the uptake of BIM in isolation within a single organisation does not pose a need to study the collaborative use and environment that supports the application which contradicts the implementation of BIM in a collaborative environment. Therefore a preliminary interview which is also performed as a pilot interview is needed to gain an insight of the current implementation of the organisation that would be investigated. In addition, the preliminary interview would also assist the researcher to understand the context and level of BIM implementation by each organisation.

2.4 READINESS ASSESSMENT

This subchapter discusses related literature review regarding readiness assessment to form fundamental knowledge area. The literature review was done to satisfy the scope of research which has been specified early in chapter 1, section 1.4, and the achievement of objective two which is to explore, appraise and synthesise concept, currently available readiness model, and its component. The readiness component is pertinent to the research as it forms a basis for developing theoretical framework, which will be used to guide the research line of inquiry and to develop the interview questions.

2.4.1 REVIEWS AND CRITICS ON NBIMS CAPABILITY MATURITY MODEL

Before the concept of readiness assessment is further discussed, the current commercially available BIM readiness model is important to be reviewed to understand the current existence of the knowledge and the position of this research within that knowledge. In 2007, The US National Building Information Standard (NBIMS) developed NBIMS Capability Maturity Model to enable the BIM user to evaluate their business practices along a spectrum of desired technical levels of functionality. In addition, the NBIMS CMM is also used to measure the degree to which building information model (rather than modelling) implements a mature BIM standard (National Institute of Building Science, 2007). According to Smith & Tardif (2009) the model established BIM implementation benchmarks to measure the maturity of building information model and the processes used to create it.

NBIMS developed two versions of the CMM for BIM. The first version is a static tabular form identifying 11 index of measurement against 10 level of increasing maturity, as can be seen in Table 2.3. Based on the first version, the second version is developed in a multi-tab Microsoft Excel workbook and known as the Interactive Capability Maturity Model (I-CMM). According to Suermann et al. (2008), the I-CMM is targeted to be used as an organisational internal tool to determine the level of maturity of an individual BIM as measured against a set of weighted predetermined criteria. NBIMS I-CMM is based on the concept of Minimum BIM in which achieving a minimum total score for maturity across the 11 indexes, failing which, a project is not considered 'true BIM'. In version 1 of NBIM Standard, a minimum score of 20.1 is mentioned in order to consider true BIM maturity. The minimum score for the distinction of a 'Minimum BIM' is however not fixed but is dependent on the date the I-CMM is used. The minimum score thus keeps on changing depending on the owners' demands for the models to be delivered (NIST, 2007). Also, each of the 11 indexes used in the CMM are weighted. This weighting scheme is not conceptually fixed but can be preferentially altered by the organisations as to suit their needs. As for criticising the model, by referring to Table 2.3, the following argument is prepared:

- a) The NBIMS employs 10 levels of maturity. The 10 levels of maturity exceed the maximum of 6 levels, which defines the main principles in maturity model (Klimko, 2001). In addition, of all the capability and maturity models that are reviewed (Table 2.4, on page 49), the level sits between four and six. The exceeding number of maturity levels has caused a very minimal distinction between them, making it confusing to position the maturity level to conduct the assessment.
- b) According to Succar (2010), the variability of the minimum score for the Minimum BIM will cause scoring inconsistencies. Pre-assigning the minimum score according to the calendar year and allowing it to be changed according to demands by owners are in sharp contrast, as it is difficult to imagine that industry's BIM maturity will increase or can be encouraged to increase in a pre-defined linear fashion, or that owners' BIM requirements can be established/ represented through a generic minimum score.
- c) According to McCuen & Suermann (2007) and Succar (2008), the NBIM CMM indexes are only useful in assessing maturity of the models and some part of the project teams but not at the organisational level. According to Alshawi (2007), organisational change to implement ICT involves change at group and individual level and an organisation will not be able to adapt itself successfully to a new situation unless the needs of the people are appropriately addressed and satisfied. According to Eastman et al. (2008) and Smith & Tardif (2009) the implementation of

BIM requires a dedicated focus on the people. The minimal focus of the people in NBIMS CMM within the context of organisation, however, has limited the usage of the model. The focus of the people as identified in Eastman et al. (2008), Smith & Tardif (2009) and Gu et al. (2008) requires a definition of new roles and responsibilities, a new skill and attitude set and training and education, which are not addressed in the NBIMS CMM model.

- d) The process focus in the NBIMS CMM is given towards the production of the building information model on a project basis rather than the process competency set that is needed to enable BIM to be implemented within an organisation. As identified in Kaner et al. (2007), Eastman et al. (2008) and Smith & Tardif (2009), the implementation of BIM changed the business process flow and thus requires a dedicated process change strategy, dedicated implementation plan, business strategy alignment and adequate software evaluation strategy, which are not addressed in the NBIMS CMM model.

Table 2.3: The NBIMS capability maturity model (NBS, 2007 in Smith & Tardif, 2009)

Maturity Level	A Data Richness	B Life-cycle Views	C Roles Or Disciplines	G Change Management	D Business process	F Timeliness/ Response	E Delivery Method	H Graphical Information	I Spatial Capability	J Information Accuracy	K Interoperability/ IFC Support
1	Basic Core Data	No Complete Project Phase	No Single Role Fully Supported	No CM Capability	Separate Processes Not Integrated	Most Response Info manually re-collected - Slow	Single Point Access No IA	Primarily Text - No Technical Graphics	Not Spatially Located	No Ground Truth	No Interoperability
2	Expanded Data Set	Planning & Design	Only One Role Supported	Aware of CM	Few Bus Processes Collect Info	Most Response Info manually re-collected	Single Point Access w/ Limited IA	2D Non-Intelligent As Designed	Basic Spatial Location	Initial Ground Truth	Forced Interoperability
3	Enhanced Data Set	Add Construction/ Supply	Two Roles Partially Supported	Aware of CM and Root Cause Analysis	Some Bus Process Collect Info	Data Calls Not In BIM But Most Other Data Is	Network Access w/ Basic IA	NCS 2D Non-Intelligent As Designed	Spatially Located	Limited Ground Truth - Int Spaces	Limited Interoperability
4	Data Plus Some Information	Includes Construction/ Supply	Two Roles Fully Supported	Aware CM, RCA and Feedback	Most Bus Processes Collect Info	Limited Response Info Available In BIM	Network Access w/ Full IA	NCS 2D Intelligent As Designed	Located w/ Limited Info Sharing	Full Ground Truth - Int Spaces	Limited Info Transfers Between COTS
5	Data Plus Expanded Information	Includes Constr/Supply & Fabrication	Partial Plan, Design&Constr Supported	Implementing CM	All Business Process(BP) Collect Info	Most Response Info Available In BIM	Limited Web Enabled Services	NCS 2D Intelligent As-Built	Spatially located w/Metadata	Limited Ground Truth - Int & Ext	Most Info Transfers Between COTS
6	Data w/Limited Authoritative Information	Add Limited Operations & Warranty	Plan, Design & Construction Supported	CM Capability	Few BP Collect & Maintain Info	All Response Info Available In BIM	Full Web Enabled Services	NCS 2D Intelligent And Current	Spatially located w/Full Info Share	Full Ground Truth - Int And Ext	Full Info Transfers Between COTS
7	Data w/ Mostly Authoritative Information	Includes Operations & Warranty	Partial Ops & Sustainment Supported	Implemented	Some BP Collect & Maintain Info	All Response Info From BIM & Timely	Full Web Enabled Services w/IA	3D - Intelligent Graphics	Part of a limited GIS	Limited Comp Areas & Ground Truth	Limited Info Uses IFC's For Interoperability
8	Completely Authoritative Information	Add Financial	Operations & Sustainment Supported	Implementing CM and Root Cause Analysis	All BP Collect & Maintain Info	Limited Real Time Access From BIM	Web Enabled Services - Secure	3D - Current And Intelligent	Part of a more complete GIS	Full Computed Areas & Ground Truth	Expanded Info Uses IFC's For Interoperability
9	Limited Knowledge Management	Full Facility Life-cycle Collection	All Facility Life-cycle Roles Supported	CM and RCA capability implemented	Some BP Collect&Maint In Real Time	Full Real Time Access From BIM	Netcentric SOA Based CAC Access	4D - Add Time	Integrated into a complete GIS	Comp GT w/Limited Metrics	Most Info Uses IFC's For Interoperability
10	Full Knowledge Management	Supports External Efforts	Internal and External Roles Supported	Implementing CM & RCA and feedback	All BP Collect&Maint In Real Time	Real Time Access w/ Live Feeds	Netcentric SOA Role Based CAC	nD - Time & Cost	Integrated into GIS w/ Full Info Flow	Computed Ground Truth w/Full Metrics	All Info Uses IFC's For Interoperability

2.4.2 THE CONCEPT OF READINESS ASSESSMENT

Generally in IT/IS application, according to Alshawi (2007), readiness assessment refers to a managerial evaluation tool to measure the readiness gap of the organisation prior to Information System/Information Technology investment where it identifies the current capability of organisation as compared to the targeted level that a company would want to achieve. Ruikar et al. (2005) on the other hand, defined e-readiness as the evaluation of the capability of an organisation to adopt, use, and benefit from information and communication technologies (ICT). Taylor (2003) defined readiness as measures of the capability of the citizens and businesses to adopt and use electronic services (e-services) that are available, such as online banking. As to understand the readiness concept better, according to Kangas (1999) and Moingeon et al. (1998), organisational capability is strategic application of competencies. Alshawi (2007) further discussed the organisational capability definitions by adding that the development and deployment of specific organisational competencies is the process of building the organisational capability. Meanwhile, the term competency according to Amit & Schoemaker (1993) refers to organisational capacity and ability to deploy resources, usually in combination, using organisational processes, to achieve specific objectives, and according to Hamel & Prahalad (1994) in Peppard & Ward (2004), represent a bundle of interrelated skills and technologies. Competence is therefore portrayed as the ability to deploy combinations of organisational-specific resources to accomplish a given task (Teece et al., 1997; McGrath et al., 1995). According to Collis (1996), they represent the collective knowledge of the firm in initiating or responding to change that is built into the organisation's processes, procedures and systems, and that is embedded in modes of behaviour, informal networks, and personal relationships.

According to Saleh & Alshawi (2003), for an organisation to implement ICT system, it needs to evaluate its capability in terms of processes, structure and work environment so that effective decisions can be made towards achieving such capability. The measurement should be carried on the capabilities in the relevant areas which could affect the development of the required IS/IT capabilities. The prediction also needs to be identified on the required level of change and the associated resources to develop the target capabilities. Figure 2.8 simplifies the measurement process:

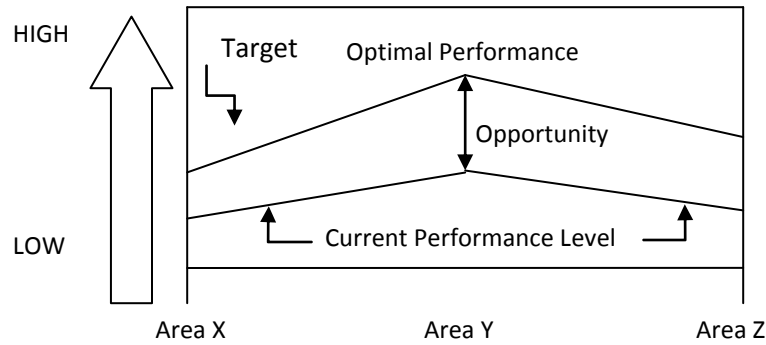


Figure 2.8: Performance analysis chart
(Alshawi, 2007, p.184)

By referring to Figure 2.8, performance level identifies the current status of the business function in terms of the pre-identified evaluation criteria, while the target performance level identifies the desirable status for this particular business function and is measured by the same evaluation criteria. The difference in the value of the evaluation criteria between the current and the target performance level is known as the opportunity gap. The information that this gap can provide is:

- a) Focus and guidance on the area for improvement by providing information on which areas are critical and which are not, so the resource can be prioritized;
- b) Level of change in order to successfully implement the selected IS;
- c) Indicator on the risk level that an organisation might face during the implementation of a new IS.

The accuracy of the gap analysis, on the other hand, is dependent on how the business function under consideration is measured and what criteria are used which measure the current performance and also progress of improvement.

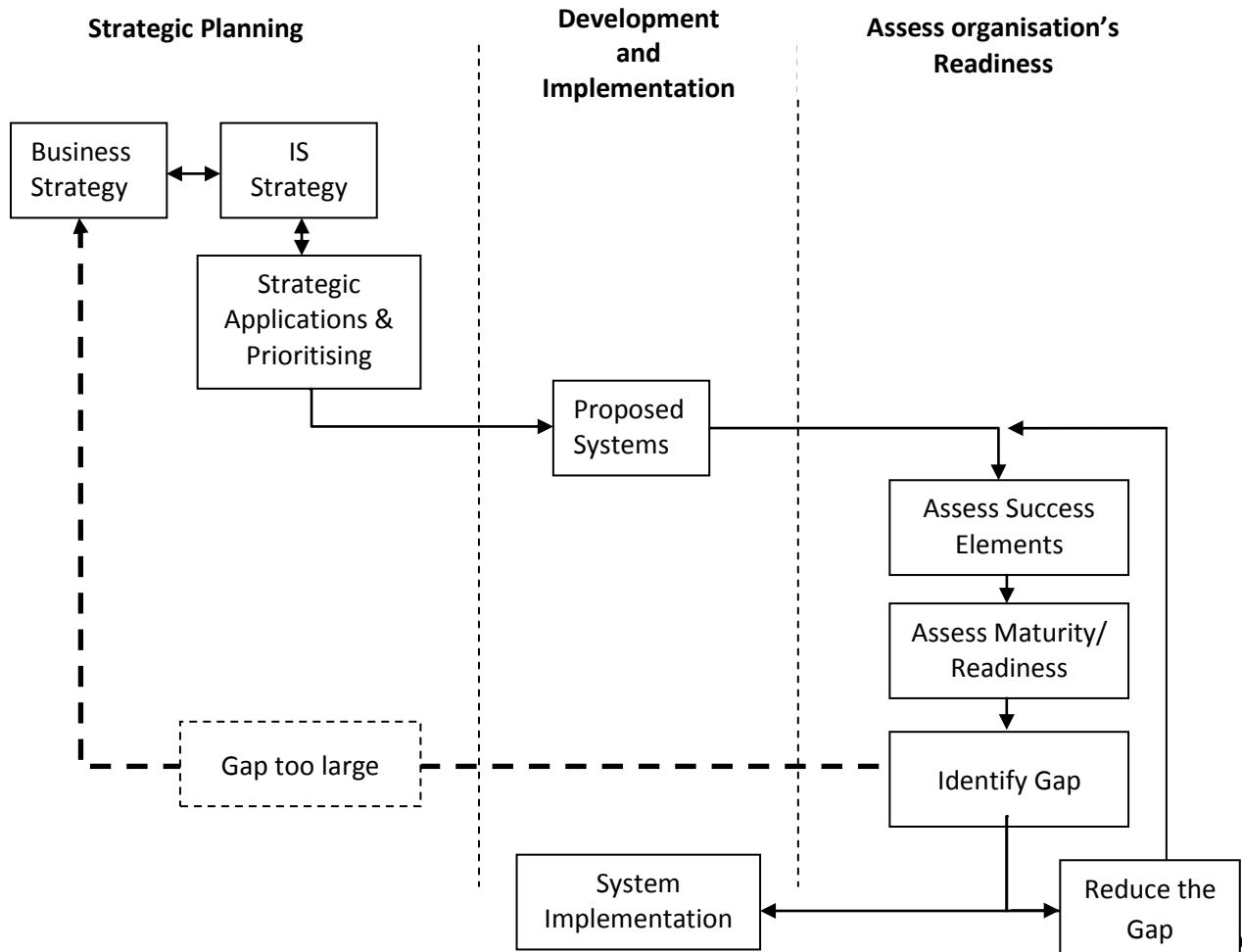


Figure 2.9: Sequence of events in conducting readiness assessment (Alshawi, 2007, p.193)

In order to deliver the readiness assessment, Alshawi (2007) proposes the framework for assessment as can be seen in Figure 2.9. The readiness assessment is placed after the proposed system is endorsed and before the system implementation. The assessment involves the key element which determines the level of organisational change required and must be assisted by a management tool to identify the readiness gap. Once the readiness gap is identified, a key decision has to be taken by the organisation to either proceed to the development and implementation phase or to plan for organisational improvement with the aim of reducing the readiness gap.

Apparently, there are two elements which are critical in the sequence of events proposed by Alshawi (2007). The first element is identifying the evaluation criteria that needs to be used (since the accuracy of the assessment is dependent on it) when Building Information Modelling is placed in the

framework as the proposed system. The second element is the target of the system implementation, which refers to the implementation requirements that need to be achieved in order to implement the system. Since the application of BIM is wide and varies between one organisation and another (Manning & Messner, 2008), it is therefore suggested to firstly carry out an investigation to understand the level of BIM implementation by the organisations. Once the level is identified, the requirements needed to implement the system using the predefined evaluation criteria will be identified and used as the target performance level (Figure 2.8). Consequently, after the assessment criteria and requirements are developed, it is possible to carry out readiness assessment by measuring the current position of the organisation and comparing it with the implementation requirements by using the same criteria of assessment. Meanwhile, according to Alshawi (2007) and Ward & Peppard (2004), the implementation of IT system takes place in an evolutionary fashion through a series of stages until it reaches the target of implementation, and no level can be left out which also agrees with Succar (2008), Bew et al., (2008) and Kunz & Fischer (2009) for BIM implementation. This research is aware of the infancy stage of BIM implementation in Malaysia and therefore, the BIM implementation stage focuses on the modelling stage by referring to the BIM readiness model that is proposed by Succar (2008) and Bew et al., (2008).

2.4.3 THEORETICAL FRAMEWORK FOR BIM READINESS

In developing the theoretical framework used for this research, eight readiness models were reviewed including the NBIMS-iCMM which has been discussed earlier in section 2.4.1 and other seven models as can be seen in Table 2.4. This research engaged the General Practitioner Information System (GPIS) model developed by Saleh & Alshawi (2003) as a base line concept with synthesisation of the other models to develop the theoretical framework. At this stage of framework development, the focus was given to determine the elements and categories of the framework where pattern matching technique was used. The selection and adaption of each category was made based on the following criteria:

- a) The frequency of occurrence among the models reviewed.
- b) The suitability of the category to be used within the context of organisation
- c) The suitability of the category to be used specifically with the context of BIM implementation

Table 2.4: Summary of readiness assessment model

Models/ Criteria	CMMI (SEI, 2009)	SPICE (Alshawi, 2007)	GPIS (Alshawi, 2007)	IS Competency Framework (Peppard and Ward, 2004)	BIMMi (Bilal, 2008)	Verdict (Ruikar, 2006)	BEACON (Khalfan et al., 2001)
Descripti on and the usage	Capability Maturity Model Integrated consists of best practice which can be used to improve process within a project, a division, or an organisation. The assessment is looking for the maturity and capability of the process and it has 5 maturity and 6 capability level 3 models available which concentrates on Product and service development, Service establishment, management, and delivery and Product and service acquisition	Standardised Process Improvement for Construction Enterprises is a systematic step by step process improvement framework for the construction industry Consist of 5 level of maturity based on the presence of key process in each level The assessment is carried out by determining the implementation of key process by the organisation	General Practitioner Information System is general IT/IS model that focused on recipient organisation Used to assess the readiness of organisation to uptake Information Technology/Information System Consist of 6 level of maturity (level 1-6). The assessment must be carried out prior to system implementation to identify the readiness gap	IS Competency framework identified six domains of IS competencies. The Framework is based on resource-based view is premised on the crucial importance to view IS competencies from an organisational perspective. The framework links strategy of both business and IS with IT supply and business exploitation The focus is given on the ability of each six domains which is translated into several competency set for each domain	Building Information Maturity Index is BIM readiness assessment specifically design to measure the maturity, capability, and organisational scale of BIM. Consist of 5 level of maturity (Initial, Defined, Managed, Integrated, optimised). Can be used for 12 organisational scale (ex: evaluating international standards) to organizational Members (BIM competencies of an individual)	Verify End-User e-Readiness is an e-readiness model that assess the readiness of organisation to adopt e-commerce tools, such as web based collaboration tools. Can be used to assess the e-readiness of construction companies, department (s) within a company or even individual work groups within a department. Consist of 3 level of readiness Red= Critical, Amber=less critical, Green=e-ready	Benchmarking Readiness Assessment for Concurrent Engineering is a concurrent engineering readiness assessment model. It is conducted before the introduction of CE within an organisation. Adapted from Readiness Assessment for Concurrent Engineering Model (RACE), which is used in manufacturing, Consist of 5 level maturity which are Ad-hoc, repeatable, characterized, managed and optimizing
Key Element and category	Initial Managed Requirements Management Project Planning Project Monitoring and Control Supplier Agreement Management Measurement and Analysis Process and Product Quality Assurance Configuration Management Defined Requirements Development Technical Solution Product Integration Verification Validation Organizational Process Focus Organizational Process Definition Organizational Training Integrated Project Mgmt. Risk Management Decision Analysis and Resolution Quantitatively Managed Organizational Process Performance Quantitative Project Management Optimizing Organizational Innovation and Deployment Causal Analysis and Resolution	Initial Planned and Tracked Brief and scope of work management Project Planning Project tracking and Monitoring Subcontract management Project change management Health and safety management Risk management Project team coordination Well defined Organisation process definition Organisation process focus Integrated design and construction management Construction life cycle engineering Training programme Peer reviews Quantitatively controlled Quality Management Quantitatively process management Continuously Improving Process change management (CM) Technology CM Defect prevention	People Head of IT Staff Skill Process Generic Practice IT Infrastructure Systems Environment Culture Leadership Structure	Strategy Business Strategy Technology Innovation Investment Criteria Information governance Define the IS contribution Prioritization IS strategy alignment Business process design Business performance improvement Systems and process innovation Define the IT Capability Infrastructure development Technology analysis Sourcing strategies Exploitation Benefits planning Benefits delivery Managing change Deliver solutions Applications development Service management Information asset management Implementation management Apply technology Business continuity and security Supply Supplier relationships, Technology standards, Technology acquisition, Asset&cost management, IS/IT staff development	MATURITY Technology Software Hardware Network Process Leadership Infrastructure Human Resource Product and Services Policy Contractual Regulatory Preparatory CAPACITY Stage 1 Object Based Modelling Stage 2 Modelling Based Collaboration Stage 3 Network Based Integration ORG. SCALE Micro Organisation Meso Project Teams Macro Markets	People Head of process (Change Management) Role and responsibilities Work environment Culture People Capability Process Business Process Client The use of e-commerce tool in process Technology System Infrastructure IT policy Management (top level) Strategy Support and Commitment Awareness Performance measure	Process Management systems Process focus organisational Arrangement Strategy Deployment Agility People Teams in an organisation Discipline Team leadership and management Team Formation and Development Project Facility Design Quality Assurance Client Focus Technology Task Support Integration Support Information Sharing Co-ordination Support Communication Support
Assessme nt method	Interview and questionnaire	Interview	Interview	Interview	Is to be defined	Software prototype using Questionnaire form	Questionnaire
Status	Commercial	Research Prototype	Research prototype	Research Prototype	On-going research prototype	Research prototype	Research prototype
Can be used for BIM?	Yes but certain modification is required before applying it to assess BIM readiness in organisation	Yes but the focus is limited on the process improvement only	Yes since it focus on general application of IT/IS in any type of organisation	Yes since it focus on general application of IT/IS in any type of organisation but requires some adjustment.	Yes since it is purposely developed for BIM application in construction	Yes but certain modification is required before applying it to assess BIM readiness in organisation	Yes but major modification is required before applying it to assess BIM since the main focus is on CE

Table 2.5: Theoretical framework to explore BIM readiness criteria

ELEMENTS	CATEGORY	READINESS CRITERIA (to explore...)
PROCESS	PROCESS CHANGE STRATEGY	The degree to which an organisation has developed a documented methodology for changing its business process
	BIM IMPLEMENTATION MANAGEMENT	The presence of good management practice to incorporate BIM within the business process
	POLICY	The suitability of current contract and project delivery method for BIM use
MANAGEMENT	BUSINESS STRATEGY	The formulation of business strategy which identifies the most advantageous uses of BIM
	MANAGEMENT COMPETENCY	The management competency and support on the use and implementation of BIM
	LEADERSHIP	The management leadership to drive BIM implementation
PEOPLE	ROLES AND RESPONSIBILITY	The creation and justification of BIM associated roles and responsibility by the organisation
	SKILL AND ATTITUDE	The skill and attitude set that is required by the staff to implement BIM
	TRAINING AND EDUCATION	The educational/training program and deliverables to support the BIM implementation
	WORK ENVIRONMENT	The characteristics of good work environment to support BIM implementation
TECHNOLOGY	HARDWARE	The ICT hardware tools and infrastructure to implement BIM
	TECHNICAL SUPPORT	The software and hardware technical support to assist BIM implementation
	SOFTWARE	The type of software use and the justification of selecting the software

A theoretical framework as can be seen in Table 2.5 is then proposed. In reference to Table 2.5, the theoretical framework consists of four elements and each element consists of several categories. In the framework, the elements of people, process, and technology are proposed and justified by the importance of the three elements for successful implementation of technologies which is supported by many publications such as in Table 2.4 on page 49. In addition, Ruikar et al. (2006) introduced a management element to their Verdict model justifying the role of management to coordinate and manage the implementation of e-commerce. As they further identified, to successfully implement and use any new technology, management buy-in and belief is required in order to plan and drive policies and strategies which also shares a similar recommendation made by Smith & Tardif (2009), Eastman et al. (2008) and Elvin (2007). As Smith & Tardif (2009) further explained, management buy-in and leadership plays as a critical factor affecting the implementation of BIM within an organisation. The implementation requires total commitment from the management to lead the top down approach of BIM implementation, provide adequate support and resources, and to strategically align BIM

implementation with business needs. In addition, the authority to direct orders and make decisions also strengthens the need for the management category to be included. Meanwhile, the synthesis and justification of each readiness category are further discussed in chapter 5 rather than in this chapter to connect the logic of the data that were collected with literature validation and personal interpretation and also to avoid overlapping of the discussion.

It is important to mention that the approach of the research is not on developing the readiness framework theoretically and validating it through the case study. Instead, the proposed categories of assessments are used to guide the line of research inquiry and the development of the readiness criteria for the framework is based on the emergence of the exploratory data that is captured in the case studies. Therefore, the uses of the proposed categories are not rigid and dependable on the responses captured during the interview. As far as the research outcome is concerned, the readiness criterion which is explored and identified through the case studies becomes the main contribution of the research. The identified criteria would be fed into the theoretical framework for developing the conceptual framework which is discussed further in chapter 5. Meanwhile, it is also important to note that the readiness criteria are developed based on the BIM implementation requirement. Since the research is adopting GPIS model as the base line concept, to avoid confusion, the term readiness criteria is used across the research to reflect the BIM implementation requirement.

2.5 SUMMARY

The main objective of this research is to develop and validate an organisational BIM readiness framework for design consultants in Malaysia. In order to develop a better understanding of the concepts involved, to demonstrate some of the needs of the framework, and to identify an area of exploration for the use of data collection in the case study, a theoretical framework is proposed as can be seen in Figure 2.5, in the last paragraph of the subchapter 2.4.3. This chapter contributes to the research objectives by satisfying the following objectives:

1. To explore, appraise and synthesise relevant literature related to BIM with specific focus on the concept, usage, evolution, implementation requirement and success factor,
2. To explore, appraise and synthesise relevant literature related to readiness assessment with specific focus on the concept, currently available model and its component.

The next chapter (chapter 3) will introduce and discuss the research methodology used in this research. This research engaged a case study approach for the data collection, and the theoretical framework that is proposed in this chapter is used to guide the line of inquiry for data collection. The

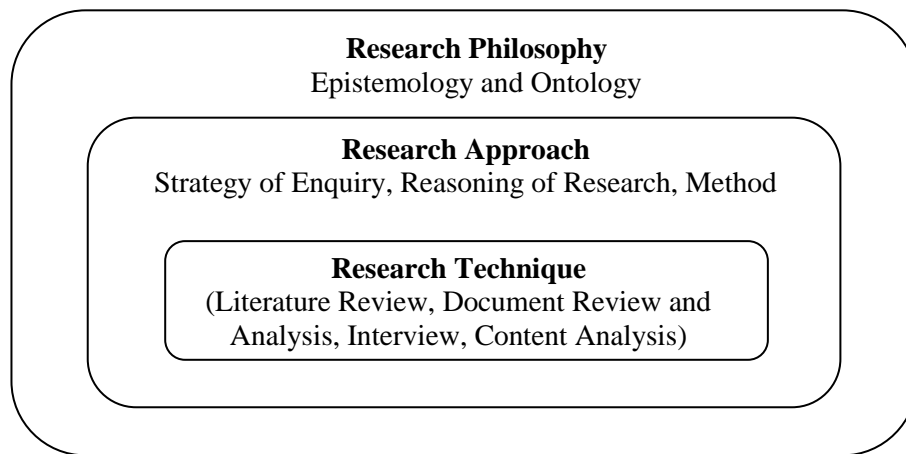
data collection strategy was therefore developed in accordance with the theoretical framework. In addition, the next chapter also discusses the framework validation approach that was used for this research. This research engaged workshop as a mean for the validation purpose.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter seeks to explore and discuss both the philosophical and methodological issues and research design and process flows associated with the case study research. Prior to proposing a research process framework, this chapter addresses the fundamental concept of case study research and the consideration needed with defining a case study. It discusses the considerations relevant to the researcher's decision to choose case study research as a preferred strategy which requires attention in various stages of the research process. The value of any research strategy, approach, or design lies in its potential for assisting the researcher to meet the aim and objectives of the research in the most effective and appropriate way possible. The case study is widely recognised in many social science studies, especially when in-depth explanations of a social behaviour are sought after. This chapter, therefore, discusses several aspects of case studies as a research method. These include the design and categories of case studies and how their robustness can be achieved. The importance of this chapter lies in the need to develop research strategies and process flows as it will outline the steps and all consideration needed to be given when collecting, analysing, and discussing the data and findings.

According to Fellows & Liu (2007), research methodology refers to the principles and procedures of logical thought process which are applied to a scientific investigation. Adam et al. (2007) further added that the research methodology consists of philosophy and science that support the investigation. In addition, according to Fellows & Lie (2007), research consists of a careful search and a systematic investigation contributing to the sum of knowledge. The research methodology therefore can be considered as the overall strategy used in the scientific investigation which consists of the component of philosophy, approach, and techniques.



*Figure 3.1: Nested research methodology approach
(adapted from Kagioglou et al., 1998)*

To better understand the component of research methodology, this research adapted the nested methodology approach introduced by Kagioglou et al. (1998) as it can assist in narrowing down and tying the research philosophy, research approach and research technique. As can be seen in Figure 3.1, the outer ring represents the unifying research philosophy, which guides and energizes the research approaches and research techniques. Research approaches consist of the dominant theory generation and testing methods whereas research techniques comprise data collection tools. The following section will discuss each layer of the nested approach in further detail. The subchapter for this chapter is therefore arranged in accordance to Figure 3.1 to ease the discussion. Meanwhile, Figure 3.2 on page 56 depicts the overall process flow of the research consisting of the main stages of research, the activities and their connection to support research objectives and aims.

3.2 RESEARCH PHILOSOPHY

According to Saunders et al. (2007), the research philosophy contains important assumptions about the way in which a researcher views the world. These assumptions will underpin the selection of research strategy and methods in pursuing the objectives. The main influence is the particular views of the relationship between knowledge and the process used to create it. Within the layer of research philosophy, the formation is made by two ways of thinking, namely epistemology and ontology.

According to Creswell (1994), in general, epistemology is the technical term for the theory of knowledge where it describes ‘how’ a researcher knows about the reality and assumptions about how knowledge should be acquired and accepted. It concerns with what constitutes acceptable knowledge

in a field of study. Within this domain, according to Easterby-Smith et al. (2002), two philosophical paradigms have dominated debate in the social science research. They are Positivism which suggests the use of quantitative experimental methods to test hypothetical-deductive generalisation; and Interpretivism which suggests the use of qualitative and naturalistic approaches to inductively and holistically understand and explain a phenomenon. According to Creswell (2009), the Interpretivism aim is to increase the general understanding of the subject of research in which the research progresses through gathering rich data from which ideas are induced. In addition, according to Easterby-Smith et al. (2002) the interpretivist focuses on the ways that people make sense of the world, especially through sharing their experiences with others via the medium of language. As for this research, since the data collection objective was exploratory in nature as it required the researcher to explore and identify the readiness criteria for BIM implementation, the research falls mainly within the interpretivism paradigm. The reason was because the research required the researcher to understand, explore, and elicit opinions and views and perceptions from the top and middle level management of each company. In addition, the interpretivism paradigm allows the researcher to get richer and deeper understanding of the justification and rationale made by each interviewee regarding each readiness criteria that they identified. Their justifications were important in assisting the researcher in making sense of the data during the analysis stage.

Meanwhile, Ontology according to Saunders et al. (2007), is concerned with the nature of reality. There are two aspects of ontology: Objectivism, which portrays the position that social science entities exist in reality external to social actors concerned with their existence; and subjectivism, which holds that social phenomena are created from the perceptions and consequent actions of those social actors concerned with their existence. Basically, it explains ‘what’ knowledge is and assumptions about reality (Cresswell, 1994). As Remenyi et al. (1998) further suggest, it is necessary to study the details of the situation to understand the reality or perhaps a reality working behind them. It was suggested that it was necessary to explore the level of BIM implementation within the organisations involved in the case study since the readiness criteria that was used to develop the readiness framework depends on the reality of the implementation.

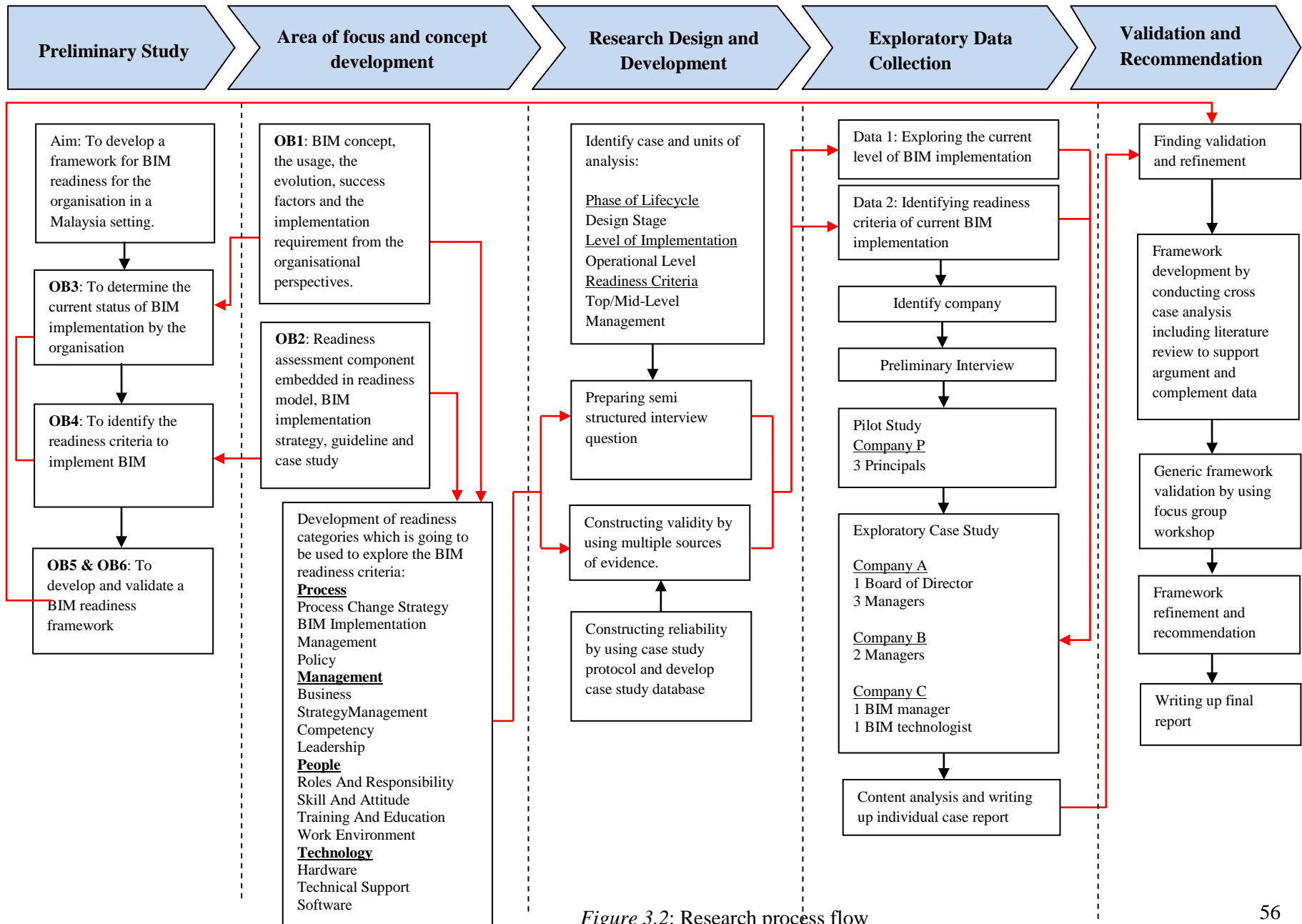


Figure 3.2: Research process flow

3.3 RESEARCH APPROACH

Within the layer of research approach, there are three embodied elements. The first element is strategies of enquiry (Creswell, 2009), which refers to the types of qualitative, quantitative and mixed method designs or models that provide specific direction for procedures in a research design. The second element is the reasoning of the research (Sutrisna, 2009) which refers to the logic of the research, the role of an existing body of knowledge gathered in the literature study, the way researchers utilise the data collection, and subsequent data analysis. The third element is research method that involves the forms of data collection, analysis, and interpretation that the researcher proposes in the study (Creswell, 2009).

3.3.1 STRATEGY OF ENQUIRY

Saunders et al. (2002) argue that in selecting the appropriate strategy of enquiry, one research approach is better than another. Each strategy is better for performing different things and the selection of the most appropriate one depends on the research questions that need to be answered. Jankowicz (2000) however, suggested that choosing one type of strategy over another ultimately hinges on the objectives of the study. In addition to research questions, the arguments for and against the use of each research approach suggest that theories can also be used to determine which methodology will be most appropriate for a particular research. Saunders et al. (2007) suggested that if the researcher understands the phenomena underlining the study well enough and aims to develop a theory about factors influencing particular phenomena and to explore the setting further, a qualitative approach is more suitable. Furthermore, one goal of qualitative research may be the identification of variables affecting the phenomenon under study (Creswell, 1994). Both the quantitative and qualitative methods are concerned with exploring phenomena (Mack et al., 2005). However, qualitative analysis is primarily concerned with understanding an individual's perceptions of certain phenomena based on an in-depth and insightful investigation and analysis, while the quantitative approach is concerned with issues such as "how much" and "how many" and seeks to document occurrences passively (Bell, 2005). Because qualitative research is an inherently exploratory undertaking, the potential for generating new theories and ideas is significant. Amaratunga et al. (2002) further strengthens this stance. Quantitative data, on the other hand, is most valuable when hypotheses and theories have already been established and are being evaluated (Saunders et al., 2007; Fellows & Liu, 2007).

As discussed earlier, this research adopts the readiness concept to develop a framework which could assist organisations in assessing their readiness towards BIM implementation. The critical element of

the research is firstly to understand the level of BIM implementation within the business process of a chosen organisation. Also mentioned in the aims and objectives, to tackle this element, is the exploration needed to be carried out on what application is used within the business process and how the organisation is currently using it. Subsequently, the readiness criteria are identified by using a set category that was developed from the literature review. Within this context, the research addresses the question of the reason for assessing the application used by the organisation and readiness criteria, and how to understand the use of BIM within an organisation business process. As the question addresses the ‘what’ and ‘how’ questions, it makes the research exploratory in nature and according to Creswell (1998), the research question with inquiry of ‘how’ and ‘what’ can be classified as qualitative. It therefore positions the research in the category of qualitative, which eradicates the selection of quantitative and mixed methods approach. Another element that should be discussed is that the ‘what’ and ‘how’ questions posed in the research are also explanatory because they seek for the justification and explanation of BIM implementation within the organisation business process and the readiness criteria of the implemented system. Even though a set of readiness categories have been developed from the literature review, it serves as a guide for research line of inquiry where each category carries no content at the beginning of the research. The readiness criteria are developed through the analysis and conceptualisation of the data collected. In addition, according to Daymon & Holloway (2003), qualitative research is a form of social inquiry that focuses on the way people interpret and make sense of their experiences and the world in which they live. It seeks to gain insights and to understand people’s perception of world views whether as individuals or groups (Fellows & Liu, 2007), which brings us to the next justification of why the qualitative approach is chosen. The main source of data collection is people/respondents, and through their experience, thought belief and understanding, readiness categories and its criteria are modified and developed.

3.3.2 REASONING OF RESEARCH

For the reasoning of the research, according to Saunders et al. (2007), there are two different approaches, namely: deductive and inductive. The deductive research tends to move from theory to data while the inductive research tends to move from data to theory. In conducting research, the deductive approach tends to develop a theory and hypotheses through literature reviews, and the research strategy is designed to test the hypotheses. Meanwhile, the inductive approach tends to collect the data first and the theories are developed as a result of the data analysis. To describe the major differences between the deductive and inductive types of research reasoning, Saunders et al. (2007) suggested the following, as can be seen in Table 3.1:

Table 3.1: Major differences of emphasis between deductive and inductive approaches to research (Saunders et al., 2007, p.120)

Deduction emphasis on...	Induction emphasis on...
<ul style="list-style-type: none"> a) scientific principles b) moving theory to data c) the need to explain causal relationships between variables d) the collection of quantitative data e) the application of controls to ensure validity of data f) the operationalisation of concepts to ensure clarity of definition g) a highly structured approach h) researcher independence of what is being researched i) the necessity to select samples of sufficient size in order to generalise conclusions 	<ul style="list-style-type: none"> a) gaining an understanding of the meanings humans attach to events b) a close understanding of the research context c) the collection of qualitative data d) a more flexible structure to permit changes of research emphasis as the research progresses e) a realisation that the research is part of the research process f) less concern with the need to generalise

Saunders et al. (2007) suggest that even though there exists a rigid division between deduction and induction, it is possible however to combine them both within the same piece of research. In fact, based on their experience, the combination of both within the same piece of research is often advantageous. According to Creswell (1994), a topic on which a wealth of literature is available from which a theoretical framework and hypotheses can be defined, lends itself more readily to deduction since the topic has enough literature to support and justify the content of a theoretical framework. With research into a topic that is new and exciting, has much debate, and on which little literature exists, it may be more appropriate to work inductively by generating data and analysing and reflecting upon what theoretical themes the data is suggesting. Relating to this research, two areas of research exist; namely the ICT readiness and BIM implementation. A wealth of literature discussing the ICT readiness has made it possible to conduct a deductive reasoning by identifying the element and category of ICT readiness that are embodied in the literature source. As a result, a theoretical framework is proposed by reviewing eight readiness models through literature review as can be seen in chapter 2, Table 2.4, Summary of readiness assessment model, on page 49. In addition, the categories outlined in the investigation scope and the research can be focused on specific relevant areas without going too broad for investigating the subject matters during the case studies. The scope and focus is important in justifying the cost and time constraints of the researcher to conduct the research.

On the other hand, the context specific to BIM implementation, especially within a Malaysian context however, suffers from a limited literature source in addition to the nature of BIM topic which is quite new. Consequently, it did not allow readiness criteria to be developed deductively. Therefore, in identifying the readiness criteria to fit into the proposed category of theoretical framework, a deductive approach was engaged. The deductive approach has also allowed richer and deeper information to be gathered and thus increase the researcher's understanding. Furthermore, the inductive approach positions the research in a more natural setting where respondents are free to provide their response since the predefined index is absent (Yin, 2009). In this context, the situation in which respondents are influenced by a set of indexes could also be avoided.

3.3.3 RESEARCH METHOD

This research engages two types of qualitative research methods depending on the purpose of research inquiry. The first one is an exploratory case study which serves the purpose of collecting case study data for identifying the readiness criteria. Once the readiness criteria were identified for each case, a cross comparison findings was conducted to determine the pattern of findings. Succeeding that, by theoretically validating the pattern with a literature review, a conceptual framework was proposed. As the conceptual framework was as good as limited only to the organisations involved in the case studies, therefore a more general validation was required and led to the second approach of research, which was a workshop. The workshop served the purpose of validating the conceptual framework by involving broader participants from a few companies.

3.3.3.1 Case Study Research

Within this subchapter, two important components are discussed. The first one is the justification of the case study, which seeks to justify the suitability of selecting multiple case studies as a research method, while the other one is to discuss the criteria that was defined in selecting companies for case studies.

3.3.3.1.1 Justification of Case Study Research

To justify the selection of case studies as the research method, Fellows & Liu (2007) suggest that specifically for construction, there are five methods that can be considered, and they are action research, ethnographic research, surveys, case studies, and experiments. The critical consideration is the logic that links the data collection and analysis to yield results and thence conclusions to the main research question being investigated. Therefore, it was suggested that the research design must take into account the research questions, determine what data is required and how the data is to be

analysed (Creswell, 2009). As the research is positioned within a qualitative approach based on the research questions posed, the options that were available are action research, ethnographic research, and case studies. This research however, opted to choose case study as a research method.

Table 3.2: Justification of selecting research method (Yin, 2009, p.8)

METHOD	Form of Research Question	Requires Control of Behavioural Events	Focuses on contemporary Events
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much	No	Yes
Archival Analysis	Who, what, where, how many, how much	no	Yes/no
History	How, why?	No	No
Case study	How, why?	No	yes

By referring to the guide as given by Yin (2009) which can be referred to in Table 3.2, the selection of case study as the research method was strengthened by the following justification:

a) *The type of research question posed.*

As discussed previously in the research approach, this research poses the question of ‘what’ and ‘how’ in an exploratory way. The questions posed deal with operational links needing to be traced over time rather than mere frequencies or incidence (Yin, 2009). Aimed at developing a readiness framework based on theoretical framework, it explored and modified the framework once the data was collected.

b) *The extent of control an investigator has over actual behavioural events.*

Describes the degree to which the researcher can manipulate the behaviour of the subject, for example by giving or withholding motivators (Yin, 2009). Within this context, the options available were reduced to histories and case studies since the researcher had no control over the implementation of BIM by the organisation, condition of respondents during data collection, or any policy engaged within the organisations that were investigated.

c) *Focuses on contemporary events.*

In this justification, the only difference between history and case study is that histories are dealing with data of dead past where no relevant persons are alive to report, even retrospectively, what occurred (Yin, 2009). Therefore it requires an investigator to rely on primary documents, secondary documents, and cultural and physical artefacts as the main source of evidence. Case studies, on the other hand, besides utilising the same evidence, add two more sources of evidence: direct observation of the events,

and interviews of the persons involved in the events. Therefore, it justified the need of selecting case studies as the research method for data collection as the researcher managed to utilise the two sources of evidences.

In addition, according to Saleh & Alshawi (2005) a case study is the most appropriate investigation method for determining the criteria for readiness assessment model of ICT implementation as compared to the survey. Case studies present the information in the context of a particular organisation, inclusive of the characteristics of the organisation and give actual data. Experimentation and surveys are ineffectual because the implementation of a new system has variables and factors that cannot be extracted out of the original context. Furthermore, in determining the readiness criteria for IT implementation, it involves the understanding of the organisations' business process, perception of people and unique work environment subjective to the organisation.

3.3.3.1.2 Selection Criteria for Each Case

As for the number of cases for selecting case studies, according to Tzortzopoulos (2004) there is no consensus in the appropriate number of cases which need to be developed when engaging in a multiple case study approach. According to Yin (2003), a selection of cases should be dictated by the replication of logic. Each case should be considered as an experiment in itself, and subsequent cases will be used either to confirm or refute previous findings, and as a consequence, according to Saunders et al. (2007), direct the need to generalise from these findings. Therefore, the decision on the number of studies is intuitive and depends on what new information or insights that can be collected by studying further cases (Dyer et al., 1991). The case studies in this particular research are selected for the researcher's expectation on yield similarity results (literal replication). This is also supported by Eisenhardt (1989), as the cases may be chosen to replicate previous cases or extent emergent theory, to fill theoretical categories and to provide examples of polar types of result. Careful but rigid selection of cases is also important to ensure enough information is obtained by the researcher in order to generate the final conclusion at the end of the study.

The selection of cases is based on the aim and objectives of the research and the research context and simplified as following:

- a) The type of organisation is a Malaysian design consultant. Therefore, the organisation must have registered with Construction Industry Development Board (CIDB)'s registration scheme, or Association of Consulting Engineer Malaysia or Malaysian Institute of Architect.
- b) The organisation must currently be implementing BIM within the business process.

- c) The primary BIM technology used by the organisation should be the 3D parametric authoring tools.
- d) The organisation must also be willing to cooperate and provide access to the researcher to acquire data.

As BIM is currently becoming the buzz word among the construction industry, an assumption was made prior to the research investigations that a few organisations are taking BIM as potential business marketing, which led to the claims of implementing BIM, although their statuses were arguable. Many publications recognise the use of 3D parametric tools as the primary technology for BIM (Eastman et al., 2008; Smith &Tardif 2009; Elvin 2007; Construction Project Information, 2009; National Institute of Building Science, 2007). Therefore, the selection of the organisations were made based on the use of 3D parametric tools applications, to avoid the marketing claim issues in addition to limit the research scope. To identify the company which at least, has started implementing BIM, a few techniques were engaged:

- a. The local jobs advertisement on the webpage or newspaper that offer a BIM related post such as BIM manager, Revit Designer, etc.
- b. Direct communication with BIM tools providers such as Tekla and Revit to request a list of their clients.
- c. Attending a local BIM seminar and directly approaching the speaker and participants.
- d. Attachment and collaboration with Construction Research Institute of Malaysia (CREAM), for Construction Industry Development Board of Malaysia (CIDB). In the informal collaboration, the researcher was allowed to use their resource and networking. In the informal collaboration with CREAM, the researcher was given a workstation to conduct the research during the time spent at Kuala Lumpur. In addition, the researcher was also granted permission to use their letterhead for correspondence matters. The letterhead was so important to penetrate access to the organisation, justifying the authority and image CIDB has in Malaysia.

Ten companies were identified and through the company's webpage, internal contact, and CREAM networking database, contact numbers and email addresses were obtained. Applications for conducting preliminary interviews were then requested via phone calling, emails, and formal application letters. Out of ten companies, six positively responded to the request. A preliminary interview is a process where the researcher attempts to get a brief picture regarding the current

implementation of BIM within the company. The same question set for data collection was used but with different purposes, which are:

- a. As part of screening process: To make sure the company has fully/partially implemented BIM within their business.
- b. As part of refining the interview question: To get a brief picture of the company. This information helps to identify related questions that suit the company level of BIM implementation.
- c. As part of research strategy: To develop trust and credibility so that the researcher could gain access to carry data collection.

Based on the interviews that have been conducted, there were only 5 companies currently using BIM or starting the implementation process. One of the companies however gave a low level of willingness to share information, thus reducing the number of companies to four, as following:

Company P: Company P is the pilot case used for this research. The company is a BIM management consultant providing bespoke and value added solutions to the client. The services include consultation regarding the use of BIM, service as a BIM manager, delivering 3D process and deliverable for multidisciplinary professionals such as 3D architect models, Structural Model, MEP services model and coordinating clash detection and resolution. BIM has been used within the company since 2009 by delivering a pilot project and utilising Autodesk product line namely Revit Architecture, Revit Structure, and Naviswork.

Company A: Company A is an oil and gas engineering consultant providing a complete design service to the oil and gas and petrochemical industry. The company was selected due to the fact that it has been implementing BIM successfully since 1995. In this way, it provided richer evidence on identifying the readiness criteria over a long period of time. The company's services cover primarily the area of design engineering of offshore oil and gas production and processing facilities, design engineering of onshore receiving facilities and loading terminals and deliver turnkey Engineering, Procurement, Construction, and Commissioning (EPCC) projects of facilities. The company is a one stop design engineering consultancy where the technical area consists of seven departments which are Project Management, Process, Instrument, Pipeline, Electrical, Mechanical and Structural. The use of BIM within the business process has commenced since 1995 through the use of Aveva Plant Design Management System (PDMS) and BOCAD within the Mechanical and Structural departments respectively.

Company B: Company B is an Industrialised Building System (IBS) Specialist delivering design and construction for precast building and facilities. The company provides a one stop service centre for precast projects where it has internal departments for delivering precast design engineering, civil engineering, mechanical engineering, manufacturing and also project management and building assembly. The use of BIM is not yet fully implemented but has just started the pilot implementation on one project.

Company C: Company C is an integrated property development company involved in property development, asset management, hospitality, and leisure. The company has finished a BIM pilot project. The project aims at testing the BIM technology and process during the design stage and producing BIM standards and manuals to be imposed on every consultant involved in their future projects. As part of the effort, the company has set up a temporary design division which consists of architect, structural engineer, and mechanical engineer.

3.3.3.2 Pilot Case

According to Yin (2009) a pilot case study will help to refine data collection plans with respect to both the content of the data and the procedure to be followed. The use of a pilot interview with regards to this research was to make sure the researcher made the right inquiries which reflect the specific condition of the company. The use of preliminary interview has also served the purpose. However, as part of the research procedure, a pilot interview study was also conducted at company P. It is important to note that Company P is quite different in the nature of its business as compared to the other three companies which deliver design as part of their main business which is either architecture, structure, mechanical or combination of these. Company P on the other hand focuses on two scopes of businesses which specifically focus on BIM; to be directly involved in a project as an integrated design consultancy to design, produce and manage Building Information Models and associated processes, and as a BIM implementation consultancy to assist architectural, structural and integrated design firms to implement BIM within their organisation. The latter has justified the selection of Company P as a pilot case. The justification lies on the experience of the company in assisting any organisations to be a BIM capable organisation in which suits the need of the research. Consulting various companies as an independent consultant also provides an extra advantage to select them as they have a generic idea or bird's eye view of what works and what may not work in implementing BIM. In addition, their bird's eye view was also important as it enabled them to comment the suitability of the interview questions as far as the terms and language were concerned. Since some parts of BIM are technical and at the same time most of the companies in Malaysia are

still at the infancy stage of BIM implementation, the alignment between the technical terms and their level of BIM understanding are therefore important in getting the right data. The alignment could only be done by consulting a company that is familiar with the situation and therefore Company P was chosen. Based on the pilot study, the researcher found that all of the questions posed were understood and easy for the interviewee to respond to.

In addition, the use of a pilot case is also needed to get an early exposure of the research process so that the research strategy can be refined. According to Yin (2009), the pilot study helps to refine the data collection plan with respect to both the content of the data and the procedure to be followed. In this regard, the pilot test is not a pre-test. The former is more involved with formatting and providing some conceptual clarification for the research design whereas the latter is more like a dress rehearsal. From the methodology perspective, a pilot study has provided some conceptual clarification for the research design. It gives explicit lessons learned for both research design and field procedures (Yin, 2009). From the pilot study experience, the researcher had anticipated problems regarding data shortage and limited access to Company P due to the nature of construction business which involves many participants and the possession of unclear project information belonging to which company. Therefore, to play safe, company P opted not to discuss the project in detail, especially when it comes to the characteristics of the project. Based on the pilot case, limitation of access in the company had been well expected in the case study research. The researcher would expect that in some future cases the respondents might refuse to participate and the researcher might rely on secondary data instead. The possibility of the researcher being unable to make a repeat visit to the company is also well predicted.

Also, as the research is dealing with management issues of the companies, the key to success for the case study lay in careful selection of respondents. It had been learned during the pilot case that the quality of the respondents is more critical than quantity in obtaining good detailed information from relevant personnel. The selected respondents should have possessed imperative knowledge and understanding on the company policies and processes. In addition to the preliminary interview to mitigate these problems, the researcher also obtained a support letter from the Construction Industry Development Board (CIDB), which the researcher was collaborated with. This supporting letter improved access to the company cases due to an increased level of trust. The researcher was also very careful in selecting interview respondents. The researcher interviewed the top and middle management of each company, whenever possible. Through this strategy, though the number of respondents was limited, the researcher should be satisfied with the respondents' level of knowledge.

The researcher, however, was fully aware of the issue of respondent's bias. The findings from the case studies were therefore further validated with the industry focus group.

3.3.3.3 Focus Group Workshop

According to Krueger & Casey (2000) a workshop technique is considered to be a useful and effective data collection as it provided a conducive platform for making sense of the various concepts. The workshop is considered to be a highly efficient technique for qualitative data collection since the amount and range of data is increased by collecting from several people at the same time (Robson, 2004). In addition, the focus group workshop is the most appropriate and effective in obtaining information, insight, experience, and knowledge of a large group of industry players in the shortest period of time. By adopting a workshop as an approach for understanding and facilitating BIM adoption in the AEC industry, Gu & London (2010) recognise that the workshop also provides a forum for the different disciplines within the AEC industry to share and clarify their views on various BIM adoption issues such as common understanding of benefits, hurdles, requirements, and expectations of BIM.

The approach of focus group workshops is similar to focus group interviews. However, the workshop involves activities along with responses to the set of questions as seen in Marshall-Ponting & Aouad (2005), Lee et al. (2003) and Sacks et al., (2010), Howard & Bjork (2008) and Gu & London (2010). The type of activities involved varies from one workshop to another depending on the purpose of the workshop. Marshall-Ponting & Aouad (2005) for instance, in investigating nD modelling approach to improve communication processes for construction, were using the provision of a case study scenario workshop to obtain discipline-specific knowledge and to establish what some of the similarities and conflicts in the design requirements would be. In doing so, this would start determining the level of communication differences, conflicts, and potential problems. Howard & Bjork (2008) in investigating the expert views on standardization and industry deployment for BIM, used a workshop which was attended by six leading international BIM experts, while Sacks et al., (2010), used three focus group workshops to evaluate the visual interfaces for BIM-based construction management systems. Langford & McDonagh (2005) argue that many examples of projects have incorporated aspects of focus group methods, but are described differently, for example, discussion groups, Design Decision Groups, group meetings and user workshops. This is partly because the term 'focus group' has only recently become widespread in the media, and many of these methods pre-date this. According to Saunders et al. (2007), 'group interview' is a general term to describe all non-standardised interviews conducted with two or more people, and the term 'focus group' is used to

refer to those group interviews where the topic is defined clearly and precisely and there is a focus on enabling and recording interactive discussion between participants.

As for this research, the focus group workshop is the most appropriate and effective way of obtaining information, insight, experience and knowledge of a large group of industry players in the shortest period of time. It produces data from a real-life situation and provides better details on the behaviour of the subject. It also become a platform for generalisation and method triangulation. The main purpose of conducting a workshop was to evaluate and validate the proposed conceptual BIM readiness framework from the perspective of key Malaysian BIM experts and executives. This method of data collection is believed to assist in revising and modifying the proposed conceptual framework for the successful implementation of BIM.

3.4 RESEARCH TECHNIQUE

This subchapter discusses three main research techniques that were used to complete the research with the focus of justifying the use of each technique. The research techniques were correlated to each other and they are the literature review, in-depth semi-structured interview and focus group workshop, data collection and validation technique, and finally data analysis technique which used content analysis for qualitative data and quasi Average Index analysis for quantitative data.

3.4.1 LITERATURE REVIEW

This research engages two stages of literature review. The first stage of the review carries two purposes as following:

- c) As a starting point of the research, the first stage literature review was conducted to form knowledge of the current issues in the construction industry and subsequently to identify the research problems and form the research aim and objectives as discussed earlier in this chapter.
- d) After the aim and objectives were identified, a more detailed literature review was conducted on the subject matter to form knowledge regarding BIM and readiness assessment model, concentrating on the theoretical and fundamental concepts. It was directed to develop a theoretical framework for organisational readiness for BIM implementation.

Meanwhile, the second stage of the literature review concentrates on making sense, justifying, and theoretically validating the research findings. Therefore, it was conducted and positioned after the data collection and analysis were made, as can be seen in chapter 5.

The first stage of literature review was to form knowledge of the current issues in the construction industry and subsequently identify the research problems and form the research aim and objective. Through the literature review, it is discovered that fragmentation and drawings are associated problems among the major problems occurring in Malaysia. Currently, the use of BIM is identified as a potential solution. The problems however arise on the readiness of the organisation to implement BIM which leads to the formation of research aims and interrelated objectives as has been discussed in chapter 1.

The objective that has been outlined has also demanded a more detailed literature review to be conducted within the first stage of the literature review. The need is to form knowledge regarding BIM and readiness assessment model, concentrating on the theoretical and fundamental concepts. It was directed to develop a theoretical framework for organisational readiness for BIM implementation. The use of the theoretical framework is pertinent to help the researcher prepare the data collection strategy and interview questions by outlining the important areas that need to be investigated or explored. According to Saunders et al. (2007), the literature review provides the foundation on which the research is built and the main purpose is therefore to assist in developing a good understanding and insight into relevant previous research and the trends that have emerged. As they further recommend, the precise purpose of reviewing literature depends on the research reasoning, where for some research, the literature is used to help identify theories and ideas which will be tested later using data. This is known as deductive approach while on the other hand, some pieces of research are planned to explore data and develop theories from them that will subsequently relate to the literature, known as inductive approach. As for this research, both purposes of literature are engaged. The deductive approach involves the literature review as being pertinent to the topic under investigation by exploring, appraising, and synthesising relevant literature related to BIM with specific focus on the concept, usage, evolution, implementation requirements and success factors readiness assessment with specific focus on the concept, currently available model and its component. According to Jankowicz (2000), the literature review provides a description and critical analysis of the current state of knowledge in the subject area. In addition, the literature review justifies any new research through coherent critics of what has gone before and demonstrates why the research is important (Gill & Johnson, 2002). As a result, from the literature review, a theoretical framework which consists of readiness element and categories was proposed as can be seen in

chapter 2, on page 49. The 17 categories of the framework are not intended to be tested during the case study but rather set as an area of exploration to collect the data by identifying the readiness criteria.

Meanwhile, as an inductive approach was engaged during the case study, the second stage of the literature review was used to support the approach of the qualitative data by relating the data with the literature review to make sense, justify and theoretically validate the research findings of the case studies. Therefore, it was conducted and positioned after the data collection and analysis were made. The initial theoretical framework which consists of 17 readiness categories was fed with 38 readiness criteria accordingly, which beforehand were identified and justified after the data collection and analysis were completed. As a result, a conceptual framework was developed as can be seen in chapter 5, on page 199.

3.4.2 DATA COLLECTION TECHNIQUE

In collecting the data for the research, Yin (2003) identified six primary sources of evidence with their strengths and weaknesses, which can be used for case studies, as shown in Table 3.3. These sources of evidence have initially provided the checklist for this research regarding source of information to be collected. According to Stake (1995) and Yin (2003), not all sources are essential in every case study but the importance of having multiple sources of data lies on the grounds of the reliability of the study.

Table 3.3: Types of case study evidence (Yin, 2007, p.102)

Source of Evidence	Strengths	Weaknesses
1. Documentation	<ul style="list-style-type: none"> • stable - repeated review • unobtrusive - exist prior to case study • exact - names etc. • broad coverage - extended time span 	<ul style="list-style-type: none"> • retrievability – difficult • biased selectivity • reporting bias – reflects author bias • access - may be blocked
2. Archival Records	<ul style="list-style-type: none"> • same as above • precise and quantitative 	<ul style="list-style-type: none"> • same as above • privacy might inhibit access
3. Interviews	<ul style="list-style-type: none"> • targeted - focuses on case study topic • insightful - provides perceived causal inferences 	<ul style="list-style-type: none"> • bias due to poor questions • response bias • incomplete recollection • reflexivity - interviewee expresses what interviewer wants to hear

4. Direct Observation	<ul style="list-style-type: none"> • reality - covers events in real time • contextual - covers event context 	<ul style="list-style-type: none"> • time-consuming • selectivity - might miss facts • reflexivity - observer's presence might cause change • cost - observers need time
5. Participant Observation	<ul style="list-style-type: none"> • same as above • insightful into interpersonal behaviour 	<ul style="list-style-type: none"> • same as above • bias due to investigator's actions
6. Physical Artefacts	<ul style="list-style-type: none"> • insightful into cultural features • insightful into technical operations 	<ul style="list-style-type: none"> • selectivity • availability

According to Yin (2009), the selection of the technique depends on the level of assessment the investigator could have in capturing information since some of the evidence such as acquisition records can be confidential, and the willingness to share some documents and thoughts is beyond the control of the researcher. Therefore, the interviews and direct observation during the case studies visit are treated as the main data collection techniques for the case study. Other sources of evidence were also attempted but rather treated as secondary evidence justifying the difficulty to get assessment and to keep a copy.

According to Esterby-Smith et al. (2002), the in-depth semi-structured interview is the most fundamental of qualitative methods. The interviews allow interviewee's experiences, knowledge, ideas and impressions to be documented (Alvesson, 2003) and provide an opportunity for the researcher to uncover new clues and open up new dimensions of a problem (Yin, 2009). According to Robson (2002), semi-structured interviews have predetermined questions but the order of the questions can be modified based on the interviewer's perceptions of what seems to be most appropriate. According to Yin (2009), many factors sometimes affect the interviewee's responses to the interview such as the environment where the interview is conducted, the readiness of the interviewees themselves to be interviewed and the perception of the interviewee of the researcher and thus require the researcher to be flexible and adaptable to suit the situation and needs. By posing questions flexibly and suiting oneself to these conditions, the interview can have a general purpose and focus, but also can be sufficiently flexible to explore emerging issues (Robson, 2002).

All interviews in this research had an exploratory and explanatory nature as it gave a focus to the interview, allowing the researcher to be flexible in exploring emerging issues. The interviews were carried out in a quiet, comfortable, and interruption-free setting, either in meeting rooms or the interviewees' offices, except for Company C. All the interviews were audio recorded and transcribed

verbatim for analysis. The use of an audio recorder is not only done to increase the accuracy of data collection but also permits the interviewer to be more attentive to the interviewees. When the interviews were being recorded, the interviewer also took strategic and focused notes, but not verbatim. The supplementary notes helped the interviewer to formulate new, appropriate questions, stimulate early insights for subsequent interviews before transcribing, facilitate later analysis, and provide a backup for the recording. The question list for the interview was emailed to the potential interviewees a few weeks in advance to offer enough time for the participants to think about the issue and make the interview more effective. Before the interviews, all the interviewees had been briefed on the audio recording and its purpose for the study in advance. Interviewees were ensured that they were comfortable being recorded, for ethical purposes. The interviews questions were also kept short and brief to ease the interviewee to respond. The researcher has also attempted to acquire a documentation source of BIM implementation such as implementation plan, standard operating procedure, training guide, investor report and many more. However, the written evidences were treated confidential by all of the companies. Only a few written evidences managed to be collected and the utilisation of the evidence, as requested by the interviewee, must be restricted to the use of the thesis only.

As for the focus group workshop for validating the conceptual readiness framework, the research was aware of a tight time constraint to validate the total number of 38 readiness criteria. As Marshall-Ponting (2006) recommended, the use of fixed response set for voting not only could contain the number of options presented by the workshop participants, the response gained, which is empirical in nature, could highlight the consensus level very clearly. Therefore, the readiness criteria set was prepared in a questionnaire form (Appendix 3.0) to ease capturing the workshop participant's view. By referring to the questionnaire forms in Appendix 3.0, for each readiness criteria, the workshop participants were asked to indicate the level of importance and level of the participants' organisation's current capability. Each level carries a 5 Likert scale value. For the level of importance, the value 5 indicates Highly Important, 4 indicates Important, 3 indicates Neutral, 2 indicates Not Important and 1 indicates Very Unimportant. Meanwhile for the level of capability, letters were used instead of a numbering system where E stands for Highly Capable, D stands for Capable, C stands for Neutral, B stands for Not Capable and lastly A stands for Very Incapable. The use of alphabetical letters to replace the numbering system is to avoid confusion with the level of importance value. It is worth mentioning that prior to the workshop being conducted, the questionnaire form was reviewed by 3 industrial players to make sure it was easy to understand. The players were all satisfied with the selection of words used for describing the readiness criteria but all of them were confused when the same numbering system was initially assigned to the level of

capability. Consequently, the level was changed into an alphabetical system. As for validating the readiness criteria qualitatively, the workshop participants were distributed into three groups and were required to discuss the justification on the importance of each readiness criteria, and prior to the end of the validation session, the group representatives were asked to present the findings. It is important to note that the use of a questionnaire is to make it easy for the participants to respond, guide the area of discussion, and complement the qualitative data. The main data for validation lies in the group discussion and presentations. In each group, one person was assigned (the workshop secretariat member) to assist in capturing the points and preparing the presentation slides. Also, a Dictaphone was used in each group to capture the discussion. In the workshop, the researcher was involved as a workshop moderator to assist the running of the session and respond to questions that arose.

3.4.3 DATA ANALYSIS TECHNIQUE

According to Yin (2007), data analysis involves examination, categorisation, tabulation, or otherwise recombining the evidence to address the initial propositions of a study. Most researchers need to rely on experience and the literature to present the evidence in various ways, using various interpretations. This becomes necessary because statistical analysis is not used in all case studies.

For data collection, the theoretical framework that was proposed during the literature review was used to develop the case study protocol. The case study protocol is a set of semi-structured interview questions used throughout the case study and is very significant for multiple case studies. Besides increasing the reliability of the case study data, it guides the data collection through a pattern-matching method. Pattern matching links the data to propositions whereby several pieces of information from the same cases may be related. If the pattern matches, the internal reliability of the study is enhanced. It is important to understand that this work developed the concept and framework by making data induction from the case and does not begin with a theory to test or prove. The theoretical frameworks which consist of readiness category, besides guiding the research line of inquiry, has also helped in preparing an initial category for pattern matching used in the data analysis. The approach follows a recommendation by Eisenhardt (1989) which stated that the patterns within cross-case studies are constructed from the literature, and then look for within-group similarities and inter-group differences. He further argues that the cross-case analysis should preferably be used for searching patterns, and three tactics are suggested as following:

- Select categories and look for within-group similarities coupled with inter-group differences.
- Select pairs of cases and list the similarities and differences between each pair.

- Divide the data by data source to exploit unique insights possible from different types of data collection.

Therefore in this research, the categories were based on the readiness categories that were identified during the literature review (the theoretical framework) and the case study data for readiness criteria was analysed to fit into the categories. In the case where no categories seem to fit, a new category would be introduced. Furthermore, Company A as the most complete case, was selected as a control case to determine similarities and differences derived from all other cases.

In addition to data analysis, most researchers need to rely on experience and interpretation of data from interviews and the literature to present the evidence in various ways. This becomes necessary in the situation where statistical analysis is not used in the analyses. Content analysis is a methodology in the social sciences for studying the content of communication. According to Manning & Cullum-Swan (1994), the technique can involve any kind of analysis where communication content is categorised and classified. Content analysis involves quantifying oriented techniques by which standardised measurements are applied to metrically defined units and these are used to characterise and compare the documents. The classification depends on identification of a group of words with the same meaning or connotation (Webber, 1990). The transformation of data into text involves reducing the data collected into a manageable, informative database. Strategies are taken to ensure that the quality of data is not lost during the process.

As for this research, the case study data was analysed by using the content analysis technique. The content analysis that was carried out for the interview was done to ascertain a pattern of responses amongst the participants according to the predefined category. The analysis of interviews began with the intra-case analysis of each case and was followed by cross-case analysis for all organisations involved. Intra-case analysis was concerned with individual analysis of cases based on multiple sources of evidence. The analysis aimed at gaining evidence as much as possible to identify the readiness criteria. The cross-case analysis was carried out to compare the findings from all case studies. It was undertaken simply by comparative analysis of data and information gathered during the data collection method. The comparative analysis analysed literal replication between cases and help the researcher to understand the differences and similarities of each case. Throughout the cases, the answers from different people to common questions or their analysis of different perspectives on central issues were grouped together as suggested by Patton (1990). The answers were classified in the context analysis on the issues, and were still based on the predefined categories which form the

literature. Subsequently, the emergent readiness criteria were theoretically validated by using the literature source, and a conceptual framework was proposed.

All interviews and workshops were audio recorded where allowed and suitable. Recordings were transcribed verbatim for analysis. Transcribing offers a point of transition between data collection and analysis as part of data management and preparation (Patton, 1990). All transcriptions were conducted by the interviewer rather than any outsourced transcribers, which provides an opportunity for the researcher to get immersed in the data and generate emergent insights. Coding allows the researcher to simplify and focus on specific characteristics of the data and assists the researcher in abstracting or thinking up from the data (Morse & Richards, 2002). It has been claimed that the excellence of the research rests in a large part on the excellence of the coding (Strauss, 1987). Morse & Richards (2002) distinguished three kinds of coding: the storage of information, termed descriptive coding in Miles & Huberman (1994), topic coding, and analytic coding for developing concepts. They suggest that the researcher needs to go beyond storing information and gathering materials by topics and move to creating and developing abstractions from the data. Coding, therefore, functions as a way to link data with information, topics, concepts, and themes. Content analysis is used to interpret data.

Furthermore, the data analysis of a case study research may occur simultaneously as data collection can be carried out as an interactive process. The research can move between the case studies and the literature review and back to the case studies to improve the design, analysis, and the researcher's understanding of the core issues. Patton (2002) stated that the term 'pattern' usually refers to a descriptive finding while a 'theme' takes a more categorical or topical form. Morse & Richards (2002) suggested that categorisation and conceptualisation are processes that enable the identification of a pattern. Therefore, the actual comparison between the predicted and actual pattern might not have any quantitative criteria. The discretion of the researcher is required for interpretations. Interpreting the results and the present findings is the last step of the process of qualitative data analysis. Interpretation goes beyond the description of data. It means attaching significance to what was found, making sense of findings, offering explanations, drawing conclusions, extrapolating lessons, making inferences, considering meanings, and otherwise imposing order on an unruly but surely patterned world (Patton, 2002). During qualitative interpretation, the researcher works back and forth between the data and their own perspective, as well as their understandings, to make sense of the evidence. The procedure of qualitative data analysis is as follows:

- a) Data from the document-checking process is compiled and summarised.
- b) All the interview results are made in the form of draft transcripts and written reports.

- c) Both the data from the document checking and interviews is compiled and categorised using content analysis based on a predefined category (theoretical framework).
- d) Within each category, the data and information is further identified and classified into nodes (classification system). The nodes represent the readiness criteria that were identified in each company.
- e) Each readiness criteria from the research is identified and elaborated. The draft of the individual report is written.
- f) The cross-case analysis is conducted to measure consistency in findings between cases by combining the findings in a matrix of categorisation and nodes.
- g) The data from the cross-case analysis is theoretically validated with the literature review and further discussed to make sense of data and conceptualise a readiness framework.
- h) The final report is drafted and conclusions are developed.

As for the workshop, a similar content analysis was conducted to make sense of the qualitative data of three different groups that were assigned in the workshop. In addition to that, in analysing the quantitative data for the questionnaire, a frequency of answers and an average index analysis was used for both. A capability and importance measurement of each individual readiness criteria and the presentation of the result were made in a radar form as can be seen in chapter 6, Framework Validation. Both of the analyses were used to depict the pattern of response made by the workshop participants. The average index (A.I) (Lim & Alum, 1995) is calculated by using the following formula:

$$\text{Average Index} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{(n_5 + n_4 + n_3 + n_2 + n_1)}$$

where n is the frequency of workshop participants who answered the following:

Table 3.4: The representation of n for the level of importance and capability

n	Level of Importance	Level of Capability
n_5	Highly Important	Highly Capable
n_4	Important	Capable
n_3	Neutral	Neutral
n_2	Not Important	Not Capable
n_1	Very Unimportant	Very Incapable

It is important to note that the main use of the A.I was to determine the average response of the workshop participants for each readiness criterion. The A.I value reflected the importance of each readiness criterion where the closer the value to 5, the more importance the particular criterion imposed. The A.I value therefore assisted the researcher to justify whether the readiness criteria should stay within the framework or needed to be omitted from the conceptual model. The level of capability, on the other hand was just used to describe the average capability background of the workshop participants as measured accordingly to each readiness criteria. It served as additional information and did not contribute to the validation of the readiness criteria.

3.5 VALIDITY AND RELIABILITY

The potential weaknesses of the case study research are a problem of accessibility, lack of rigour, sloppiness, biased view, and lack of scientific basis for statistical generalisation. The case study methodology usually faces validity and reliability issues. According to Gibbs (2007), validity in qualitative research refers to the verification process of the findings employed by the researcher. Yin (2009) identified two aspects of validity: internal validity and external validity. The former is concerned with the truthfulness of the case study and interference, and the latter is a question of generalising the findings beyond the immediate case study. On the other hand, reliability according to Gibbs (2007) indicates that the researcher’s approach is consistent across different cases and projects and concentrates on the errors and bias of the study. To address these issues, the research followed a case study validation strategy, as proposed by Yin (2009) and is depicted in the following Table 3.5:

Table 3.5: Validity and reliability procedures for case study (Yin, 2009, p.41)

TEST	Case study tactics	Proposed measures
Construct Validity	Use multiple source of evidence Establish chain of evidence Have key informants review draft case study report	Triangulation - integrating theories - multiple sources of evidence (documents review, survey & interview). - Integrating data analysis methods: content analysis & cognitive mapping.
Reliability	Use case study protocol Develop case study database	Documenting procedures and steps used in the case study Verification of transcripts Consistent interview

In the test of construct validity, the use of multiple sources of evidence can increase the level of validity. In this research, besides having multiple respondents for interview as the primary source of evidence, other sources were also proposed such as documents, reports, etc. However, when the data

collection phase was executed, most of the written data was treated as confidential by the respondents. This research therefore could only rely on the use of multiple respondents to satisfy the validity requirement. Also, once the framework had been developed, it was validated by using a focus group workshop in order to confirm the findings of the research by the key informants. For the reliability issue, along the process, the case study protocol was also developed and documented. The case study protocol in a form of interview questions can be further referred to in Appendix 1.0, the interview questions. Besides documenting for the purpose of reliability, outlining the step by step procedure in collecting and analysing data and reporting findings would also serve as guidance for the researcher. Meanwhile, for each individual case that was investigated, reports of finding were prepared and sent back to the organisation involved in the case study to comment. The purpose of this exercise was to address the reliability issue to make sure that what the researcher transcribed and reported was really what the respondents meant.

As discussed, within the validation process, there are two types of validation that are required for this research. The first one is individual case validation, which focuses on validating the individual findings to make sure that what the researcher is reporting reflects the actual company's views and practice. The second type of validation is focusing on generalising the conceptual framework that was produced by the research. The latter, after the readiness framework was conceptualised, to validate the framework, a focus group workshop was conducted on 17th November 2011 at Cyberview Resort and Spa, Cyberjaya, Selangor, in collaboration with CREAM. In the collaboration, CREAM agreed to support all expenditure and human resources to enable the focus group workshop to be conducted. In return, the researcher was required to manage a one-day roundtable event, entitled "Industrialised Building System (IBS): Mechanisation through Building Information Modelling (BIM) as can be seen in the following Table 3.6. In addition, the researcher was also required to prepare an industrial report regarding the events, including the workshop validation findings and industrial roundtable discussion findings. Therefore, during the event, the researcher was officially appointed as event coordinator, industrial report editor, and workshop moderator for the researcher's slot of workshop validation. The event was attended by 25 participants representing private developers, government agencies, universities, and design consultants. The objectives of the roundtable workshop were:

- To highlight the concept of mechanisation, automation and robotics in construction and its relation with Industrialised Building System (IBS)
- To showcase BIM actual implementation
- To discuss the potential application of BIM towards mechanisation of IBS
- To discuss the issues of BIM organisational readiness

Table 3.6: Tentative agenda for the roundtable program entitled Industrialised Building System (IBS): Mechanisation through Building Information Modelling (BIM)

TIME	ACTIVITY
08.00-09.00	Registration and Breakfast
09.00-10.00	Opening address and Presentation of Industrialised Building System (IBS) / Building Information Modelling (BIM) Roundtable: Mechanisation of IBS through BIM <i>Ir. Dr. Zuhairi Abd Hamid, Executive Director of CREAM</i>
10.00-10.45	A Case Study of BIM Implementation in Malaysia <i>Presented by En. Shaharin Hashim, BIM Manager of IPMS</i>
10.45-11.30	A Case Study of BIM transformation in Oil and Gas Organisation <i>Presented by Ir Dzulaidin Tasrin, Head of Mechanical and Piping Engineering of Kencana Beswide</i>
11.30-12.00	Coffee Break
12.00-13.00	BIM Industrial Transformation in Australia (Video conference) <i>Presented by Mr Bilal Succar, Director of Change Agents</i>
13.00-14.00	Lunch Break
14.00-16.00	Industry Workshop: BIM Readiness Framework <i>Moderated by Ahmad Tarmizi Haron, PG University of Salford/Lecturer of University Malaysia Pahang</i>
16.00-17.00	Taskforce Discussion <i>Moderated by Ir. Dr. Zuhairi Abd Hamid, Executive Director of CREAM</i>
17.00-18.00	Closing and hi-tea

3.6 SUMMARY

In summary, this chapter provides some discussion of case studies in terms of the different types found in the literature. Case studies are considered useful in this research as they enable researchers to examine a rich information data. The case study presents the data of real-life situations and it provides better insights into the detailed behaviours of the subjects of interest. In addition, the exploratory nature of this research to identify the readiness criteria has positioned the case studies as a better option. The use of case study research attempts to explore the current level of BIM implementation and readiness criteria by the organisations involved in the case studies. Meanwhile, a focus group workshop was also held covering the needs and data validation techniques, which was done via questionnaires and a group discussion. The next chapter 4 will discuss the case study findings for each individual case. It describes the current level of BIM implementation of each company and the readiness criteria that was identified in each company. The next chapter will discuss the findings of each individual case. The discussion was made in two parts where the first part discusses the company's background and current implementation of BIM. The second part is

pertinent as it discusses each readiness criteria that was identified in each case. The readiness criteria would then be used to be cross-analysed and developed further into a case conceptual framework, as can be found in chapter 5.

CHAPTER 4: REPORT ON CASE STUDIES

4.1 INTRODUCTION

This chapter discusses the case studies findings for the achievement of the research objectives, to identify the organisational requirement for BIM implementation. To avoid confusion, it is important to mention that the term ‘readiness criteria’ used in this research is developed based on the organisational requirement for BIM implementation, and the detailed discussion about the readiness concept can be found in chapter 2, Literature Review. Four companies were involved in the case studies where one BIM consultancy was chosen for piloting the case study, while the remaining three companies, an oil and gas design consultancy, and two A/E/C based integrated consultancies were chosen for the actual case studies. All of the companies are based in Malaysia. The case study findings draw from a number of face to face interviews, observations, and a compilation of physical documentations concerning BIM with key management and technical BIM personnel in the company.

In each of the companies, the first part discusses the background and current level of BIM implementation to understand the context of BIM implementation. The later part focuses on the identification and discussion of the readiness criteria which underpinned the company in implementing BIM. The case studies focus on the main elements of the readiness category which was identified in the literature review as following:

- 1) **PROCESS**
 - a. Process Change Strategy
 - b. BIM Implementation Management
 - c. Policy
- 2) **MANAGEMENT**
 - a. Business Strategy
 - b. Management Competency
 - c. Leadership
- 3) **PEOPLE**
 - a. Roles and Responsibility
 - b. Skills and Attitude
 - c. Training and Education
 - d. Work Environment
- 4) **TECHNOLOGY**
 - a. Hardware
 - b. Technical Support
 - c. Software

The importance of this chapter, with respect to the framework development is it provides the primary data for each individual case. Since the data is qualitative in nature, it provides a better understanding of the justification that was made by the interviewee for each readiness criteria that was identified. This understanding is highly useful to guide the researcher to cross-analyse, discuss and theoretically validate the readiness criteria, as can be found in chapter 5.

4.2 PILOT CASE STUDY FINDINGS FOR COMPANY P

This subchapter discusses the data that was found at Company P. It starts by providing the background of the company which is then followed by the current status of BIM implementation to provide the overview of the context and status of BIM implementation. After that, the readiness criteria identified within the company are discussed according to the categories that they belong to.

4.2.1 BACKGROUND OF COMPANY P

Company P was set up in 2009 to provide bespoke and value added solutions to clients in the construction industry. The company has two offices located in Kuala Lumpur, the capital city of Malaysia, and Johor Bahru, the southern part of Peninsular Malaysia. As part of the data collection in Company P, the case study was conducted at the office located in Johor Bahru, where the researcher was able to interview all three of the company's principals, reviewing related BIM software that was used, and reviewing the associated BIM archives such as the design deliverables, implementation plan and requirement and training module. However, the researcher was not allowed to have any copy of the documents. Meanwhile, the interviews were conducted on the same day in two sessions, in the morning around 10.00 a.m. with Interviewee CP1 and at the afternoon around 2.30 p.m. with Interviewee CP2 and CP3 together. The interviews lasted about two hours for each session. All of the interviewees were the principals of the company P. The list of the interviewees and their background is as following:

Table 4.1: List of the interviewees for Company P

Name	Background	Area of Expertise	Designation	Experience(years)
CP1	Architect	Design and Development Management	BIM Manager/BIM Strategist	More than 20
CP2	Building	Planning and Scheduling	4D Planner/BIM Strategist	More than 20
CP3	Civil Engineer	Construction Engineering Services	Project Manager	More than 20

Serving as a BIM integrated consultancy, the members of the company consist of 12 permanent staff with different BIM expertise in the field of architectural, structural, project management, 4D modelling, construction engineering and building services. The BIM related job designations that the company has assigned right after its establishment were the BIM Manager, BIM Modeller, 4D Planner and BIM Strategist.

4.2.2 CURRENT STATUS OF BIM IMPLEMENTATION

As for 3D BIM modelling tool, the company has acquired a few licenses for Revit Structure, Revit Architecture and Navisworks along with other software tools such as SkechUp, Microsoft Project and AutoCAD. Company P has two scopes of business; to be directly involved in a project as an integrated design consultancy to design, produce and manage Building Information Model and associated process, and as a BIM implementation consultancy to assist architectural, structural and integrated design firms to implement BIM within their organisation. The services offered by Company P are listed as follows:

- a) Consultation regarding the implementation of Building Information Modelling to a company including design consultant, contractor and developer
- b) As a project counsel providing advice to the project team
- c) As project facilitator assisting team in managing and delivering BIM
- d) Serve as counsel to party in BIM-related project
- e) Lead BIM workshops pre-contract and for contract negotiation
- f) Serve as a BIM manager
- g) Serve as a Project Management Consultant

In consulting the implementation of Building Information Modelling to an organisation, some of the services provided by the company are:

- a) Executive Briefing
The service targeted at providing BIM awareness and exposure to the management of the company. The activities are not limited to, but include presentation of the BIM business benefits, demonstration and hands-on experience for Revit and BIM transition approach.
- b) BIM Implementation
The service is not limited to, but includes preparing BIM implementation plans, identifying BIM areas of application and expected benefits, identifying the Revit technological and people requirements and transferring the office CAD standards

from an AutoCAD and/or Microstation to a Revit Platform. Company P will work hand in hand with the internal staff of the company to align and suit the company's needs with Revit's requirements.

- c) Technical Support
- d) Training

The idea of setting up an integrated BIM consultant was first initiated by Interviewee CP1 based on the worldwide BIM trends and a few initiatives made by major developers and a government agency to implement BIM. By serving different companies previously, ranging from architect consultant to contractor, Interviewee CP1 was convinced that the Malaysian industry was moving towards BIM and a limited amount of BIM expertise within the industry was identified as a business opportunity to set up a BIM consultancy company. For the record, Interviewee CP1 has been using Revit Architecture since early 2000 and has been involved with three different companies in implementing BIM before deciding to form Company P. Interviewee CP1 was recognised as the backbone of Company P by Interviewee CP2 and CP3 based on experience and BIM technical competency.

Right after Company P was formed, it was involved in a Design and Build project for a multipurpose hall. The company was first approached by the main contractor, Contractor A to win the tender, justifying the client's need to complete the project within 9 months with pre-specified building specification and contemporary Malay design and a limited budget of around RM30 million. The time and cost constraints made it impossible for Contractor A to use a typical fast tracking design and build approach to deliver the project. Thus Contractor A needed to try something more effective which led them to use BIM. Since the contractor did not have BIM capability, the contractor therefore appointed Company P. During the presentation of the proposal, as far as BIM is concerned, the client was so convinced with the BIM methodology and process flow that was presented by Contractor A via Company P that it resulted in them winning the tender. For the presentation, Company P used a simple 3D SketchUp model to communicate their conceptual design and a 4D model to convince the client about their planning for the construction. As for the BIM methodology to design, a collaborative design approach was used to optimise the design delivery. The collaborative design approach as according to the company, required the whole design and build team to come together as early as the design phase to give their input for better decision making, quality improvement and risk mitigation. The approach was realised through a series of design workshops participated in by the architects, engineers, main contractors, subcontractor and client's representative. In each workshop, Company P carried the responsibility as a workshop facilitator to manage the flow, collect and process the views and data before producing the BIM model. At the

time the case study was conducted, the project had just finished with the design phase and Company P were finalising the design documents and deliverables for construction. Within the project, Company P was responsible to lead the design development phase to:

- a) Liaise with the design consultants (Structural, Mechanical and Electrical and Architectural) regarding the 3D BIM model development
- b) Model the multipurpose hall in 3D BIM
- c) Ensure clash free design via automated clash check in BIM
- d) Manage all the design deliverables and construction documentation
- e) Develop 4D modelling for construction planning and monitoring

Meanwhile, the company has also been appointed by private design consultants and a public integrated design consultant to assist the BIM implementation within their company. Company P was appointed as a BIM strategy/implementation consultant, responsible to educate and give awareness to the people within the organisation ranging from the operation up to the management, consulting the BIM implementation plan that was pre-developed by the organisation, and providing technical support. The next section will discuss further the readiness criteria that were identified by Company P. It is important to note that the identification and view of the readiness criteria is not focused on Company P as a BIM Consultant, but instead on their clients as design consultants to become a BIM-capable company as suits the scope of the research. Due to the confidentiality of their clients, Company P was only comfortable to discuss the identification of BIM readiness criteria in general without specifically pinpointing any company that has appointed them.

4.2.3 ***BIM READINESS CRITERIA***

This subchapter discusses the readiness criteria that were identified in Company P. The discussion is arranged accordingly to the readiness elements and categories that each of the readiness criterion belongs to.

4.2.3.1 **Process**

Table 4.2: Readiness criteria for process element that were identified in company P

PROCESS ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
PROCESS CHANGE STRATEGY	Process Flow Redesign Small and Incremental Approach Communication

IMPLEMENTATION MANAGEMENT	Implementation Plan Monitoring and Controlling Pilot Project
POLICY	Design and Build Contract Amendment

Table 4.2 summarises the readiness criteria within the process element that was identified in Company P. Eight readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.2.3.1.1 Process change strategy

The first readiness criterion as identified by Company P is the need to change the current process flow. According to interviewees CP1 and CP2, the BIM process flow is centred on the production and exchange of the electronic 3D model rather than the document-based drawings as normally used in a CAD process flow. Therefore, the 3D model has become the main deliverable and thus requires a process change to suit the need. The most important activity within the process change is to incorporate the 3D model production into the current process flow, as interviewee CP1 further added. As the model has become the main deliverable, the accuracy and consistency of the model is very important and requires any company who would want to implement BIM to allocate much time and effort to focus on authoring the model. The unfamiliarity with BIM software tools and process has also demanded a longer time to reach the drawings extraction phase in BIM. Therefore, the company must carefully plan their process flow redesign to satisfy the BIM need, their current capability and also the project's need. Company P itself has encountered difficulty when changing the process flow in a project due to the different level of understanding especially with their clients as evidenced in the following:

[...] Early during the proposal presentation, when we proposed the new process flow the client verbally agreed and was ready to go with it. However, when we presented the detailed process flow during the first conceptual design workshop, the appointed Project Management Consultant representing the client did not approve the process flow and forced us to deliver the drawings within 3 months to comply with the contract requirement or else we may not receive the payment. We tried our hardest to explain that the thing about BIM is to model first and the drawings come later but their mentality was still stuck in the previous process flow to produce drawings first and the model comes later. Therefore, we have to compress our modelling activity within 3 months and we have compromised our model accuracy as a result [...]
Interviewee CP3

Meanwhile, according to Interviewee CP1, the implementation of BIM must also consider a small and incremental approach to allow the people to adapt and feel comfortable with the new BIM technology and methodology. The small and incremental approach is therefore identified as another readiness criterion by Company P. When reviewing the BIM implementation plans made by their client, according to Interviewee CP1, all of them tailored their implementation plan in a small and incremental approach by spreading the 12 BIM applications into a certain timeline to implement. However, one of them was too radical by trying to implement all 12 BIM applications within the duration of 18 months. This approach is not advisable as it will cause additional pressure on the people which comes from the activity to learn the BIM tools, change the process flow and deliver their daily job at the same time. Interviewee CP1 also supported the need to implement BIM in a step by step approach, evidenced as following:

[...] We advise our client to simply focus developing low detail of architect and structural models, just enough to satisfy the drawings coordination and 3D clash check. The first stage targeted the user to appreciate the visualisation and the ease of delivering clash check as both are their main challenges working in CAD. The drawings are still refined and drafted in detail by using CAD. Once they have achieved a certain level of modelling competency, only then we move on to detail modelling to enable drawing and BQ extraction [...] Interviewee CP1

Effective means of communicating BIM also plays an important part in implementing BIM and thus is identified as another readiness criterion. According to Interviewee CP2, the importance lies on the grounds of informing all the staff about the company's BIM direction and gaining staff acceptance. By giving an example of their client, the interviewee further supported his discussion as follows:

[...] Although BIM initially affects the drafting department, the big picture of BIM must be communicated effectively to all individuals within the company. Sooner or later BIM will become primary and therefore important for them to be aware of, especially in what way everybody could support and contribute. One of our clients invited us and have organised a half-day meeting with all of their staff to present the BIM strategy and discuss the staff's concern. The meeting is so important to gain the staff acceptance on BIM and reduce the internal resistance. Implementing BIM means "change" and not all people are comfortable with that, especially the senior staff [...] Interviewee CP2

In the meeting, Interviewees CP1 and CP2 were responsible to present BIM business and technical benefits with a live demonstration to show the ease of BIM in authoring the 3D model, extracting and managing design deliverables, and targeting at attracting and gaining staff acceptance for BIM implementation.

4.2.3.1.2 BIM Implementation Management

An implementation plan is a must in implementing BIM as agreed by all interviewees and thus identified as another readiness criterion. Based on Interviewees' CP1 and CP2 experience in developing the BIM implementation plan at the organisational level, the plan must consist of a software and hardware acquisition plan, a training schedule, assigned roles and responsibility and the methodology to change the internal process flow. The plan, as interviewee CP2 further explained, will break the target into small objectives and therefore ease the company to plan the resource allocation, and direct and monitor the implementation. Since BIM is a new approach to design, the company should take some time to develop the implementation plan and international guidelines. Best practice was mentioned important to assist developing the plan as evidenced in the following:

[...] In developing the implementation plan, we have a very limited source of reference that suits our local context especially the absence of local BIM standard. Therefore, we must refer to the international document such as BIM Project Execution Plan, AEC (UK) BIM Standard, and CoBIM and some case studies and technical papers. Of course it is not suitable to adopt it as it is but rather than reinventing the wheel, it is a lot better to make adjustments from the documents. After all, the document makes it easy to identify the important BIM requirement. The next thing is to identify the company's needs and current condition and later try to match and suit the BIM requirement with it [...] Interviewee CP1

Meanwhile, Interviewee CP 3 stressed on the importance of monitoring and controlling BIM implementation to achieve the pre-determined objectives that were approved by the management of the company. The implementation plan, besides assisting BIM implementation, is also important to be used as the baseline for monitoring. The most important aspect is whether BIM improves the process in terms of speed of design delivery and quality of design deliverables. Many of their clients claimed to their management that BIM speed up the delivery process (and has become a BIM objective). Therefore, it is important to prove the claim and to achieve it. A close monitoring is important especially in identifying the challenges and corrective actions. The BIM monitoring and controlling of BIM implementation progress is therefore identified as another readiness criterion.

Piloting BIM projects was identified as another critical readiness criterion when implementing BIM as agreed by Interviewee CP1, CP2 and CP3. The justification lies in the need to test and refine the selection of the technology, newly defined roles and responsibility and predetermined process flow to suit the BIM and project needs. As Interviewee CP1 further added, the pilot project should be selected based on the projects that are common to the company to ease the implementation process. However, within their experience, the pilot project was conducted on a challenging project which has a unique design with a highly constrained time duration and budget. The complexity of the project

has minimised their chances to fully execute and explore the BIM implementation during the pilot due to the strict dateline and low level of BIM readiness by other project participants.

4.2.3.1.3 Policy

Another feature of BIM readiness criterion that was identified by Company P is the use of design and build as a project delivery method when implementing BIM in a project. According to Interviewee CP2, the nature of design and build, which is more flexible in the process flow, is the ability to choose the team members and a single entity responsible for both design and construction which has created an excellent opportunity for the company to implement BIM. The decision to use BIM early in the design stage with a collaborative approach can be negotiated directly with the main contractor.

Meanwhile, when discussing the policy that enables BIM to be implemented, Interviewee CP2 further directed the discussion to the current standard form of contract used by the local government. The way a standard form of contract is written satisfies the CAD requirement but is not suitable for the implementation of BIM. By giving an example of the current condition of the contract, the interviewee further supported his argument:

[...]In BIM, the main deliverable has shifted from the drawings to the 3D models. The drawings are still there but have becoming secondary. However, if we look at the standard form of contract, the drawings have been specified as the design deliverables over the 3D model. The problem exists in exchanging the design deliverable, for instance, architect to the structural consultant. Since the contract does not specify the 3D model exchange as part of the requirement, the architect will simply send the 2D CAD drawings to the structural consultant and as a result manual re-entry of data is required to process the information. This is totally contradicted with the BIM concept of data exchange and will create room for error [...] Interviewee CP2

Meanwhile, Interviewee CP3 further added the need to have dedicated policy in BIM implementation by concentrating on the need to avoid liability for infringement of third party intellectual property rights. A policy must be in place to ensure that all contributors warrant that they hold the intellectual property rights over the contributions they make and provide an indemnity to all other parties who may use such contributions in the event of a third party intellectual property dispute. To satisfy the policy need, both Interviewee CP2 and CP3 suggested that a contract amendment is needed to allow BIM process flow and deliverable to be performed and thus features as another readiness criterion.

4.2.3.2 Management

Table 4.3: Readiness criteria for management elements that were identified in Company P

MANAGEMENT ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
BUSINESS STRATEGY	BIM Objectives Alignment BIM Negotiation
MANAGEMENT COMPETENCY	Knowledge and Awareness Commitment and Support
LEADERSHIP	Top Down Approach

Table 4.3 summarises the readiness criteria within the management element identified in Company P. Five readiness criteria were sorted accordingly to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.2.3.2.1 Business Strategy

According to Interviewee CP2, the implementation objectives of BIM or any new technology must be made clear to support the business need as evidenced in the following:

[...] If we look at it, there are so many business needs that the management would want to satisfy but it always goes back to the basic of making more profit. And how BIM could increase the profit making is important to justify the investment as it is related to the management buy-in and commitment [...] Interviewee CP2

Meanwhile, in consulting their clients on BIM implementation, Interviewee CP1 also added a few BIM applications that were identified to support the business need as evidence in the following:

[...] Most of the cases that we consulted mentioned about the potential of BIM to improve productivity through integrated drawings production, automated clash check and material taking off. Additionally, the ease of reviewing the design via 3D has also made the jobs better as it eliminates the 3D imagination in one's head [...] Interviewee CP2

The BIM objectives to support the business needs are therefore identified as another readiness criterion by Company P.

Meanwhile, negotiation of BIM implementation with business partners is also identified as readiness criteria by Company P based on the argument of the construction nature which involves many parties in the delivery process as evidenced in the following:

[...] Since the nature of construction business involves many parties, each one of them must be kept informed about the company's BIM implementation. The management must play an active role to negotiate their BIM implementation with their partner. Whether they are together with the company implementing BIM or not is not the issue but their support to assist and understand the company's situation is important. There is one of our client cases whereby they justify their BIM implementation to their client, explain how the client could benefit in the long run once they manage to develop their competency and lucky them, the client was so supportive and encouraging and even granted a new date for drawing submission just to ease and allow the company to implement BIM [...] Interviewee CP2

It is important to mention that in the example of this case used by the Interviewee CP 1, the consultant and the client had a long term partnering arrangement and the project that was granted a new date was not very tight in schedule and cost.

In strengthening the need to negotiate BIM implementation with business partners, Interviewee CP3 shared Company P's experience in implementing BIM on their first project as following:

[...] In our first project, we have to admit that we did not clearly negotiate our BIM implementation process with our client. Many issues have arisen and we had to pull back our effort very hard mainly because of the low level of readiness especially from the client's side and client's representative. When we said we want to deliver 3D model, the client themselves did not have the tools and competency to check our deliverable and at the very beginning we ourselves did not address and discuss this issue. As a result, they had to decide to go with CAD process flow as it was the only way they can do it [...] Interviewee CP2

Meanwhile, another issue as raised by Interviewee CP2 that requires a negotiation was trust among the business partners when implementing BIM in a project as evidenced in the following:

[...] Trust among the project participants has also created another issue. Since everybody is dealing with a new thing, they are so worried with the risk that BIM entails as they do not know what to expect. When we try to consult them, let's say for instance the process flow of implementing model first before drawings production, the way they saw it was that we were trying to take advantage and they are all very skeptical with our suggestion. I'm not talking about the client alone, but the overall team members. That sort of issue by right should be resolved early to get things clarified and officialised [...] Interviewee CP2

4.2.3.2.2 Management Competency

The management awareness of BIM requirement features as another readiness criterion as was identified by Interviewee CP2 in the following statement:

[...] In directing the BIM implementation, the management themselves must acquire a certain level of BIM knowledge. We are not expecting the management to the extent of being able to author the model, but at least they must understand the BIM change process covering the technical and human needs. When they are clear with that, the implementation could become easy [...] Interviewee CP2

Meanwhile, all of the interviewees mentioned the importance of having consistent support and commitment from the management to implement BIM and this was identified as another readiness criterion. The evidences are as following:

[...] BIM is a long term investment and sooner or later will become the norm within the construction industry. The management in the very first place must believe in BIM so that they are able to provide consistent support to direct the implementation. The support from the management is very critical as they will dictate the success of BIM implementation. The support must be comprehensive to cover the technical needs such as software and hardware and soft needs of the human such as motivation, encouragement and such. [...] Interviewee CP1

[...] The commitment and support from the management must be made visible to the staff to let them know how serious the company is with the implementation. [...] Interviewee CP2

The management is the one who authorises the budget and determines the direction of the company. Therefore, it makes sense to have their support to drive the implementation [...] Interviewee CP3

4.2.3.2.3 Leadership

In discussing the leadership of BIM implementation, all of the interviewees strongly believe that the only way BIM implementation can succeed in any company is by engaging a top down approach. According to Interviewee CP1, the initiation is possible from many angles such as operational or external influence such as client’s demand or product demonstration by the software vendor, but the actual BIM implementation must be made in a top down approach. The justification as was captured by all interviewees lies in the authority to direct and decide, and the understanding of strategic business needs.

4.2.3.3 People

Table 4.4: Readiness criteria for people element that was identified in Company P

PEOPLE ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
ROLES AND RESPONSIBILITIES	Head of Change BIM Modeller BIM Manager

SKILL & ATTITUDE	BIM Administrator/Manager BIM Designer/Modeller
TRAINING & EDUCATION	Formal Training On-the-job Training
WORK ENVIRONMENT	Knowledge sharing

Table 4.4 summarises the readiness criteria within the people element that was identified in Company P. Eight readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.2.3.3.1 Roles and Responsibility

Within the context of Company P as a BIM consultancy, the dedicated BIM designation that the company has assigned is BIM Manager, BIM Modeller, 4D Planner and BIM Strategist. Interviewee CP1 however, further suggested that for any design consultancy company who wants to implement BIM, they should at least create new roles and responsibilities as following:

- a) BIM Manager
- b) 3D Modeller
- c) Head of Change

No specific number was mentioned to be appointed for aforementioned roles and responsibilities as the number depends on the capacity of the company to handle the projects and the number of staff. The 3D modeller was viewed a must but not as critical as BIM manager and Head of Change as it only related to the technical usage of BIM tools such as authoring the 3D model and extracting the drawings. The most important tasks lie in the roles and responsibilities that are carried by the BIM manager and the Head of Change. Generally, the BIM manager is responsible to manage the technical aspect of BIM implementation while the Head of Change is responsible to manage the change or transition process within the company and therefore must be working very closely together. The BIM manager's roles and responsibilities are simplified as following, as were mentioned by Interviewees CP1 and CP2:

- a) Administrating the BIM software including setting up the library or family, incorporating new versions and customisation of the product
- b) Managing the technical needs of the BIM implementation
- c) Technical Support and Trouble shooting
- d) Internal BIM standard development and implementation

- e) Training and assistance of the internal staff for BIM software
- f) Identify and Evaluate BIM software to be used by the company
- g) Liaison the BIM implementation with the management, clients, staff and software vendors
- h) Keep informed, trained and educated for BIM by attending seminars and conferences and be responsible for disseminating the information to the teams

Meanwhile, according to Interviewee CP2, the Head of Change must have good leadership as to direct the implementation. Observing their clients, all of the companies appointed the middle manager as the Head of Change, justifying the authority and leadership that the manager has. Meanwhile, the roles and responsibilities for the Head of Change, as mentioned by all interviewees, are simplified as following:

- a) Directing and controlling the BIM implementation
- b) Acquiring and managing the resources for BIM implementation
- c) Identifying and specifying the requirement for changing the process flow
- d) Identifying new wedges scheme for BIM newly created roles
- e) Liaison with the staff and top management to align and fulfil their needs and expectations
- f) Reporting the progress of BIM implementation
- g) Prepare and execute the BIM implementation plan
- h) Keep informed, trained and educated for BIM by attending seminars and conferences and be responsible for disseminating the information to the teams

The newly created roles and responsibility for BIM managers, modellers and head of change, is therefore identified as another readiness criterion.

4.2.3.3.2 Skills and Attitude

Right skills and attitude is identified as another readiness criterion by Interviewees CP1 and CP2 for selecting a BIM Manager or BIM modeller. The current situation of the Malaysian industry, which is lacking competent people, has forced their clients to train their internal staff to become BIM modellers or Managers, over hiring external people. Additionally, a high cost and some confidentiality of internal information were also mentioned as justification to select internal people. Generally, the skills and attitude depends on the roles and responsibilities that were defined by their clients but Interviewee CP1 further simplified the skills and attitudes based on what he poses as following:

- 1) Strong multi-disciplinary knowledge and more than 10 years of experience in drafting and design.
- 2) At least have completed three projects by using BIM from start to the handover.
- 3) Highly competent in AutoCAD
- 4) Good communication skills
- 5) Computer savvy and have good technical skill in troubleshooting
- 6) Initiative and leadership

The justification for having multi-disciplinary knowledge is further supported by Interviewee CP1 in the following evidence:

[...] When the 3D models are brought together, the BIM manager is required to check, comment and ensure the accuracy of the model and therefore, he must have a multi-disciplinary knowledge to enable that. The most important part, he must know every component that makes up a building regardless of what discipline he is representing [...] Interviewee CP1

Meanwhile, the justification of having completed 3 projects by using BIM from start to the end is supported by Interviewee CP2 in the following evidence:

[...] When a person is implementing a new thing, for the first project, he is not yet confident and tends to explore rather than really implement it. In doing so, many mistakes will take place and that will teach him to become better. In the second project, he starts to feel more confident and deliver what he has learnt in the first project. The theoretical and practical knowledge gap has also started to shrink. In the third project, they will implement it accordingly and become more confident and efficient. Only by that time he will become good enough, know what to expect and be able to guide and assist other people and the project team [...] Interviewee CP2

Meanwhile, for the BIM modeller, the positive attitude was mentioned as very important by Interviewee CP1 along with right skills such as IT and CAD literacy, being computer savvy, and possessing troubleshooting skills. The positive attitude is evidenced in the following:

[...] To me, the skills, training or any other stuff is only made up of 20% of what is required to become a BIM modeller. The rest of the 80% is really up to his attitude. If he is eager and has initiative to learn, is a quick learner, smart and simply listens to the trainer, everything will become easier. After all, it is not easy to change people's attitude and therefore people with the right attitude are important to be identified first [...] Interviewee CP1

4.2.3.3.3 Training and Education

In selecting a training method for BIM implementation, according to Interviewee CP1, their clients are engaging formal training and on-the-job training. The formal training normally comes when a company buy software licenses from a vendor. It's very important to strengthen the theoretical

foundation of the software which includes the interface of the software, terms that are used and the modelling concept. Meanwhile, on-the-job training is targeted at making practical use of the knowledge that people acquire from the formal training, improving the skills and increasing the confidence level. The on-the-job training and formal training are therefore identified as another readiness criterion.

4.2.3.3.4 Work Environment

To assist the BIM implementation, a work environment that supports knowledge sharing among the staff is also identified important as was mentioned by Interviewee CP2 and thus features as another readiness criterion. By sharing one of their client’s cases, the environment was good at the company where they had developed a mentoring program and internal tutorials and learning guide. The effort helps the staff a lot by creating a reference and a learning point and speeding up the learning process. The learning materials and tutorials were uploaded onto the website so everybody could have easy access.

4.2.3.4 Technology

Table 4.5: Readiness criteria for technology element that was identified in Company P

TECHNOLOGY ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
HARDWARE	Adequate ICT Infrastructure
TECHNICAL SUPPORT	Vendor Evaluation Strategy Technical Support
SOFTWARE	Software Evaluation Strategy Compatibility and Interoperability

Table 4.5 summarises the readiness criteria within the technology element that was identified in Company P. Five readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.2.3.4.1 Hardware

According to Interviewee CP1, to run BIM software smoothly, the workstation requires a higher capacity of RAM and Graphic Card and a more powerful processor. An adequate workstation is a must to avoid disruption to the BIM implementation and therefore identified as another readiness criterion. Any company therefore must carefully plan their hardware either to go for an upgrade or

totally change to a new workstation. The justification must not look into a short-term plan but should be projected to at least 3 years duration to include further BIM advancement. Since Company P was established from scratch, it acquired new workstations rather than upgrading.

4.2.3.4.2 Technical Support

Technical support features as another important readiness criteria as agreed by Interviewees CP1 and CP2. However, based on their experience, the local vendor has a limited capability in delivering technical support especially when dealing with trouble shooting to the extent that the vendor is required to consult with the expertise from Singapore to resolve the problem. The limited capability has caused delays to their pilot project and therefore, in selecting a vendor, Interviewee CP1 strongly suggests to properly evaluate the vendor capability upon appointment to avoid such problems. No details of the problems however, managed to be captured during the interview.

4.2.3.4.3 Software

Software evaluation strategy is identified as another readiness criterion within Company P, taking into consideration a variety of BIM tools that are currently available in the market. Company P is currently using Revit Architecture, Structure and Navisworks as part of BIM software tools. Although no specific approach was engaged, according to Interviewee CP1, the selection of the software was justified based on the business objectives that the company would want to achieve and the competency that he, as the BIM manager, has before certain sets of evaluation criteria are listed down. The selection criteria that are used in selecting Revit as compared to other products are as following:

- a) The software interface which is easy to use and similar to AutoCAD
- b) The cost of software per license
- c) The compatibility of the software with CAD systems
- d) The comprehensiveness of the software product line to cover multidisciplinary nature of the construction (Architect, Structural and Mechanical and Electrical)
- e) The number of users of the software within the industry.

The number of users of the software within the industry was identified as important by Interviewee CP1. Based on their observation, most players in the Malaysian construction industry prefer to use Revit as compared to the other products due to the same company, Autodesk, which produces the AutoCAD. More users mean less problems of compatibility of the software when getting involved in a project when the project participants are expected to use Revit platform.

4.3 CASE STUDY FINDINGS FOR COMPANY A

This subchapter discusses the data that was found in Company A. It starts by providing the background of the company which is then followed by the current status of BIM implementation, the chronology of BIM implementation, the benefits of BIM and the challenges of BIM implementation. After that, the readiness criteria that were identified within the company are discussed according to the category that they belong to.

4.3.1 BACKGROUND OF COMPANY A

Company A is an integrated design consultancy. It has a main office in Kuala Lumpur with 3 satellite offices located in Terengganu, Sarawak and an overseas branch in Jakarta. It is a local Bumiputera status company for oil and gas engineering consultants in Malaysia and provides a complete engineering design service to the oil and gas and petrochemical industry. Its service covers primarily the areas of:

- Design Engineering of offshore oil & gas production and processing facilities
- Design Engineering of onshore receiving facilities and loading terminals
- EPCC projects of facilities

In 1984, the company was formed in a joint venture with an established American oil and gas company. In 1990 however, upon the decision made by the American company not to continue the joint-venture, Company A bought over the company's shares and changed its name. The company was accredited to MS ISO 9001 Quality System since December 1993 and later to MS 9001: 2000 in 2002. With a paid-up capital of RM5 million, authorised capital of RM10 million and an annual turnover achieving RM94 million in 2008, the company has a very good track record working with major oil and gas companies such as Exxon Mobile, Shell, Talisman, Murphy Oil, Nippon and Petronas. Currently, the company employs more than 450 people comprising experienced engineers, draughts persons and support personnel. Within the Malaysian context, Company A is a registered service provider for Petronas, the biggest oil and gas client in Malaysia, and also G7 contractor with Construction Industry Development Board of Malaysia.

As for the company structure, it is divided into two main areas, Technical and Corporate Function. Technical area consists of seven technical departments which are Project Management, Process, Instrument, Pipeline, Electrical, Mechanical and Structural. The Technical team delivers the core business activities of the company which are process design, mechanical and piping design and drafting, structural and civil design and drafting, electrical and instrumentation, and project and

construction management services that includes EPCM and PMC. Meanwhile, the Corporate Function area is responsible to provide support for the company and it consists of five departments, which are Development and Commercial, Quality Assurance, Finance and Administration, Human Resource and Management Information System. As for 3D authoring tools, the company is using Aveva Plant Design Management System, PDMS and BOCAD within the Mechanical and Structural departments respectively. The list of interviewees involved in the case study is simplified in Table 4.6 as following:

Table 4.6: List of the interviewees for Company A

Name	Background	Area of Expertise	Designation	Experience(years)
CA1	Mechanical Engineering	Mechanical Design and Engineering	Engineering Manager/ Board of Directors	More than 20
CA2	Mechanical Engineering	Piping Design and Engineering	Senior Engineer/PDMS Administrator	More than 20
CA3	C&S Engineering	C&S Engineering and Management	Lead Design Engineer/Coordinator	More than 20
CA4	C&S Engineering	Structural Design and Drafting	Designer/Bocad Administrator	More than 20

4.3.2 CURRENT STATUS OF BIM IMPLEMENTATION

Company A has demonstrated the most advanced status of BIM implementation as compared to other companies that were investigated. In addition, the researcher was also granted almost unlimited access to collect the data which resulted in a much richer data collection from the company. Therefore, in discussing the BIM status of implementation, three subchapters are prepared to avoid too much information loaded into one subsection. The discussion starts with the associated BIM designation found in the company, followed by BIM use within the current practice, and finishes with BIM related design deliverables that were common to the company's practice.

4.3.2.1 Associated BIM Designation

Before the associated BIM designation is discussed, it is important to understand the departmental structure of the company. The 3D modelling authoring tools are used by two departments to deliver the 3D model as part of the design work requirement. The two departments are Mechanical and Structure and are led by a Mechanical Engineering Manager and a Structural Engineering Manager respectively. Generally for both departments, the people who are working within the department are divided into two divisions; the engineering and drafting. The engineering division consists of engineers, and is responsible to undertake all engineering activities including conceptual and detail

engineering design activities, studies, calculation, reports and specification. The division is led by the Engineering Coordinator. Meanwhile, the drafting division consists of drafters and designers who are responsible to undertake associated work related in producing the design deliverables based on the engineering output. The division is led by the Design Coordinator who is also carrying the responsibility as PDMS and BOCAD Administrator in the Mechanical and Structural Departments respectively. The associated BIM designation within the departmental structure of the company is simplified in Figure 4.1.

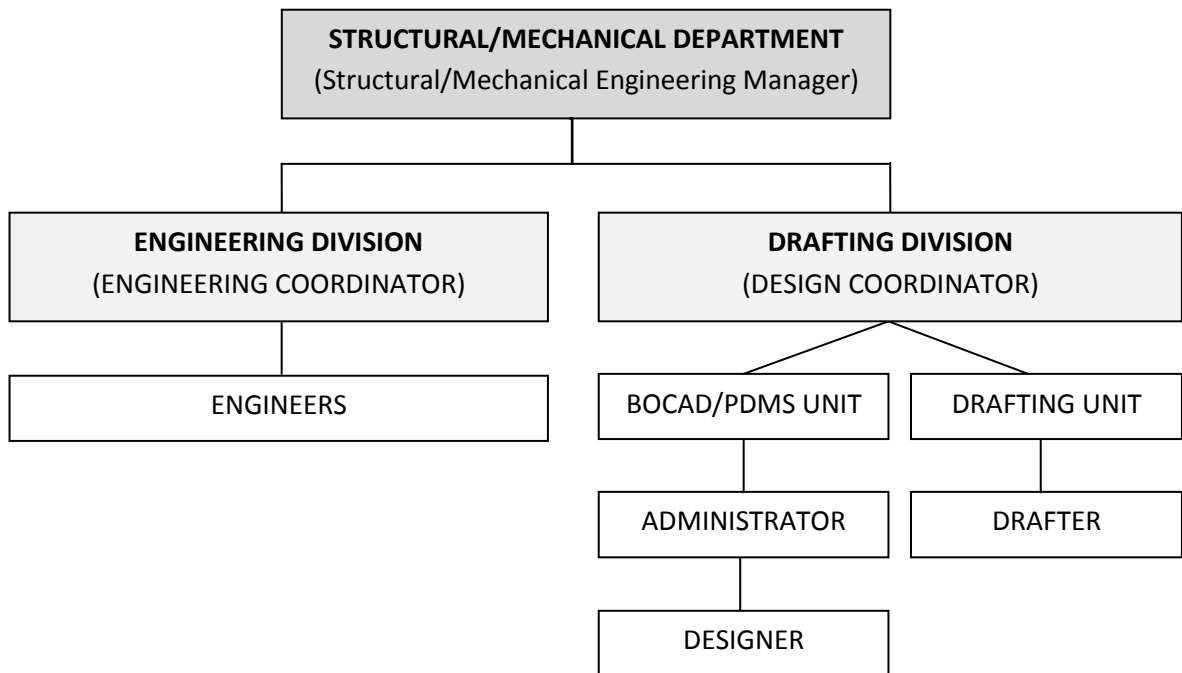


Figure 4.1: Associated BIM designation within the departmental structure of Company A.

By referring to Figure 4.1, company A has created 2 associated BIM related designations, which are the Administrator and Designer, residing within the drafting division. At the time the case study was conducted, Case A had three PDMS Administrators and five PDMS designers working in the Mechanical Department while 2 BOCAD Administrators and five BOCAD designers were working in the Structural Department. All of them are hired on a permanent basis. The number of designers and administrators on the contract basis is not revealed, and depend on the number of projects that the company needs to undertake at one time. For both BOCAD and PDMS designers, the job scopes are limited to the authoring the 3D model and preparing the design deliverables which is normally extracted from the model such as the drawings and material taking off and delivering clash check. The backbone of the BOCAD or PDMS teams lies on the Administrator where they carry a management and administrative role of the software system together with technical modelling

responsibilities. The roles are further listed as following according to both PDMS and BOCAD administrators:

- a) The administrative role of the software (such as creation of project, setting up of users and environment, setting up database, database management functionality, database integrity checking utility).
- b) Preparing and updating catalogue components and specifications to be used by the designer.
- c) Data checking and liaison with internal and external engineers to ensure the completeness of the data and information that is received to produce the 3D models and other design deliverables.
- d) Focal point for all disciplines related to the 3D model and it's deliverables
- e) Monitoring and controlling the production of design deliverables by the designer and drafter in terms of the dateline, the consistency and accuracy of design deliverables. The deliverables must also be in compliance with client's contractual requirement, industrial standards and codes.
- f) Troubleshooting and assisting the designer with the technical problem of the software.
- g) Organising and delivering training courses for newly hired designers. The roles are expanded as a mentor and trainer for on-job training.
- h) Developing and updating training modules and materials.

4.3.2.2 BIM Use within Current Business Process

BIM use within the current business process of company A can be seen either during the conceptual design or detail design or both, depending on the contract that was awarded. Therefore, the BIM use is further be discussed in a separate subchapter to provide a better focus of narration.

4.3.2.2.1 Conceptual Design

The use of BIM model in the organisation's Standard Operating Procedures starts as early as the conceptual design stage. Briefly, the conceptual design starts after the company receives a Feasibility Study Report from the client. The Feasibility Study Report is in a form of a paper-based document consisting of a brief description regarding the need of the client, location and technical data of the site and facilities. Some examples of the technical data are the coordinates of the site, volume of gases or crude oil that the facilities will produce, the oil composition, volume of gases inside the well, the expected lifespan of the well, seismic data and commercial value of the platform. The Feasibility

Study Report will firstly be submitted to the Process Department to deliver the process engineering and design. At the end of the process engineering and design, the Process Flow Diagram (PFD) and Plant and Instrumentation Diagram (P&ID) will be produced and distributed to the other departments i.e. Structural, Mechanical, Electrical and Instrumentation. Both the PFD and P&ID are issued in softcopy in PDF format and printed documents for further reference by the related departments.

The Feasibility Study Report, Client's Technical Spec, PFD and P&ID and equipment layout are then used by the structural department to produce the conceptual 3D structural model before the other departments can commence their conceptual engineering design. The conceptual 3D structural model is a pre-requisite deliverable to guide other departments in design, position and route of their component which also minimises clash between the various systems. The focus of the conceptual 3D structural model is on the structural element of the facilities since the cost of the project is highly dependent on the volume of the steel used. There are 2 types of conceptual 3D structural model, the BOCAD conceptual model and the SACS conceptual model. The structural engineer first starts the design activities by calculating and analysing the engineering aspect of the structure by using the structural design software, SACS. The software is an integrated finite element structural analysis suite of programs that provides the design, fabrication, installation, operations, and maintenance of offshore structures. The SACS software is used in determining the type and size of each structural element and the long lead item. The long lead item, for instance the primary beam, is any structural component that requires more than 6 months to be delivered at site after the order is placed. Therefore, across the project life cycle, after the long lead item is designed and decided, it cannot be altered anymore. The time consuming nature of the item has also forced the client to dictate within the contract terms that the item must be determined as early as the conceptual design stage. It is worth noting that within the conceptual design; only the design of the long lead item is locked while other components such as secondary beams, braces and staircases are still subject to change and further refinement as the structural design progresses in the detail design stage. Subsequently, the output of SACS software in the form of paper-based 3D model and drawings are delivered to the BOCAD team to work out the BOCAD conceptual model. The interoperability issue between the software SACS and BOCAD has forced the company to reduce the workflow into manual data entry since the direct transfer of the model is not possible. Once the conceptual model is authored in BOCAD, the deliverables in the form of BOCAD model and SACS output both in paper-based documents and electronic PDF format are then delivered to the engineers in the Mechanical and Piping Department and Electrical and Instrumentation Department. The 2D BOCAD extracted drawings of the plan view, elevation and cross section are also submitted alongside the BOCAD model and SACS output.

Similarly with the structural department, once the mechanical and piping engineers have determined the major equipment, conceptual piping route and mechanical long lead item, the output is then delivered in a paper-based format to the PDMS team to work out the conceptual 3D PDMS model. Although it is still at the conceptual stage, normally around 70% of the components are precisely determined. At this stage, the PDMS designer will also upload the conceptual BOCAD model into PDMS software to detect clash simultaneously while authoring the mechanical equipment and piping system clash with the structural system. Once the 3D authoring is finished, the PDMS conceptual model, which is integrated with BOCAD conceptual, is passed to the reality review workstation within the same Mechanical Department to deliver the accessibility review. The review, which is also known as a walkthrough review, is developed by using the software Reality Review where the PDMS model is first uploaded into the software. A representation of a human avatar, which is scaled down from a 6-foot man, is used. The avatar grasps a walking stick in the right hand and a tool box in the left hand. The width between both hands is set at 1.2m to represent the clearance of walking width which is in compliance with the Client's Technical Specification. The avatar is then navigated to walk through the escape route inside the platform to evaluate any obstacles that inhibit the actual people to access the route, passing machinery and instruments. If the review results in zero clashes, the output of the reality review will then be developed further into an animated MP4 video format. If not, the obstacle report is prepared and sent to the engineers for revision. Meanwhile, the video is also submitted to the client for review together with the conceptual design proposal which has both a softcopy and hardcopy of PDMS and BOCAD conceptual 3D model.

Soon after, a meeting is set and arranged in a big room with the client to get approval for design. A proposal is presented by the lead engineers with a roughly estimated budget, technical advantage, cost advantage and also operation and constructability advantage. During the meeting, the PDMS model which integrates the BOCAD model will also be projected on the white screen, while discussing the aspect of operation, maintenance, safety, escape route and ergonomics of the design. The MP4 video of the walkthrough review is also screened to demonstrate the accessibility of the design. The comments and feedback from the client is then taken into account for further refinement of the design before the detail design is commenced. Upon discussion and agreement, some data and information is also provided by the client to produce the Design Basis Memorandum (DBM) as part of the Conceptual Design deliverable. The DBM comes with detailed specification and information regarding the project's need which is not included in Client's Technical Specification (CTS). Some examples of the information are storm water and soil data, water level, borehole analysis, water depth, and the amount of mechanical equipment that needs to be installed. The detail design activities are then governed and guided by the DBM and CTS.

4.3.2.2.2 Detail Design

After the conceptual design is completed, the team from the department of Process, Mechanical, Electrical and Instrumentation will conduct the detail design activities. At this stage, secondary equipment or instrumentation is designed and refined in further detail. Examples of the equipment are the vessel, pump, and pipe type and route and conductor slot. All of the data and information coming from various engineering departments on paper will be combined together by the PDMS administrator before they are distributed to the PDMS designer for the purpose of authoring the PDMS Model and Structural Team to deliver detail structural design activities. There are two 3D models (according to the discipline) that are authored in PDMS software, which are Mechanical and Piping Model, and Electrical and Instrumentation Model. At this stage, the PDMS team will work hand in hand very closely with structural design and other engineering team members. A variety of 3D Models thus require a PDMS administrator to carry an essential responsibility to ensure the accuracy and completeness of all data and information provided by engineers from various departments. At the same time, the PDMS administrator must also prepare the database and compartmentalisation of the PDMS software to be used by the PDMS designer. Meanwhile, the PDMS designer's scope of work is just limited to authoring the 3D model and extracting design deliverables from the model.

Meanwhile in the Structural Department, upon receiving all of the technical data and information from other departments, SACS software is used by the structural engineer to conduct detail structural analysis and design. The most important data needed from other departments is the live load and dead load from various systems. Some examples of the loads are machinery and instrumentation loads and piping route loads. Since the loads are only available after the other departments have completed their engineering task, therefore the structural teams can only start executing the detail design activities in concurrence with the PDMS team authoring the detail PDMS model. The location and size of each structural component is all calculated in detail by using SACS. Lastly the foundation is designed after the total weight of the structure is determined. The final output of the SACS in drawings format and specification data sheets are then sent to the BOCAD administrator to manage the authoring of the 3D BOCAD model and to produce the design deliverables. The responsibility and job scope of the BOCAD Administrator and Designer is similar to that of the PDMS Administrator and Designer in the Mechanical Department. Once the 3D BOCAD is fully developed, the model is then submitted to the PDMS team to conduct another round of Clash Check by using PDMS software.

After all of the detail engineering analysis and design is completed, another meeting will be arranged with the client to finalise the detail design and obtain approval for the design documentation.

Similarly, in the Conceptual Design meeting, the discussion and comments on the design are centred on the PDMS and BOCAD models that are projected on the screen in the big room. The meeting is attended by lead engineers of all departments coming from the client and Organisation A. Only after the design is approved the company can prepare the detail deliverable to be submitted to the client and EPC contractor. The list of the deliverables is further explained in the next sub-section. It is also important to mention that within the Case A practice, the Material Taking Off or Bill of Quantity as part of the design deliverables is carried out individually according to the department before it is combined together during the detail design stage. The practice is slightly different from the AEC industry in Malaysia where the quantity of the whole building is 'taken off' by dedicated personnel which is the Quantity Surveyor.

In both the PDMS team and BOCAD team, along with 3D models, 2D drawings are also extracted from the models and further detailed in AutoCAD by the drafting unit which resides within the Mechanical and Structural department. The use of AutoCAD drawings are still needed to comply with contract requirements although the organisation has implemented 3D BIM since 1998. Furthermore, the site people still rely on 2D drawings in fabricating and installing the structure as further explained by one of the lead engineers. Also, another issue that is worth mentioning is the interoperability issue between various software packages which has demanded the company to conduct manual data entry in authoring 3D model in PDMS and BOCAD software. Therefore, in order to ensure consistency and accuracy of information, two departments are established to carry the responsibility. The first one is Internal Document Check (IDC) which focuses on checking the consistency and accuracy of information within an individual department, and is especially important in situations of manual data transfers between SACS and BOCAD. Secondly is the Interdisciplinary Document Check which focuses on checking the consistency and accuracy of information across the department.

In summary, the use of BIM within the company process flow is to:

- a) Communicate design intent and information via 3D model
- b) Author the 3D model
- c) Extract drawings from the 3D model
- d) Determine associated information such as the Material Taking Off, Weight, Surface Area and Centre of Gravity
- e) Conduct Automated Clash Check
- f) Deliver Walkthrough Review
- g) Laser scanning technology for existing structure

4.3.2.3 BIM Related Design Deliverable

Before the findings of the detail design deliverable is further discussed, it is important to clarify again that the researcher could only gain access into the drafting divisions within the Mechanical and Structural departments. Therefore, the design deliverable is limited to both divisions and does not comprehensively cover the overall design deliverables produced by all departments within the company.

The BIM related design deliverable of the company, at the end of Detail Design activities, can be categorised into two types i.e. primary and secondary design deliverable. The PDMS model which consists of Mechanical and Piping Model and Electrical and Instrumentation Model are the primary deliverable for the PDMS team, and the BOCAD model which is meant for structural models is the primary deliverable of the BOCAD team. Therefore, the databases of all 3D models in the native format of the software are burnt onto a separate CD as part of the detail design deliverables including clash check review in PDMS. Meanwhile, the secondary deliverables, mainly the drawings and documentation are the deliverables that are extracted from the 3D Models. They are:

- a. Electronic and hardcopy of Drawings which consist of piping drawing, isometric, cutting plan and bar nesting, equipment layout, framing layout, structure member profile, joint details and fabrication. The electronic file format that is compiled is native BOCAD and PDMS format and DWG AutoCAD Format.
- b. Material taking off (MTO) and specifications
- c. Clash check report.
- d. Centre of gravity report. Within the company, the centres of gravity drawings are extracted from BOCAD rather than SACS software due to the accuracy of the software according to the lead engineer.
- e. Weight of the structure and surface area report

4.3.3 THE CHRONOLOGY OF BIM IMPLEMENTATION

According to Interviewee CA2, in 1994 the client started a project which targeted at identifying and implementing any system that could reduce the design and construction cost as much as 30%. One of the solutions was by implementing the 3D parametric tools across the industry. Through a series of workshops and open table discussions with the representatives from the EPC contractors and design consultants (which was attended by Interviewee CP2), the industrial players finally achieved a consensus, that Aveva PDMS was to be used for the offshore project and PDS system was to be used

for the onshore project. For the Structural Modelling, BOCAD software was agreed upon. The justification that was made by the client was to standardise and align the software use with the majority of the early adopters within the industry and minimise the interoperability issue between the players in the same projects. Once a consensus was achieved in 1995, the client mandated the use of software in their contracts.

The specific client's demand for a type of software had a direct impact on Company A. Since the company is focusing on the design of offshore projects, it was obligated to only implement PDMS and BOCAD. The company started the implementation in 1995 by acquiring a few licences for BOCAD to be used in the Structural Department, followed by an acquisition of PDMS software licences for the Mechanical Department slightly later within the same year. The number of software that was acquired, however, could not be retrieved since it happened 14 years ago and none of the interviewees could remember the amount.

Subsequently, after the purchase of both softwares, a formal training was also conducted by the software vendor to a selected number of staff. Simultaneously, Company A hired a very experienced PDMS Administrator from United Kingdom to assist the implementation process. For the BOCAD administrator, the company appointed their internal staff to undergo an intensive training in Germany where the software was developed. The training was conducted over the period of one month and covered a formal in-class and on-the-job training where the staff were sitting beside the trainer and were guided through the project. The cost and complexity of the software has justified two different approaches in appointing PDMS and BOCAD administrators but PDMS cost was higher and more complex.

Within the first year of the BIM implementation, the urgent demand made by the client forced the Administrators to carry a one-man-show job where they are responsible to carry all of the roles listed in the subchapter 4.3.2.1 Associated BIM Designation. The focus, however, concentrates on the latter to meet the contract requirement. The company therefore has paid a special rate for the administrator which also considers the pressure, technical and non-technical complexity of the software to be implemented within the current CAD-based process flow. It is also worth mentioning that although the implementation of PDMS and BOCAD are mandated by the client, the project dateline still remained unchanged, following the CAD-based process flow which exacerbates the implementation progress. Meanwhile, a number of personnel were also selected and trained to become PDMS and BOCAD designers. The formal training during that time was conducted by the software vendor right after the acquisition was made, while the on-job training was assisted by the Administrator. As far as

people are concerned, the implementation of both PDMS and BOCAD has created two new roles for the company, the Administrator and the Designer. A few years after the implementation, after achieving a certain level of competency through a series of on-job trainings, the Designer took over the Administrator roles in delivering the 3D models and associated deliverables. During that time, the Designer was still responsible for refining the drawings in CAD and shortly after that, the company reduced the Designer roles to fully concentrate on the 3D model, while the CAD drawing refinement was given to the drafters in the CAD team. As a result, the roles and responsibilities that were listed in the section subchapter 4.3.2.1 Associated BIM Designation, has become the company's standard definition of roles and responsibility for Administrator and Designer.

Meanwhile, the model-oriented process demanded the company to restructure their current process flow in 1995. The main source for consulting the restructuring came from the externally hired Administrator, the trainer from the software vendor and by the management team itself, who attended a series of awareness programs prior to the software acquisition. As compared to the CAD process flow, the main focus when implementing BIM has changed from drafting the drawings into authoring the 3D model for both PDMS and BOCAD software. Therefore, the 3D model has become the central focus as main deliverables. Drawings nonetheless are still needed to comply with the contract requirement, but instead of drafting them individually in CAD, they are all extracted from the model. Meanwhile, the restructuring process was made by analysing the previous CAD-based process flow and identifying the change that is required to place BIM within. Company A has identified that a new additional activity, the 3D model development, must be incorporated into the previous CAD-based process flow and therefore all of the engineering design outputs must be sent to the associated Administrator. The BIM implementation during the first year, however, was focusing on authoring the 3D model and extracting the drawings. Once the selected Designer and Administrator were confident with the drawings extraction, they then started to move onto extraction of the other deliverables such as Material Taking Off. During that time, the implementation took place in isolation, simply to fill the departmental need rather than to cater for the whole business process. For instance, the PDMS was used only to model the piping route in the Mechanical Department whereas the BOCAD was used to model the offshore facilities structure in the Structural Department. After achieving a certain level of confidence and competency, the implementation of BIM has moved beyond departmental boundaries, as witnessed by the need to integrate Structural BOCAD model with PDMS piping route model for clash check, which has also redefined the process flow and job scope of the Administrator. All of the interviewees of the company proudly mentioned that their company was the first oil and gas consultancy in Malaysia to have successfully integrated BOCAD model into PDMS software for clash check by using a special protocol. The claim was also made on

their company profile and milestones of achievement. Later on, the application of PDMS software was extended to cater to other departmental needs, occurring in a few stages until reaching the standard operating procedure as explained in Section 4.3.2, Current Status of BIM Implementation.

4.3.4 THE BENEFITS OF BIM

During the implementation of BIM, the company received many benefits. The benefits were better communication of design intent, knowledge gap reduction between junior and senior staff, reduced risk of losing project information process; it was streamline, and time saving. The details of the benefits are further discussed in the following subchapter.

4.3.4.1 Communicate the Design Intent Better

All of the interviewees agreed that the implementation of 3D parametric modelling tools as part of BIM has improved the communication of design intent that takes place within and outside the organisational boundary. The improvement lies on the 3D visualisation and drawings consistency where everyone involved has the same understanding of what is being designed.

4.3.4.2 Reducing the Knowledge Gap between Junior and Senior Staff

After the BIM implementation, the management noticed that the knowledge gap between junior and senior staff had drastically reduced as compared to using the 2D approach alone. As Interviewee CA1 explained, the main reason is the fundamental nature of 3D modelling where each component is represented with digital 3D objects that carry attributes and parametric rules. The tools have assisted the junior designer to understand every component that they are authoring by providing 3D visualisation and the attributes that need to be assigned. In 2D approach on the other hand, every object is made of a collection of lines and requires the designer's interpretation and imagination to define what the object is. The 2D approach therefore requires a longer technical site experience to understand each component and its attributes and thus makes it difficult for the junior staff with a lack of experience. Furthermore, the 3D modelling tool has enabled the junior staff to try and experiment with the design which helps a lot in sharpening their skills and understanding.

4.3.4.3 Reducing Risk of Losing Project's Information

One of the main problems with Company A is keeping their manpower. Since there are not so many players in the Malaysian Oil and Gas Industry, the manpower comes and goes, depending on the offers made by their competitors. Therefore, the use of BIM has helped the company to keep and

structure the project's data and information in a digital repository. When somebody in charge is moving out, the newcomer can simply refer to the BIM database and continue the job from there.

4.3.4.4 Process Streamline and Time Saving

In previous CAD-based process flows, one of the biggest challenges faced by the company is to ensure drawings consistency and clash free design. The massive number of drawings that were produced individually in a project has made document consistency and clash checking a very time consuming and tedious process through the manual approach. Therefore, most of the time was spent on documentation and checking rather than focusing on the aspect of engineering and design. With the implementation of BIM, since the virtual 3D model is the source for all drawings, design errors caused by inconsistent drawings are all eliminated. Meanwhile, the clash checking process and Material Taking Off are taken automatically by using the software which also shortens the time duration. As an overall result, the time spent for documentation, checking and taking off material is reduced significantly and the people can give extra focus to the aspect of engineering and design. Thus, the company has managed to streamline the process flow and save time.

4.3.5 CHALLENGES OF BIM IMPLEMENTATION

The implementation of BIM, especially during the early stage, has caused Company A to face many challenges. Some of the challenges captured during the case study were a difficulty to retain team members, interoperability issues of the software, negative perception of new technology, pressure to meet unchanged project's dateline and also resistance by the senior staff. The challenges are further discussed in the next subchapters.

4.3.5.1 Difficulty to Retain Team Members

The ad-hoc nature of BIM pushed by the client has created a high demand for competent BIM Administrators and Designers. A limited number of such professionals to cater for industrial needs has forced Company A's competitors to pinch their BIM Administrators and Designers by offering better wages and benefits. As part of Company A's risk management strategy, during the BIM implementation, the company trained more than 8 personnel to become BIM Administrators and Designers. The company predicted that they might lose some of their staff early before BIM implementation and therefore chose to train as many as they could. After three years of BIM implementation, as predicted, half of the trained personnel have moved to other companies while the remaining half, mostly their BIM Administrators, chose to stay with the company due to the counter offer made by the company.

4.3.5.2 Interoperability of the Software

One of the main motivations of adopting BIM software is to carry automated clash check between PDMS and BOCAD. During the early years of implementation however, the nature of both software, which were created for different disciplines and by different companies, created an interoperability issue whereby the model that was created in the BOCAD software could not be integrated automatically into the PDMS software. Therefore, the clash check could not be delivered in the PDMS software. For the company, the integration is very crucial since it would save a lot of time and effort through the automated clash check. Therefore the company has driven their own initiatives to resolve the matter by calling representatives from PDMS and BOCAD to sit down together with their PDMS Administrator to work out the matter. Although initially the integration was not perfect with some components missing and mismatched, the company has finally managed to develop a special protocol and is known as the first user of PDMS to have successfully integrated BOCAD files into the PDMS environment in Malaysia.

4.3.5.3 Negative Perception of the New Technology.

During the early stage of BIM implementation, many people within the company involved either directly or indirectly, were not convinced with the benefits that BIM could offer even though some of the awareness programs had been organised. The problem was worsened by the need to learn new software and a lot of mistakes being made during the learning and delivery process which slowed down their main business activity.

4.3.5.4 Pressure to Meet Project Dateline

All of the interviewees admitted that the early stage of BIM implementation was very tough. The BIM Administrator and Designer had to attend the formal and on-job training while at the same time accomplishing the project deliverables on time. Meanwhile, the BIM software itself requires a dedicated task of customisation to produce the drawings that meet the client's requirements, especially the isometric drawings. The numerous intense activities that needed to be delivered was worsened by the client, who had not changed the project dateline despite making BIM compulsory, and demanded the digital 3D model to be submitted straight away.

4.3.5.5 Resistance by The Senior Staff.

The company has identified internal resistance by the senior staff as the biggest challenge during the early stage of implementation. The compulsory demand made by the client was unable to persuade the staff to accept the change. The situation was also worsened with one of them coming from the

middle level management. The seniority and management post that they were holding were considered very critical as they could influence the subordinates and people around them to pull back the implementation. As mentioned by Interviewee CA1, one of the main reasons for their behaviour is they struggled to learn new things as all of them were over 40 years old and very comfortable with CAD process flow. Meanwhile, the other reason was the staff did not want their position to become vulnerable.

4.3.6 BIM READINESS CRITERIA

This subchapter discusses the readiness criteria that were identified in Company A. The discussion is arranged according to the readiness elements and categories that each of the readiness criterion belong to.

4.3.6.1 Process

Table 4.7: Readiness criteria for process element that was identified in Company A

PROCESS ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
PROCESS CHANGE STRATEGY	Communication Small and Incremental Approach Incentive and Reward Process flow Redesign
IMPLEMENTATION MANAGEMENT	Implementation Plan Monitoring and Controlling Adequate Resources BIM CAD Coordination
POLICY	Contract Amendment

Table 4.7 summarises the readiness criteria within the technology element that was identified in Company A. Nine readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.3.6.1.1 Process Change Strategy

As discussed in Section 4.3.3, The Chronology of BIM Implementation, the process flow redesign is identified as a readiness criterion in implementing BIM. The justification lies in the model-oriented approach where the 3D model itself has become the focal point which has created new deliverables

and process flows which consist of a new sub-department and new roles of people. According to Interviewee CA1, the documented Standard Operating Procedure (SOP) prior to the BIM implementation as part of ISO-Certification requirement was identified important in assisting the process flow redesign. The SOP has eased the company in reviewing the CAD-based process flow, identifying the changes that are needed and standardised the new process. The externally hired BIM Administrator and representatives from the software vendors were also mentioned important to consult the change.

Another feature of BIM readiness criteria at Company A was engaging a stage by stage approach as can be referred to in Section 4.3.3, The Chronology of BIM Implementation. Occurring first in an isolated approach, both structural and mechanical departments were focusing on developing technical competency in filling the departmental need before moving beyond departmental boundaries through the integration of the model for the clash check, and finally catering to the needs of the whole company. The progression of BIM uptake as mentioned by Interviewees CA2 and CA3 must be defined through a series of small objectives which must also align with the technological trend of the software tools.

As explained in Section 4.3.5, Challenges of BIM Implementation, the early stage of BIM implementation was very tough with a high intensity of activity to develop BIM competency and concurrently deliver the project with an unchanged dateline. Hence, the BIM Administrator and Designer were required to carry multiple tasks at one time. To facilitate the extra effort, stress and motivation of the staff, Interviewee CA1 explained how the company has introduced several incentives such as monetary and working leave. Initially, a little amount of monetary incentive was paid along with the wages to the designers to motivate the staff to keep on going. Overtime, the incentive was replaced with a new wages scheme which was higher than the drafter. Meanwhile, the Administrator received special rates of pay during the early stage of implementation before it became a norm hitherto justifying the importance of the roles and responsibilities that the Administrator must carry for the project and the company. The use of monetary incentives also helped to avoid the Designer and Administrator from being pinched by another company. Although the specific amount of incentives and wages was not mentioned by all interviewees due to the confidentiality issue, the incentives and rewards system is identified as the readiness criteria within Company A.

According to Interviewees CA2, CA3 and CA4, although the initial stage of BIM implementation occurred in only two departments, the interconnected nature of process flow has made BIM impact other departments, especially in coordinating and producing design deliverables. They agree that all

departments must be prepared to expect some delays and hiccups in the mechanical and structural departments as both were implementing a new process. Therefore, to assist the whole team, a new model update dateline was set up which consisted of a small portion of the model that needed to be delivered to enable other departments to deliver their job. Interviewees CA2 and CA3 also agree that the implementation of BIM must be communicated not only to the affected departments, but to all people within the company to make sure all personnel understand the situation better, thus avoiding causing extra pressure by pushing their department too hard to meet the dateline. Interviewee CA1 also supports the importance of communicating the change and has used direct personal contact to explain BIM implementation to all departments, evidenced by the following statement:

[...] First we need to get a buy-in from all of the people considering it will impact the whole process either directly or indirectly. We need to explain the benefit of having the change, and our commitment to take it as the company's standard procedure. We need to do the field work and I used direct personal contact. I walk around, meet them personally, especially the drivers in each department and talk it over. I am very confident, this morning you spread the words, they will talk to each other and by the afternoon everybody got the message [...] Interviewee CA1

Therefore, communication features was another readiness criterion identified in Company A. It is worth noting that 'drivers' is the term used by Interviewee CA1 which refers to a person who carries a positive attitude to develop themselves and walk the talk. Most importantly, the driver has the ability to convince people and brings people on board. The driver is not necessarily posted in a managerial position but can exist in each hierarchy of the company.

4.3.6.1.2 BIM Implementation Management

According to Interviewee CA1, part of Company A's practice and policy is to document any procedure or changes in the business process flow to comply with ISO requirement. The practice of documenting the procedure has brought benefits to the company in implementing BIM since it enables the implementation plan and procedure to be stored, referred to and refined in a structured approach. Meanwhile, prior to BIM implementation, plans were developed by the 3D teams from both the Structural and Mechanical departments which were led by the design coordinator, and the head of drafting unit. Although no specific guidelines were mentioned, Interviewee CA2 and Interviewee CA3 mentioned that the company was adapting to an international guideline to suit their BIM implementation needs. The researcher however, was not allowed to view Company A's BIM implementation plan, but it was mentioned that the plan consists of a series of objectives and technical competency that the company would want to achieve, which were connected with the milestones of budgeted cost and estimated time over a period of five years. Thus, the implementation plan is identified as one of the readiness criteria within Company A.

The monitoring and controlling of BIM implementation is also identified as an important readiness criterion in Company A. According to Interviewee CA1, an important aspect of monitoring and controlling was the monetary and expenditure. The implementation process must suit the limited and dedicated budget that was allocated. The documented implementation plan that comes with a series of objectives, which was discussed earlier, assists the monitoring and controlling process where it specifies clearly the milestones that need to be achieved. Meanwhile, Interviewee CA3 also mentioned the importance of monitoring the people's competency in implementing BIM. Since the company was adopting on-job training for the staff, the competency measurement and monitoring were made based on the speed and accuracy of delivering the 3D model. Both interviewees also agreed that the implementation of BIM came with unforeseen risks and challenges. Therefore some adjustments and alignments were required to keep the implementation on track and strengthen the need to conduct monitoring and controlling of the implementation progress as the readiness criteria.

All interviewees agreed that the implementation of BIM comes with dedicated expenditure, extra effort and time to cater to the need of acquiring the software tools, changing the business process and developing staff competency. Therefore, the company must allocate adequate resources to fill all the needs. From the technical and operational perspective, the most critical need was to have a highly competent BIM administrator to assist developing the competency of the people and to deliver the project at the same time, according to Interviewees CA2 and CA4. As evidenced in the Chronology of BIM Implementation, the management has responded to the need by hiring external staff from U.K to carry PDMS Administrator roles, and sending out their internal staff for a one month intensive training in Germany to carry BOCAD Administrator roles. Meanwhile, the top management mentioned the cost of developing staff competency as a critical requirement in implementing BIM. The different perspective of answers is expected judging from the different focus taken by the operational and management level. Since the management is responsible for managing the expenditure and profit of the company, many of the justifications are made based on a monetary basis. The supporting argument regarding expenditure to develop staff competency is as following, using PDMS as an example:

[...] We need to be extra careful with the cost of implementation and any possibility must be taken into account. The hardware and software and the training are among the known common costs. But when we projected the cost over a certain time period we started to realise that some costs are not worthy enough. Take for an example developing the staff competency. Based on our experience, a minimum period of 3 years is all that is needed to become acceptably competent in PDMS. At the first year of acquiring the software, we already paid a certain amount of money to the vendor, let's say RM100,000 with zero competency at our side. Every year we need to pay the maintenance fee of 25% and at the end of the third year we already spent

RM150,000 just to pay for the software alone, not to mention the cost of errors and any indirect costs that we needed to pay along the time. [...] Interviewee CA1

Although the focus slightly differs by comparing the top management perspective with the operational, the evidence suggests that the readiness criteria of BIM require adequate resources which come from monetary, competent manpower and also time.

Meanwhile, the implementation of BIM within Company A has started since 1995 and up until now, although the BIM tools are capable of producing the drawings, the CAD-based drawing production and team still exist within the company. Several factors were identified regarding the need of maintaining the CAD process and team as following:

- a) The limitation of PDMS and BOCAD tools require some components to be drafted in CAD
- b) Contract requirements that state the need to submit 2D CAD based drawings since the site people are still using 2D CAD-based drawings to fabricate the structure.
- c) People issue that causes some staff to lose their jobs if the CAD team is diminished.

Therefore, according to Interviewee CA1, it is important for the company to coordinate the process flow for the CAD and BIM with a clear job scope, thus adding another readiness criterion identified in Company A.

4.3.6.1.3 Policy

The only trace of evidence that supports the policy as part of BIM readiness criteria was the client demand of 3D PDMS and BOCAD models to be submitted as the main design deliverables. The demand was made compulsory in a form of drawings and native electronic copy as stated in the contract according to Interviewees CA2 and CA3. Therefore, as compared to previous contract arrangements, some new addendums of the contract were made by the client.

4.3.6.2 Management

Table 4.8: Readiness criteria for management element that was identified in Company A

MANAGEMENT ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
BUSINESS STRATEGY	BIM Objectives Alignment BIM Negotiation BIM Market Demand

MANAGEMENT COMPETENCY	Knowledge and Awareness Risk Management Commitment and Support
LEADERSHIP	Vision and Mission Motivation Top Down Approach

Table 4.8 summarises the readiness criteria within the technology element that was identified in Company A. Nine readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.3.6.2.1 Business Strategy

The main justification for BIM implementation was to comply with the client’s demands as can be seen in the following evidence:

[...] The enforcement of 3D modelling was started in 1995, and during that time, our clients made it mandatory to the industry. That is the major factor that has driven the change. The client simply pushes the button but the challenge is for us to face it since we do not know what and how the client wanted it to be delivered [...] Interviewee CA2

[...] The client has decided that for the offshore project, the data and information should be presented in PDMS and BOCAD. If there was no client involvement to enforce this, I don’t think this 3D would become a standard practice. [...] Interviewee CA3

Therefore, to remain competitive and ensure survival, the company has decided to invest in BIM implementation, being one of the pioneers although the client did allow some room for delaying the implementation according to Interviewee CA1. The enforcement by the client has triggered the company to start aligning the BIM implementation objectives with their business goal. During that time, a time-consuming and labour intensive CAD approach was identified as a major drawback. By engaging the BIM approach, the company could increase productivity as part of their business goals. The intelligent and integrated drawing production in 3D modelling has increased the productivity. Meanwhile, part of BIM objectives as can be seen in Section 4.3.4, The Benefits of BIM, is to have automated clash check which features the most important BIM objectives that support their business goal in providing an error-free design besides increasing productivity. Thus, the alignment of BIM objectives with a clear business goal is considered important criteria for readiness.

Interviewee CA2 also suggested a readiness criterion that is associated with a negotiation with business partners to develop common understanding when implementing BIM in a project. The interviewee further supported his suggestion by giving the following challenge that the company has encountered in a project:

[...] Although the client enforced the implementation of BIM within the industry, the players however had different levels of readiness. Therefore, in some cases the client has granted a few requests from EPC contractors to postpone the BIM implementation. The situation however has created difficulties in coordinating and communicating design deliverables between our company and the EPC contractor resulting in drawing errors due to conversion and information loss [...] Interviewee CA2

[...]A different level of BIM understanding during the early stage of implementation has also created an opportunity for dispute. For example, in PDMS there exist two types of clash, which are real and unreal. Some of the EPC contractors were not familiar with the unreal clash and simply put the blame on us and queried our design [...] Interviewee CA2

4.3.6.2.2 Management Competency

According to Interviewee CA1, the management buy-in to implement BIM starts with the awareness of the rewards that BIM could offer as the return of investment. The awareness aids in justifying the investment by comparing the effort and fiscal aspect with potential rewards such as streamlining the clash check process and consistent drawings production. Meanwhile, the management awareness of the BIM requirement was also mentioned as important covering the technical and non-technical issues. The importance lies in the need to direct the BIM implementation progress effectively and keep steering although the constraint is huge. The management competency to be aware of BIM requirement is also supported by Interviewees CA2 and CA3 in the following evidence:

[...] Unlike AutoCAD, where we purchased it as a one-off, the PDMS software license is on a yearly basis. Each year, the company needs to allocate expensive budget to renew the license and if the management is not aware of it, the implementation progress will definitely be interrupted [...] Interviewee CA2

[...] Implementing BIM is like when we first drive a car. Initially, we are not going to speed the car straight away. We need to drive slowly. Sometimes the car stops and sometimes we almost crash. Since the BIM process and software were new to us, the business process itself has slowed down due to a lot of mistakes that happened and even pressure with the project dateline remaining unchanged although the enforcement was made by the client. The management therefore should understand the situation and provide any means to make things easy [...] Interviewee CA3

Therefore, management competency to have an awareness of BIM requirement and potential rewards features as readiness criteria within Company A.

Another aspect of management competency that was identified important as readiness criteria is the effective risk management. According to Interviewee CA1, the BIM risk assessment and potential solution is a must prior to the BIM implementation to minimise disruption which could affect the implementation progress and consequently the business delivery. Similarly with the BIM challenges, some of the risks that were mentioned are as following:

- a) Losing BIM technically trained people
- b) Interruption of business process flow
- c) Staff resistance
- d) Budget overflow

Meanwhile, all of the interviewees recognised that BIM implementation requires long-term effort, energy and expenditure to develop the competency. A continuous commitment and support from the management therefore is identified as another readiness criterion. According to Interviewee CA1, the commitment and support from the management must be communicated and translated into visible actions. As can be referred to in the History of Implementation, the support and commitment of the management were evidenced and most importantly, according to Interviewees CA2 and CA3, satisfy the needs of the staff technically and non-technically. The support and commitment are evidenced by:

- a) Hiring technically competent personnel from U.K
- b) Sending out the staff to attend intensive training
- c) Making BIM a Standard Operating Procedure
- d) Monetary expenditure that never stops
- e) Monetary incentive to ease the pressure

4.3.6.2.3 Leadership

The implementation of BIM at the industrial level, within Company A, occurs in a top-down approach, evidenced with the client's compulsory demand. Consequently, the approach has enforced the management to implement BIM within their business practice following the same top-down approach. All of the interviewees agree that a top-down approach to drive the implementation features as an important readiness criteria. The justification lies in the management authority to make decisions and to provide adequate resources, as Interviewee CA2 supported in agreement. Meanwhile, according to Interviewee CA1, the management-led approach enables the business requirements such as business strategy and objectives to be aligned with BIM implementation. The interviewee further backed up the agreement by giving the examples of BIM in satisfying the business demand:

[...]The labour intensive nature, manual drawings coordination and manual clash check in CAD has inhibited us to cater for more business demand at one time. Therefore, what we could foresee was by implementing BIM, the process flow would be streamlined and the productivity would improve. As a result, we can take more jobs on at one time and as far as business needs is concerned, we would be able to increase our profit [...] Interviewee CA1

[...] As the client mandated it through the contract, we really have no choice other than to go for it or else we would be losing our job [...] Interviewee CA1

According to Interviewees CA2, CA3 and CA4, the early stage of BIM implementation has caused stress to the staff especially to the BIM Administrator and BIM Designer who are involved directly in the BIM implementation. The stress is rooted in a number of activities that need to be delivered simultaneously. Unfamiliar process flow, the need to learn and practice new software, the number of projects in hand and unchanged project datelines were mentioned as the activities causing a stressful environment. Looking from the human or soft issue, the management therefore must be able to ease staff emotion and motivate the staff. This was mentioned as an important readiness criterion according to Interviewees CA1 and CA2. The management were using a personal communication approach to motivate the staff, evidenced in the following statements:

[...] We need to use Public Relations. I did it by explaining to them this is their opportunity to upgrade themselves, prove their skills and reduce the gap between the senior people. We give them reasons why BIM is important to them and the company as a whole [...] Interviewee CA1

[...] I personally go to their workstation, talk to them personally about how important BIM is to support our business vision and mission, to make them aware that they are part of something important. But most importantly, I listened and responded to their problems [...] Interviewee CA1

[...] We will motivate them, ask them to keep on trying and make them aware of their personal value when they are capable of operating BOCAD software [...] Interviewee CA3

The first two of the above statements have also revealed another readiness criterion that needs to be included within the leadership category, a clear understanding of BIM vision and mission. The importance lies in directing the BIM implementation in accordance with the business strategy which is related to the business strategy category, to effectively motivate the staff and to effectively communicate BIM implementation to the whole company, which is also related to process change strategy.

4.3.6.3 People

Table 4.9: Readiness criteria for people element that was identified in Company A

PEOPLE ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
ROLES AND RESPONSIBILITIES	BIM Administrator/Manager BIM Designer/Modeller Head of Change Empowerment
SKILL & ATTITUDE	BIM Administrator/Manager BIM Designer/Modeller
TRAINING & EDUCATION	Formal Training On-the-job Training Continuous Education
WORK ENVIRONMENT	Knowledge capturing Knowledge sharing

Table 4.9 summarises the readiness criteria within the people element that was identified in Company A. Eleven readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.3.6.3.1 Roles and Responsibility

As evidenced in Section 2.2, two designations are identified which have clear roles and responsibilities, the BIM Administrator and BIM Designer. Along with the direct interview with the Administrators, the other evidence that supported the existence of the two roles came from the company's profile and training module. Basically, the Administrator is responsible to manage, administrate and facilitate all the technical aspects of BIM, while the Designer is the operator of the BIM software and therefore the roles are only limited to authoring the 3D model and preparing the design deliverables. According to Interviewee CA1, in defining the roles and responsibilities, the company has consulted an externally hired administrator, software vendor and has referred to the international technical report. In defining the roles and selecting the people to be trained as BIM Administrators and Designers, the interviewees also suggest the following:

[...] I kept it very simple. I look at who did the drafting. These are among the people that I would select to use the PDMS or BOCAD because they are responsible to generate the drawings. These should be the people to come in to use or operate BOCAD or PDMS. But at the same time, I must realise, there is a slight difference between 2D and 3D drafting where we need people to maintain the system and thus

we need the system administrator. We are looking at system maintenance so better for me to engage the engineer because their training is deference and they have deeper understanding of technology. An Administrator must be an engineer but the modeller is either a drafter or designer [...] Interviewee CA1

A clear definition of roles and responsibilities of BIM Designer and Administrator is therefore identified as another readiness criterion.

Another feature of readiness criteria within Company A is the presence of the Head of Change. The Head of Change is responsible to manage and drive BIM implementation towards achieving the company's expectation which is contrary to the BIM Administrator who concentrates on the technical aspect of BIM. In both mechanical and structural departments, the design coordinators were appointed as the Head of Change. According to Interviewee CA1, the seniority and experience, authority and leadership were mentioned as the criteria to lead the change and justify the appointment of design coordinators. On top of that, the Head of Change must also believe in BIM and possess a competitive and positive attitude.

A few roles were also mentioned, combined from all interviewees:

- a) Development of BIM implementation plan
- b) Coordinating and putting BIM designation in place
- c) Resource management to satisfy BIM implementation needs
- d) Liaison the BIM implementation between operational and management

Meanwhile, the selection of the design coordinator as the Head of Change is also associated with the authority to drive the BIM implementation. By appointing the design coordinator, according to Interviewee CA1, the line of order can be made easy as the staff are already used to receiving orders from their same superior. In addition, the BIM Administrator should also be empowered to make decisions in order to run the process effectively. The right to propose and implement process flow, the data that needs to be delivered by other parties, and the right to push the dateline were mentioned as part of the BIM Administrator's empowerment. The empowerment thus features as another readiness criterion in Company A.

4.3.6.3.2 Skills and Attitude

The right set of skills and attitude features as another readiness criterion in determining the success of BIM implementation as according to Interviewees CA3 and CA4. In selecting internal people with the right attitude to be trained as BIM Administrators and Designers, the management has set several

common criteria such as experience with a strong technical knowledge, quality of design works, relationship between associates, high competency of CAD, and IT savvy and literate. The BIM Administrator however, requires additional attributes, justifying the more important roles. The additional requirements are holding a degree in the related discipline, leadership, coaching skills and troubleshooting skills. Interviewee CA2 further stressed that technical knowledge is very important based on the following evidence:

[...] I think strong technical knowledge is essential. Like a few new staff that we train from fresh, they could not understand the components that are required to author. Take for instance the piping, they cannot see the connection of the client's requirement, specification and design basis. Myself, before I became a PDMS Administrator, I was a piping engineer for almost 5 years. So when we attend the training, we understand it better and easier [...] Interviewee CA2

[...] we will be looking for whether he/she understands every structural component that is normally involved in oil and gas industry, like what is W beam, what is U beam? and such. When we observe that he/she manages to catch up faster, we will pull them out from CAD to join BOCAD team. The most important thing is that they know what the elements/components are that they are going to author in 3D [...] Interviewee CA2

In identifying the right set of skills and attitude, Interviewee CA1 has mentioned an approach as can be seen in the following evidence:

[...]We can identify the right attitude and skill set through the interaction with our staff. Firstly, we asked the managers to screen out the names and we collected the feedback from their associates [...] Interviewee CA1

4.3.6.3.3 Training and Education

During the early stage of BIM implementation, the company engaged two types of training to develop staff competency, formal and on-the-job training. The formal training is a complementary training that was provided by the software provider, targeting the basic and entry level of the software. The training was conducted in-house for approximately one week. A more comprehensive formal training was also used to train the BOCAD Administrator by sending the selected staff to a BOCAD training centre in Germany for one month. The training targeted the development of advanced technical skills, specifically to satisfy the knowledge set to become a BIM Administrator. All interviewees admitted that the introduction of BOCAD and PDMS software into the industry was ad-hoc and the software providers themselves had limited competency in delivering advanced training which became one of the factors justifying the need to send the staff abroad, and to engage an externally hired PDMS Administrator. Meanwhile, the on-job training was conducted right after the formal training by using the currently running project. In the on-job training, the trainees were

guided and assisted personally by the Administrator. The on-job training targeted improving the modelling skills and confidence level and was conducted in a step by step approach, starting with a low risk activity.

Over time, the formal and on-the-job training became a norm within the company and the responsibility was fully taken by the Administrator. The company has a structured method to deliver the training as evidenced in their training guide and module. Although the researcher was only allowed to review the documents, the training module basically follows the same module that was provided by the software vendor with a refinement on the project sample for exercise. The project samples use the company's previous project data purposely to reflect the actual practice and reduce the gap between theoretical and practical. By using a scenario of a fresh graduate entering the company, Interviewee CA4 further explained the training process flow as following:

[...] Let's say fresh graduates enter the company, we will assign them into the CAD team to do AutoCAD first. Based on their work on AutoCAD, we will evaluate them to screen their competency especially on their understanding of every structural component that is normally involved in oil and gas industry and their initiative to develop their skills. When they manage to catch up very quickly, we will pull them out from the CAD team to join the BOCAD team. In the BOCAD team, I will formally teach them the basic and entry level of the software. Normally it takes two weeks to cover the syllabus. We used a dummy 3D model as a training example and 2 actual project data for them to practice, and prior to on-job training, we will test their competency. We cannot risk our projects in hand by asking them to go for on-job training straight away as we cannot expect any hiccups or delays anymore. Once everything is clear, we then assist them with on-the-job training, starting from low risk activities such as producing MTO or determining Centre of Gravity before letting them author the model [...] Interviewee CA4

According to Interviewees CA2 and CA4, the Administrator follows a similar training as the Designer but the experience determines whether or not one is qualified to become the Administrator. 5 years involvement with dedicated software was mentioned by both interviewees. Meanwhile, the need to continuously deliver the training lies on the need to maintain a consistent number of competent BIM Administrators and Designers. Both of the positions are in high-demand in the market and therefore the company has decided to increase the number to lower down the risk of interrupted work if the people are moving out from the company.

Besides formal and on-job training, Interviewees CA2 and CA4 also mentioned the importance to have continuous education to keep knowledge updated. The continuous education must be attended not only by the Administrators but also by the managers to align the BIM implementation with technology advancement so that the company can remain competitive. Both interviewees mentioned

that the need to attend continuous education was associated with technical knowledge such as software updates and new versions. Meanwhile, the managers must be kept educated on strategic knowledge of BIM. In summary, the formal training, on-the-job training and continuous education feature as essential readiness criteria within the category of training.

4.3.6.3.4 Work Environment

The company must have appropriate means to capture the knowledge of BIM as evidenced in the documented BIM process flow and training module that are updated from time to time, featuring a few versions. According to Interviewee CA1, as part of the company practice which also aligns with the ISO requirement, the staffs are responsible to document any change occurring in the process and technology, resulting in the knowledge to be captured and stored. The documented knowledge in the form of a written manual, procedure or module has helped the junior staff a lot in developing their competency. Therefore, an appropriate means to capture knowledge appears to be one of the readiness criteria.

During the visit at Company A, through observations, the researcher noticed that the company has five discussion rooms each located in the Mechanical and Structural Departments. Meanwhile, the Administrator has a bigger space in his workstation which could hold five people at one time, including himself, and the environment was very conducive to the junior staff being free to approach their senior to learn or ask for help. When the researcher directed the questions to Interviewees CA3 and CA4 regarding the work environment that supports knowledge sharing, the interviewees admitted that all of the aforementioned observations are important in creating the right and supportive environment to successfully implement BIM. The observation thus has formulated another readiness criterion, the work environment that supports knowledge sharing among staff.

4.3.6.4 Technology

Table 4.10: Readiness criteria for people element that was identified in Company A

TECHNOLOGY ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
HARDWARE	BIM ICT Policy Adequate ICT Infrastructure
TECHNICAL SUPPORT	Technical Support
SOFTWARE	ICT System Review

Table 4.10 summarises the readiness criteria within the technology element that was identified in Company A. Five readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.3.6.4.1 Hardware

According to Interviewee CA2, the implementation of BIM within the company requires a new acquisition of desktop since the currently available desktop could only satisfy the minimum system requirement. The minimum, as presented by the interviewee to the top management was not enough to support smooth running of the software, justifying the upgrade is not an option due to the inadequate motherboard support to receive maximum capacity of the RAM and graphic card. Other than that, adequate infrastructure must also be present, and is especially important when it involves communicating BIM with business partners and acquiring technical support from the software vendor. Therefore, an adequate ICT infrastructure features as another BIM readiness criteria.

Meanwhile, according to Interviewee CA1, the long-term investment of BIM software also requires a dedicated resource allocation to fill the needs of future advancement. Therefore, a well-defined policy must be in place to support the long term investment and is identified as another readiness criterion within Company A.

4.3.6.4.2 Technical Support

Interviewees CA2 and CA3 recognise that the technical support from the software provider is one of the key elements that ensure the successful implementation of BIM. The support must be considered as a long-term commitment and needs to include any updates and new versions of the software, training and troubleshooting. Limited internet service in 1995 was also mentioned as a critical drawback in providing responsive support. However, the company was so lucky since the software provider office for both PDMS and BOCAD are located in close proximity to the company, enabling the technical personnel to be called in very quickly whenever a technical problem occurred. Meanwhile, Interviewee CA1 also reinforces the need of having adequate technical support as following:

[...] The software provider must also assign us with competent technical personnel for the technical support. Implementing new things always comes with technical difficulties and the support must be adequate enough to assist the solutions. Some of the problems that we encountered last time were the drawings and Material Taking Off could not be extracted by the system [...] Interviewee CA1

The importance of having adequate technical support is evidenced and thus features as another readiness criterion.

4.3.6.4.3 Software

According to Interviewee CA2, the selection of BIM software occurs at the industrial level through a series of workshops and open table discussions with representatives from the EPC contractors and design consultants. A few criteria were used in deciding on the use of PDMS and BOCAD. However, Interviewee CA2 could only recall one criteria, that being the compatibility of BIM software with legacy CAD system. The importance of the criteria lies in the need to seamlessly exchange the data and information between systems and is therefore identified as another readiness criterion.

Meanwhile, according to Interviewee CA2, the BIM software features and advancements keep changing over time. Some of the features are simply related to the update of the software but some also require new purchases of software extensions to satisfy the current need of the company. In addition, the advancement of the software should also be aligned with the optimum hardware requirement to run the system effectively. Therefore, both the software and hardware advancement requires a regular review by the Administrator to keep abreast with the latest technology. This constitutes another readiness criterion that was identified in Company A.

4.4 CASE STUDY FINDINGS FOR COMPANY B

4.4.1 BACKGROUND OF CASE B

Company B was incorporated in August 2001 on the core business of trading fertilizer. From 2006 until today, the company has expanded with a diversified business majoring in the area of power, marine and shipping, and engineering and construction. The company headquarters are based in Kuala Lumpur with an annual turnover of RM10 million. Meanwhile, the company's authorised capital is RM10 million, of which RM6 million is fully paid up.

Within the engineering construction market sector, the company would like to describe itself as a one-stop centre specialising in Industrialised Building System (IBS), and providing a wide range of products and services for precast and offsite construction. It is important to note that the IBS system is similar to the offsite construction where the building components are cast and manufactured in the factory before being transported to the construction site for installation/fabrication. The company's service covers the planning, design and engineering, manufacturing and installation of precast components for a complete building and infrastructure. As for the departmental structure, the company has two departments, namely the engineering design department and manufacturing

department. The engineering design department is further divided into Mechanical and Electrical Division and Structural Division, making the company also serve as an independent integrated design consultancy. The implementation of BIM during the case study was only in evidence at the structural division although the company claims to expand the implementation across the company in their future plan.

Meanwhile, by utilising in-house resources, including over 50 tradesmen who cover 155 of the full range of construction skills, the company is capable of handling single projects up to the value of RM50 million. The company has a main factory and batching plant, located in Cyberjaya, in a neighbouring state of Kuala Lumpur. In 2010 the company expanded operations by adding 3 mobile factories located in the states of Johor and Negeri Sembilan, with a joint venture factory in Sarawak.

The company's business philosophy is designed around providing a quality service that will meet the customers' business objectives, and is underpinned by the trademark of the company's teamwork culture. The policies of the company are:

- a) Commitment to continuous improvement
- b) Quality management systems which underpin all company activities
- c) Commitment to ISO 9001 for design and manufacture
- d) Health and safety of all personnel and processes being a number one priority that is never compromised
- e) Continuous training for all employees
- f) The application of the most advanced information technology

Meanwhile, the background of the Interviewees who were involved in the case study can be referred to in the following Table 4.11:

Table 4.11: List of the interviewees for Company B

Name	Background	Area of Expertise	Designation	Experience(years)
CB1	C&S Engineering	IBS Structural Design, Development and Management	Engineering Manager/Principal	More than 20
CB2	C&S Engineering	IBS Structural Design, Development and Management	Senior Engineer	7

4.4.2 THE CHRONOLOGY OF BIM IMPLEMENTATION

The trigger for BIM implementation was initiated by the working level in 2008, considering:

- a) the need to deliver concurrent two stage design,
- b) the need to have precise drawings
- c) Problems associated with system clash

In the need to deliver concurrent two stage design, as compared to the traditional method of construction, the IBS method requires the structural team to engage a two stage design where the first stage focuses on mould design while the second stage focuses on detail structural design. After the project starts, the mould design stage must be completed within three months to allow the detail structural design to be executed concurrently with the mould casting at the manufacturing production line. The concurrent approach as the standard operating procedure within Company B has demanded every design deliverable, especially the drawings, to be delivered quickly.

Meanwhile the IBS method, the precision of the drawings is ranked at the top. To better understand the relationship between early design precision and IBS, the fundamental IBS concept is further discussed. The concept of IBS involves a production of standardised building components in which each of the components are produced in a plant located away from the site. The controlled environment of the plant has enabled the building components to be produced consistently by using industrialised method without being interrupted by the need to follow a stage-by-stage concreting sequence at the site. The process starts with mould and structural design before the production team cast all the components at the plant. The precast building component as the main deliverable of the plant production line is then transported to the site for assembly. Therefore, as early as during the design stage, the drawings must be made precise to ensure smooth running of the process flow. The precision of the drawings involves dimension, location of services, and location of opening for windows, doors and frames, which has made the CAD-based design difficult and time consuming to achieve. Therefore, a system that could support integrated and consistent drawings and design visualization was viewed as very important to simplify the process.

Meanwhile, the IBS nature and process flow has also made the site rework or adjustment become very expensive and therefore, jeopardise the profit making. The most critical site reworks are associated with soft and hard clashes which resulting in the IBS components being a misfit and clash between various systems. The CAD approach manual checking for standard 25mm tolerance (soft clash) and superimposing CAD drawings of various systems (hard clash) has resulted in a tedious and

time consuming activity which slows down the production of the drawings. The need to acquire an automated clash check has also triggered the need to implement BIM.

The company started the implementation of BIM by conducting an early review of the BIM software. The review was conducted by Interviewee CB1, who also carries the role as the Head of Change. The review was done by gathering Malaysian user feedback, product demonstration by the software representative and also by attending a series of seminars. Based on the information that was collected, Interviewee CB1 further proposed three items of software to the top management for training, SE CAD, Revit Structure and Tekla Structure. The purpose of engaging training prior to software acquisition is to satisfy the need to:

- a) Evaluate software suitability to suit the process flow and business and user needs
- b) Evaluate the technical competency of software provider
- c) Develop staff competency

Concurrently with the early review of the BIM software, the company also identified a few staff to be trained as BIM Designers and BIM Administrators. Within the context of the company practice, the engineers are also responsible to produce and refine the drawings personally besides delivering the engineering analysis and design. Therefore, in selecting the staff for developing BIM competency, the designers consisted of drafters and engineers. A total number of seven personnel were selected where four of them were chosen for designer training, focusing only on BIM modelling skills, while the remaining three were assigned not only to acquire the modelling skills but to also acquire deeper skill to become Revit Administrators. The skills include the component library development, troubleshooting skill, software configuration and administration and the management side of BIM.

The company starts the training process by organising in-house formal training conducted for the software SE CAD, followed by Tekla software, and finally Revit Structure. The training focused on the entry and intermediate level to satisfy the modelling skill. The training was conducted in a few months of time lag, to minimise interruption of the actual design job and responsibilities, and to allow the personnel to have some time to digest their new knowledge. In evaluating the software suitability, all of the seven personnel were responsible to report their evaluation of the software by using several criteria. The criteria were developed based on the user requirements and a few of them are mentioned by both interviewees as following:

- a) The user friendliness of the software,
- b) The flexibility,
- c) The interface of the software,

- d) The ease of use of the software which is related to the time that is required for achieving appropriate modelling skill,
- e) Customisation of template and components,
- f) The interoperability of the software.

During the early review of the software, the SE CAD was viewed as very promising, justifying the ability of the software to provide authoring and analysis capability within a single platform. However, after attending the training, the rigidity of the software limited its full use within the Malaysian construction practice. All of the components within the SE CAD are designed to comply with the standard of Singaporean IBS components.

Meanwhile, the Tekla software which focuses on IBS type of building was viewed as very advantageous by the company. Many of the functionalities are tailored to meet the IBS needs covering not only the conceptual and design stage but also including the production and construction lines. By using the user requirement criteria, the software satisfied almost all of the user requirements except the customisation of the software which requires a sophisticated programming skill and a longer learning time to master. From the top management view, the cost of investment for Tekla was viewed as very expensive, featuring the biggest drawback to justify return of investment and expansion of the license number in the future.

Meanwhile, the Revit structure features less IBS related functions. However, the similar interface with CAD (which comes from the same company) represents the biggest advantage where most of the personnel feel very comfortable to be working in a Revit Structure environment. Additionally, the ease of use to customise the IBS components and reasonable cost of investment features as the biggest advantages, justifying the decision of the company to go with the Revit Structure. The company had acquired 3 Revit Structure licenses at the time of study.

After the acquisition of the Revit Structure licenses, three out of seven trained personnel were assigned to attend the complementary training that was provided by the software vendors. At this time, the training was tailored to focus on the advanced level to fill the technical need of the Revit Structure Administrator. The training used the company's previous project data to practice. After the complementary training was completed, the company continued with on-the-job training and piloting the implementation concurrently on a small scale project which they have won recently. At the time the case study was conducted, the companies had just started the on-job training and were piloting the implementation. For the record, the difference between pilot implementation and on-the-job training

lies in the purpose of implementation. The on-the-job training aims at developing practical competency of the people while the pilot implementation focuses on testing and adjusting the proposed BIM implementation approaches to suit the needs of the project and the company. The approach not only covers the requirement of people but is also extended to cover the most suited process flow, software and hardware.

4.4.3 BIM READINESS CRITERIA

4.4.3.1 PROCESS

Table 4.12: Readiness criteria for process element that was identified in Company B

PROCESS ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
PROCESS CHANGE STRATEGY	Process Flow Redesign Small and Incremental Approach Incentive and Reward
IMPLEMENTATION MANAGEMENT	Implementation Plan Adequate Resources Pilot Project BIM CAD Coordination
POLICY	Design and Build Contract Amendment

Table 4.12 summarises the readiness criteria within the process element that was identified in Company B. Nine readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.4.3.1.1 Process Change Strategy

Both of the interviewees agreed that the implementation of BIM requires a process flow redesign since BIM focuses on developing the 3D model and the 3D model itself will become the main deliverable. Therefore, an additional 3D model development phase must be incorporated within the current practice. Contrary to CAD-based process flow, the drawings, specifications and Bill of Quantity in BIM will become secondary deliverables as they are all extracted from the model rather than created individually. The new process flow is included within the company's BIM direction but according to Interviewee CB1 the low level of people competency has inhibited the total implementation of the model oriented process flow, at the time the case study was conducted. The process redesign therefore features as a readiness criterion, identified by Company B.

Meanwhile, the company has also engaged a stage by stage approach by dividing the BIM implementation into small technology applications. According to Interviewee CB1, BIM offers a lot of benefits by engaging varied applications, but to grab them all is viewed to be impossible. The implementation must be tied with a long-term investment that is distributed into a series of small milestones. Based on the technology application perspective, the implementation started with developing the product library and authoring the 3D model to satisfy the needs of visualisation and soft clash check. The drawings extraction and coordination, Material Taking Off and other related deliverables will be explored once the drafter and BIM Administrator are satisfied with the aforementioned application. The implementation of BIM as standard operating procedure is considered as midterm planning while the collaboration of BIM models among business partners is treated as a long-term plan. Interviewee CB1 further explained the current on-the-job practice to satisfy visualization and soft clash needs, as evidenced in the following statement:

[...] At this stage we simply model the surface of each component by using Revit to support the visualisation. The visualisation makes it easy for us to view the position, drops, opening and tolerance and how each component connects to each other to form the whole building. We can play around with the components and make adjustments very easily. Although the application is very simple, it does help us a lot by eliminating the need to imagine the coordination of the building components in our mind. After modelling the surface of each component, we send each component into AutoCAD to detail down the reinforcement [...] Interviewee CB1

Meanwhile, Interviewee CB2 also supported the company's stage by stage approach by considering the effort that is required to master the software and delivering the daily engineering design responsibility at the same time, evidenced in the following statement:

[...] The software took some time and extra effort to master and dealing with the hiccup. It is normal with any new software that we purchased. Similarly to a human being, stage by stage we learn to crawl, stand, and walk before we are able to run easily. Each stage requires some time to master and coupled with our actual daily jobs to deliver the design, the implementation therefore must go in stages [...] Interviewee CB2

Another feature of readiness criteria within Company B is evidenced by incentives and rewards, although dedicated incentives and rewards in a quantitative form such as monetary, new wage scheme or working leave were not evidenced within Company B. However, according to Interviewee CB1, the Revit Structure competency in carrying the roles either as Designer or Administrator were considered as one of the main criteria used by the company to consider wage increment and promote the senior post which aligns with company policy regarding continuous improvement and the application of the most advanced information technology. Meanwhile, according to Interviewee

CB2, the chance to learn new software is considered as a reward, which adds extra value to the engineer, as evidenced in the following statement:

[...] I do not see dedicated monetary incentive as important. For me, the chance to learn and master the software itself is a reward as far as training and practical BIM uses are concerned. After we master the software, we have added extra skill in our resume as compared to other engineers. Our value within the market would automatically increase and sooner or later the company will increase our salary or even offer a higher post as direct implication of it [...] Interviewee CB2

4.4.3.1.2 BIM Implementation Management

A proper implementation plan is considered an important readiness criterion according to Interviewee CB1, to facilitate the implementation. The company has documented their implementation plan, which is also supported verbally by Interviewee CB2. The researcher however was not granted permission to view the documents. As Interviewee CB1 further mentioned, the documents consist of a framework of implementation which covers:

- a) The objective of implementation
- b) software evaluation strategy
- c) Stages of implementation which are specified in short, medium and long-term time series
- d) Selection of people
- e) Definition of new roles and responsibilities

Basically, the development of the implementation plan was aligned with the company's policy, mission, and vision which support the business needs of the company.

Adequate resources also feature as another important readiness criteria within Company A. The evidence suggests that without adequate resources, many of the activities are not possible to be carried out. Some activities that have already taken place within Company B are as following:

- a) The implementation of paid in-house training upon three BIM software
- b) Managers to attend BIM seminars and workshops to increase awareness and knowledge
- c) The software decision making which compares the implementation cost with return of investment
- d) BIM competency development for the human resources

According to Interviewee CB1, although BIM could eventually replace the role of CAD, the situation might not happen in the near future within the Malaysian construction industry. The industry may require at least 20 years to totally replace the role of CAD. The nature of the industry which heavily

relies on CAD-based drawings is mentioned as the biggest drawback and is evidenced in the following statement:

[...] For the moment, CAD drawings are used very comprehensively. The usage covers the tender and contract document, the transfer of information between parties, and to satisfy the requirement by the client and local authority. It would take a very long time, probably 20 years for the industry as a whole to change and therefore, I cannot see the role of CAD becoming obsolete. Therefore we must coordinate the existence of both CAD and BIM approaches to make full use of them.
[...] Interviewee CB1

The co-existence of BIM and CAD therefore requires a proper coordination between both as they are using different process flows and deliverables.

Piloting BIM implementation is evidenced right after the complementary training has been completed, which was delivered concurrently with on-the-job training, and therefore features as another readiness criterion. As discussed in the last paragraph of section 2.0, the pilot implementation was carried out on small scale projects to minimise the risk. According to Interviewee CB1, the pilot implementation focused on testing and adjusting the planned BIM implementation approach to suit the needs of the project and the company by using real project data, process flows, deliverables and datelines. The approach not only covers the requirement of people but also extends to cover the most suited process flow, software and hardware. The BIM Administrators are assigned to record any benefits, drawbacks, adjustments or deviation of the planned BIM implementation approach for future improvement.

4.4.3.1.3 Policy

According to Interviewee CB1, as a one stop centre or an integrated company capable of delivering the design and construction activity, the company prefers to engage design and build as the project delivery method when implementing BIM. The authority to select the team makes it possible to choose a BIM-capable company, especially the architect. It is important to note that the company does not provide any architectural design services and therefore the BIM-capable architect is important in aligning the BIM process flow with the business partner who is involved in the same project. Most importantly, the 3D architect model, as part of BIM, would ease the authoring of 3D structural model and support automated clash check.

Although the company is currently at the early stage of piloting the BIM implementation, besides identifying design and build as the best project delivery method, the company also stressed that it is important to amend the contract to allow BIM process flow and deliverable to be performed in a

project. The main justification is that the current process flow and deliverable rely heavily on CAD, which is not conducive to support a model oriented process flow.

Based on the above discussion with Interviewee CB1, two readiness criteria are identified; the use of design and build as a project delivery method and contract amendment to allow BIM process flow and deliverable to be performed.

4.4.3.2 Management

Table 4.13: Readiness criteria for management element that was identified in Company B

MANAGEMENT ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
BUSINESS STRATEGY	BIM objectives alignment BIM Market Demand
MANAGEMENT COMPETENCY	Risk Management Commitment and support
LEADERSHIP	Motivation Top Down Approach

Table 4.13 summarises the readiness criteria within the management element that was identified in Company B. Six readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.4.3.2.1 Business Strategy

Interviewee CB1 agreed that the implementation of BIM must be aligned with the company's business objectives and thus features as another readiness criterion. As the interviewee further explained, the management will only invest in and be committed to implement a new technology when they can see the advantage of the technology in supporting the business objectives. In supporting the agreements, Interviewee CB2 explained that the implementation of BIM, for the short-term business objectives, is aligned to increase the productivity of the design through the elimination of obstacles that are inherited by implementing CAD. Meanwhile, for long-term business objectives, full utilisation of the current number of manpower and international market opportunities were mentioned as following:

[...] Our capability to cater for more jobs at one time is very limited due to the time consuming, labour intensive and complex CAD approach. Therefore, by implementing BIM, we could see potential to secure more jobs in the future while retaining the same number of staff [...] Interviewee CB1

[...] If we look at the international market sector, BIM is booming and many clients start requesting the 3D models as part of the contract requirement. Our business direction is moving towards the international market in the next ten years. We have to move to the international market since the local IBS demands are slowly saturated due to decreased demand by the government but increasing number of players. If we are not capable of delivering BIM, I could not see how we are able to secure the international jobs [...] Interviewee CB1

According to Interviewee CB1, the creation of BIM market demand is very important to ensure continuous use within the company and it is also related to the management commitment to implement BIM. Although currently the BIM demand is very low, the company has started an initiative to create the demand by communicating the benefits of BIM to raise awareness among clients. At the same time, communication is also targeted at informing the industry regarding the added value of BIM capability that the company has as compared to their competitors. Therefore, the creation of market demand for BIM is identified as another readiness criterion.

4.4.3.2.2 Management Competency

According to Interviewee CB2, one of the risks that was anticipated by the company when implementing BIM is the loss of BIM-competent people to their competitors due to higher pay. Although the risk has not yet materialised, the possibility is very high once the staff have achieved an appropriate level of competency, according to Interviewee CB1. The company therefore has included the risk mitigation strategy within their implementation plan by training as many staff as possible to become BIM competent, justified by the selection of seven personnel. Within that context, the company would have backup personnel if any of the seven personnel move to another company, meaning the interruption of BIM implementation could be minimised.

Management's consistent commitment and support also features as another readiness criterion. From the operational perspective, according to Interviewee CB2, the support is essential to develop competency, and within the company the interviewee admits that the management has provided excellent commitment and support by satisfying almost every need to implement BIM such as training, technical assistance and step by step implementation. As the interviewee further explained, the word 'consistent' is very important as it is closely related with staff motivation as evidenced in the following statement:

[...] The management must consistently support us to the end. Implementing BIM means we are giving the extra effort and time not only to develop competency but also to deal with the pressure, technical difficulties and hiccups while delivering our actual job at the same time. Even if the challenge is huge, the management must commit to solve it together with us and if the management refuse, it will definitely demoralise us to carry on [...] **Interviewee CB2**

Meanwhile, as Interviewee CB2 further stated, the management promise to make BIM a standard operating procedure has also convinced the operational staff about their commitment. Therefore, consistent management commitment and support are identified as other readiness criteria.

4.4.3.2.3 Leadership

The ability of the management to motivate the staff is identified as a readiness criteria under the leadership attribute. According to Interviewee CB1, the management understood the pressure felt by the staff when they were required to concurrently develop new competency and deliver the design responsibility. Therefore, rather than using a push approach which could add more pressure, the management motivated the staff by listening to and resolving their problems, and directly communicating with the staff to make them aware of their added value within the market and the potential of having salary increment and promotion. Meanwhile, according to Interviewee CB2, rather than directing the staff, the management has also brought the staff on board for decision making, as evidenced in the following statement:

[...]Last time when the management decided to buy the software, besides having our evaluation report, they have also called a few of us to discuss our judgement of selecting Revit and also attended to our needs to implement BIM such as in-house training and stage-by-stage approach[...] **Interviewee CB2**

According to Interviewee CB1, by bringing the staff together in decision making, it creates a sense of belonging with the decision that was made and results in them feeling responsible to deliver their decision.

Meanwhile, although the trigger of BIM implementation comes from the operational level, the implementation of BIM is engaging a top down approach as evidenced with the management efforts to set the BIM direction, preparing the implementation plan and driving the implementation. From the operational perspective, according to Interviewee CB2, top down approach is important in justifying the needs to align the BIM implementation with the business objectives and the authority that the management has to provide adequate resources for the implementation. The top down approach is therefore identified as another readiness criterion within the leadership attribute.

4.4.3.3 People

Table 4.14: Readiness criteria for people element that was identified in Company B

PEOPLE ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
ROLES AND RESPONSIBILITIES	Head of Change BIM Designer/Modeller BIM Administrator/Manager Empowerment
SKILL & ATTITUDE	BIM Administrator/Manager BIM Designer/Modeller
TRAINING & EDUCATION	Formal Training On-the-job Training
WORK ENVIRONMENT	Knowledge capturing Knowledge sharing

Table 4.14 summarises the readiness criteria within the people element that was identified in Company B. Ten readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.4.3.3.1 Roles and Responsibilities

Prior to software acquisition, the company had identified two new roles that needed to be created to implement BIM - the Revit Administrator and Revit Designer. According to Interviewee CB1, both roles are required to operate Revit software but the Administrator roles are extended to deal with the administrative role of the software such as developing a product library, troubleshooting, and also to deliver formal training and assisting the on-the-job training for the staff in the future. The new roles and responsibilities are therefore identified as another readiness criterion.

Another feature of readiness criteria in Company B is the presence of Head of Change which is carried out by Interviewee CB1. While the Administrator is responsible to look after the technical aspect of BIM, the Head of Change role is further listed as following:

- a) To manage the BIM implementation activity such as preparing the implementation plan, directing the implementation and also monitoring the progress
- b) Liaison between the top management and operational regarding the needs
- c) Identify and prepare BIM-related requirements such as training, hardware upgrade and software acquisition
- d) Redesigning the new roles and process flow

Both of the interviewees also suggest that empowerment plays a vital role in leading the process change. The empowerment must be tailored to suit certain levels of responsibility as explained by Interviewee CB1. The empowerment is evidenced within Company B through a collaborative involvement of the people to decide the software to purchase. Meanwhile, the senior management position that CB1 holds has also justified the need for empowerment to drive the implementation. The authority that the interviewee carries has enabled him to instruct and influence people to join the BIM implementation effort.

4.4.3.3.2 Skills and Attitude

To ensure the successful implementation of BIM, the selection of staff must satisfy certain skill and attitude sets to become BIM Administrators or Designers. This is identified as another readiness criterion. According to Interviewees CB1 and CB2, the skill and attitude sets that both the BIM Administrators and Designers must have are:

- a) Personal Interest
- b) IT literate and computer Savvy
- c) Helpfulness, especially important to support the team
- d) Ability of the staff to respond to change
- e) Technical competency of engineering design and drafting

Meanwhile, the BIM Administrator demanded extra attitude and skill sets which are listed as following:

- a) Coaching skills
- b) Troubleshooting skills
- c) Communication skills

4.4.3.3.3 Training and Education

As discussed in detail in Section 4.4.2, Chronology of BIM Implementation, the company has engaged two types of training, formal training and on-the-job training, which features as readiness criteria. The formal training which has been conducted in-house was targeted at developing entry and intermediate level of modelling competency on three different software. As Interviewee CB1 further supported, the training exposed and familiarised the staff with the software interface, buttons, function and the terms used, especially important in receiving technical assistance via telephone whenever problems occur. After the software acquisition was made, another formal training was conducted focusing on the advanced level, to fill the technical need to become a Revit Structure

Administrator. The training used the company’s previous project data so the gap between theory and practice could be minimised. After the second training was completed, the company continued with on-the-job training on a small scale project which they have won recently. The on-the-job training aims at improving the skill, developing practical competency and also increasing the confidence level of the staff.

4.4.3.3.3 Work Environment

According to CB1, BIM is a new approach to design and therefore every procedure and method must be documented to help other staff, and also for future improvement. By using the company’s IBS experience, the interviewee further explained its importance as following:

[...] Similarly to what we did with IBS, we documented in a form of hardcopy and softcopy. The technical aspect of IBS design, such as the connection and the component analysis, we want everybody to acquire the same knowledge therefore it is important to document the procedure to support knowledge sharing and retrieval[...] Interviewee CB1

Meanwhile, the importance of the work environment in supporting knowledge sharing is evidenced in the following statement made by Interviewee CB1:

[...] The mentoring and knowledge sharing is a norm within our practice. Before the BIM implementation, we had invested heavily on engineering design software and we cannot expect all of the staff to attend the training as it would interrupt our workflow. Last time when the training was conducted for StaadPro Software in a full week at the vendor’s office, we only sent 3 people to attend the training and after they completed the training, they were responsible to teach and train the other staff. The teaching and training activity not only benefitted them in terms of revising and practicing the knowledge, but they could also identify their weakness and thus consult with their instructor for improvement. Since then, the practice has become a norm within our company [...] Interviewee CB1

The above discussions suggest that the company has a structured method to capture knowledge, and a conducive work environment to support knowledge sharing among staff. Thus it features as readiness criteria within the work environment attribute.

4.4.3.4 Technology

Table 4.15: Readiness criteria for technology element that was identified in Company B

TECHNOLOGY ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
HARDWARE	Adequate ICT Infrastructure

TECHNICAL SUPPORT	Vendor Evaluation Strategy Technical Support
SOFTWARE	Software Evaluation Strategy Compatibility and Interoperability ICT System Review

Table 4.15 summarises the readiness criteria within the technology element that was identified in Company B. Six readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.4.3.4.1 Hardware

Adequate ICT infrastructure is also identified as readiness criteria within Company B. For a start, the company has only upgraded the RAM and the graphic card for the dedicated desktops. For the future, the company projected that the upgrading may not be an option and therefore consider replacing their hardware to suit with the advanced features of the software implementation. Meanwhile, the evidence that supports the criteria is as following:

[...] The computer infrastructure must match the software requirement to ensure the smooth running of the application and operation. No matter how good our software is, without an excellent infrastructure, the implementation will not be optimised [...]
Interviewee CB1

[...] We consulted with our technical team and software vendor to identify the optimum hardware requirement. For the moment, we only needed to upgrade our 4GB RAM to 8GB and our 512MB Graphic Card to 1GB. It is enough to satisfy our need but over time, suitable with the advanced application of Revit, the Motherboard may not be able to support the higher capacity of RAM and Graphic Card. By that time we will acquire a new desktop [...]
Interviewee CB2

4.4.3.4.2 Technical Support

As discussed in the current implementation of BIM, the company has engaged product demonstration and training prior to software acquisition to evaluate the capability of the software vendor in providing services, which includes a review of the vendor's track record and the availability of technically competent personnel. The capability of the software vendor was identified important by both interviewees to assist the BIM implementation and justified the company's approach for evaluating their capability. Therefore, having tools or techniques to evaluate the capability of the software vendor is identified as readiness criteria.

Meanwhile, an adequate technical support is a must to implement BIM as recognised by both interviewees. This lies on the ground of supporting the staff and avoiding disruption of the implementation. Although it is compulsory for the software vendor to provide technical support such as troubleshooting the technical problems, according to Interviewee CB1, the early stage of BIM environment in Malaysia requires the company not to rely on and expect too much from the software vendor to assist implementation. Normally, software-associated technical problems can be solved by the software vendor but other problems require third party expertise such as BIM consultants or business partners to get involved to resolve the problem. Therefore, adequate technical support features as another readiness criterion.

4.4.3.4.3 Software

Another purpose of having training prior to software acquisition is to evaluate the most suitable software for the company by incorporating the business and user needs as evidenced in the current implementation of BIM. The use of the training is identified as the company evaluation strategy and thus features as the readiness criteria. Meanwhile, another important criterion of the software, in addition to one that was discussed previously, is the flexibility to suit the company's process flow. Interviewee CB2 further supports the flexibility in the following statement:

[...] Each company has a different IBS system covering the process flow and the IBS components. The systems were long developed by considering many aspects to optimise our operation and therefore we cannot simply change our IBS system to suit with the software implementation. The software instead must be flexible enough to support our system [...] Interviewee CB1

Meanwhile, the software interoperability of BIM software with CAD systems was also stressed as important by both interviewees since most companies in Malaysia are still using the system. Furthermore, the local authority and the client specify the CAD drawing as part of their requirements and thus request the company to deliver the CAD drawings rather than the BIM model. However, to minimise manual data transfer when drafting the drawings in CAD, the interoperability of BIM software with CAD is identified as important, thus featuring as another readiness criterion.

According to Interviewee CB1, the implementation of BIM is projected in a series of timeframes to optimise the investment by spreading the expenditure into small chunks. Therefore, the BIM hardware and software requirements will change over time in line with the sophistication and advancement of the BIM implementation, and thus require the company to regularly review their ICT system. Therefore, regular reviews of the ICT system are identified as another readiness criterion.

4.5 CASE STUDY FINDINGS FOR COMPANY C

4.5.1 BACKGROUND OF COMPANY C

The parent company for Company C is a public listed diversified multinational conglomerate which involves six sectors namely plantations, motors, industrial equipment, energy and utilities, healthcare and property. The conglomerate was first incorporated in 1910 and has a market capitalisation of RM58.95 billion as of July 2012. Each sector is represented by company divisions which share the same mission and vision, core values and governance. The vision of the company is stressed on delivering sustainable value through several missions. The missions state about striving for excellent operations and high performance standards and providing an environment for the people to realise their full potential. Meanwhile, the conglomerate has also embraced four core values and four business principles across the company divisions resulting in the production of the Code of Business Conduct. The code provides guidance on the standard behaviour expected of all directors and employees. Due to the highest confidentiality of the company, the detailed explanation for each vision, mission core and core value are only discussed in general. It is also important to mention that the company was very reserved in providing the information regarding their BIM implementation. The researchers neither allowed a visit to the office nor to review any documents related to their implementation, but enabled us to interview the BIM Managers of the company. The interviews were conducted in a restaurant and at one of the other BIM manager's friend's office. The list of the interviewees can be seen in Table 4.16:

Table 4.16: List of the Interviewees for Company C

Name	Background	Designation	Experience in construction/BIM (years)
CC1	Architecture	BIM Manager	20/10
CC2	Architecture	BIM Technologist	9/4

Meanwhile, property is the focus area for Company C as an integrated property group. The core businesses for Company C are property development and investment, asset management, hospitality and leisure. Apart from Malaysia, the company has also undertaken projects in Singapore, Vietnam, China, and Australia. Within the context of the management system, the company has received certification for ISO 9001 (Quality Management System), ISO 14001 (Environmental Management System), OHSAS 18001 and MS 1722 (Safety and Health Management System) to reflect the company's commitment to deliver the best services and products to their clients. In the first quarter of 2011, the company recorded an operating profit of RM61 million, increased 3% from the previous

corresponding period. The company currently holds 19,000 acres of land bank and has identified another 18,800 acres for future development.

As part of the company's commitment to strive for excellent operations as stated in their mission, the company has identified four approaches to be implemented within their operation. The approaches are Industrialised Building System, Building Information Modelling, Vendor Development Program and Green and Sustainable Building. The first two aforementioned approaches are also targeted at improving their delivery process in response to their market study that was conducted a few years back. In the study, the company discovered that the selling price of their houses is significantly higher than their competitors, mostly due to ineffectiveness that was rooted in the delivery process. Additionally, a large amount of land bank requires the company to optimise the Return of Assets and Return of Investments which direct the need to be able to turn around a project within a year. Therefore, improving the efficiency of the design and construction delivery has become pertinent and the main focus since then.

In improving efficiency, the IBS methods of construction that include prefabrication and modularisation will reduce reliance on specialist labour, wet trades, and also provides opportunities to employ individuals with a lower skills base. At the same time, the factory-based productions enable a mass production in a controlled quality environment and will speed up the construction process. Meanwhile, BIM as the main platform will allow the company to collaborate effectively, make quicker decisions over shorter periods of time, reduce the use of paper and coordinate their delivery process effectively.

4.5.2 THE CHRONOLOGY OF BIM IMPLEMENTATION

Historically, the idea of implementing BIM within Company C came from their Research and Development (R&D) Department, originally to respond to the ineffectiveness of their delivery process. Dated a few years back, after attending a series of BIM seminars and workshops to gain knowledge and awareness, the Head of R&D department proposed BIM to the top management and since then, BIM has been included in the company's strategic direction along with IBS, Vendor Development Program and Green and Sustainable Building.

After receiving the green light from the top management to implement BIM, the R&D department has driven the implementation by setting up a BIM team within the company which comprises two architect modellers, one structural modeller and one Mechanical and Electrical modeller. All of the modellers are selected internally and at the early stage of the implementation, and none of the

modellers have BIM modelling skills. Along with identifying group members for the BIM team, the department has also acquired new BIM workstations and a few software licenses for Revit Architecture, Revit Structure, Revit M&E and Naviswork. All of the BIM modellers then attended the formal class that was conducted by the software provider. After the training was finished, the company engaged another two BIM personnel - one of them was offered on a contract basis to carry the BIM Manager role while the other one was hired on a permanent basis to carry the BIM Technologist role. By first targeting the design stage, the BIM team's scope of work is:

- a) Developing competency of the people
- b) Developing BIM standard to be used across the supply chain
- c) Piloting BIM implementation
- d) Leading and coordinating BIM modelling activity with the design consultants (architecture, structure and Mechanical and Electrical).

It is important to note that Company C was taking a proactive action to drive BIM implementation within their project. As many of their consultants were not yet ready to implement BIM, the company took over almost 80% of the BIM design activity including the model authoring and clash checking activity, carried by the newly setup BIM team. As part of the company's strategy, the implementation of BIM within the company's projects will be made compulsory in 4 years' time and by then, the consultants engaged with the company C's projects are all required to take back 80% of BIM design activity from the company while the company will only focus on the remaining 20%, mainly on managing information and data within the BIM model and monitoring the BIM process delivery.

After appointing a BIM Manager and Technologist, the BIM team then started to conduct a study by reviewing the literature sources residing in the BIM white and technical paper, BIM roadmap, BIM implementation plan and international BIM standard. The literature findings which were adjusted to suit the local construction background and the company's needs, were used to develop a BIM implementation plan, road map and standard. The implementation plan was developed to assist the internal implementation while the road map and standard specify the company's direction and modelling requirements (process and 3D model) respectively. The road map and the standard are important to communicate the company's commitment of BIM implementation to the consultants and contractors, to let them know the important milestones and the requirements to be complied with. At the same time, the road map and standard can also be used by their consultants and contractors as a guideline. The company was expected to conduct a vendor day program to communicate their BIM implementation to their consultants and contractors, a few months after they completed testing of their BIM implementation plan and standard on their BIM pilot project.

After completing the documentation for BIM implementation plan and standard, the company pursued the implementation by conducting a pilot project. The pilot project was done on 312 units of landed terrace house, just enough to satisfy the need of conceptual design, detail design and building plan submission. The pilot project, which only focused on BIM modelling activity, is used to serve several purposes as following:

- a) To deliver on-the-job training to BIM modeller.
- b) To explore collaborative approach and any potential area of technology advancement.
- c) To test the interplay of BIM software and hardware.
- d) To test and refine BIM implementation plan and standard.
- e) To document the best method, challenge and benefits.

4.5.3 *BIM READINESS CRITERIA*

4.5.3.1 **Process**

Table 4.17: Readiness criteria for process element that was identified in Company C

PROCESS ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
PROCESS CHANGE STRATEGY	Process Flow Redesign Small and Incremental Incentive and Reward
IMPLEMENTATION MANAGEMENT	Implementation Plan Pilot Project Adequate Resources BIM CAD Coordination Monitoring and Controlling
POLICY	None

Table 4.17 summarises the readiness criteria within the process element that was identified in Company C. Eight readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.5.3.1.1 *Process Change Strategy*

A stage by stage approach features as readiness criteria within Company C. The company has engaged a stage by stage approach of BIM implementation by first focusing on modelling activity

during the design stage only. According to Interviewee CC1, the modelling activity covers the architectural model, structural model and M&E model to support the design visualisation and drawings extraction and clash check review. At the same time, the process that is required to deliver the BIM model was also explored. After acquiring an appropriate level of modelling competency and optimum process flow, the company targeted to explore other BIM applications such as extracting Bill of Quantity, energy analysis and design options. Meanwhile, Interviewee CC2 also supported the company's stage by stage approach in implementing BIM by discussing the level of details that is required to author the BIM model, as evidenced in the following statement:

[...] It is not making any sense for the moment to deliver detail models up to construction detail. Some of the detail is just enough to be carried out in CAD such as the railing as it does not affect the coordination with other systems such as M&E and Structural. Similarly for the structural model, we do not need to have detail in the connection. We rather focus on the size of the structural element such as the beam, column and slab as those elements are coordinated with the M&E and Architectural system of the building [...] Interviewee CC1

According to Interviewee CC2, by implementing BIM, emphasis is not given on the drawings anymore. The BIM models have become the central focus for both the design deliverables and the processes to deliver them. A good model, as he further explained, could generate a good drawing where the drawing refinement time could be minimised in CAD when submitted to the local authority for plan submission and approval. As a result, the BIM process flow can be streamlined. Therefore, it is important for the company to redesign their current process flow effectively to incorporate and suit BIM modelling activity. The business process redesign is therefore identified as the readiness criteria within Company C. It is important to note that, the response made by CC2 was based on his view on what should be implemented but during the case study, the company have not yet delivering 3D model as the main design deliverables.

According to Interviewee CC2, all of the BIM modellers that were appointed by the company were awarded scholarships as part of the company's commitment to motivate them. The complexity of implementing new technology and multitasking roles and responsibility justify the scholarship award besides bonding their BIM competent staff through contract. BIM standard and Roadmap development, training and project delivery were mentioned as part of the multitasking role that is required of the whole BIM team. Therefore, the scholarship incentive to motivate staff to change is identified as readiness criteria within Company C.

4.5.3.1.2 BIM implementation management

Although the researcher was not given permission to view the BIM implementation plan, all of the interviewees confirmed the existence of the plan. The plan is identified as very important in guiding their BIM implementation. However, due to a lack of local BIM references, the company used international literature sources which focus on the practical implementation of BIM. The literature sources are used to understand and specify BIM requirements which are then aligned with the company's and local construction needs. By complying with the plan, the direction of the BIM implementation can be guaranteed to meet the company's expectation. At the same time, the plan would also enable BIM implementation progress to be tracked and monitored. The implementation plan therefore is identified as BIM readiness criteria for Company C.

As part of the monitoring process, Interviewee CC2 is responsible to update the BIM implementation progress quarterly by sending a progress report and present the progress to the immediate boss, the R&D Head of Department. The progress is measured based on the deliverables that the BIM team has set to deliver, among which are the BIM standard, manual and people competency. Meanwhile, the benefits and drawbacks of BIM implementation are also included within the report to assist the management about the support that shall be provided. The monitoring process, as Interviewee CC2 further explained, is also important to track and control the resources to stay within the budget. The BIM monitoring technique therefore features as readiness criteria within Company C.

Although no discussion was specifically made regarding adequate resources to facilitate the BIM implementation, there are many evidences supporting the importance of resources. The externally hired BIM Manager, the cost of acquiring BIM hardware and software and the scholarship award proves that the company has allocated a certain amount of resources to drive the implementation. Therefore, an adequate resource to facilitate BIM is identified as another BIM readiness criterion.

As discussed previously in the last paragraph in the chronology of BIM implementation, the company is currently at the stage of piloting the implementation on a real project. The pilot, which serves at achieving several purposes as listed in the paragraph, is identified as another readiness criterion implemented by Company C.

4.5.3.1.3 Policy

As far as the policy regarding contract and project delivery method is concerned, none of the interviewees discussed the matter. Therefore, the readiness criteria within the policy category could not be identified.

4.5.3.2 Management

Table 4.18: Readiness criteria for management element that was identified in Company C

MANAGEMENT ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
BUSINESS STRATEGY	BIM objectives alignment
MANAGEMENT COMPETENCY	Knowledge and Awareness Risk Management Commitment and support
LEADERSHIP	Vision and Mission Top Down Approach

Table 4.18 summarises the readiness criteria within the management element that was identified in Company C. Six readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.5.3.2.1 Business Strategy

As discussed in the Chronology of BIM Implementation, the implementation of BIM is driven by the top management to achieve business targets such as improving the efficiency of the project delivery and optimising the Return of Assets and Return of Investments of the company. According to Interviewee CC1, the implementation of BIM must be made clear to support the business objectives so that the top management can appreciate the BIM value and be committed to invest. The implementation of BIM which supports the business objectives is therefore identified as another readiness criterion.

4.5.3.2.2 Management Competency

According to Interviewee CC1, the management has acquired a certain level of BIM awareness before both interviewees joined the company. The management, through the Head of R&D unit and

his assistant, have attended a series of seminars, conducted software demonstrations and kept in contact with software providers such as Bentley, Autodesk and ArchiCAD, and set up the BIM team. The management understanding and awareness, especially for the BIM potential, business benefits and implementation requirements, are pertinent to ease the implementation as it is related to their support and commitment. According to Interviewee CC2, the BIM team was so lucky to have the Head of R&D Department and the assistant head to lead the implementation as both of them have a deep understanding of the business benefits and requirements of BIM. By relating to the assistant head background, Interviewee CC2 further explained:

[...] Even though the management did not get into the ground of BIM implementation, they must have IT affinity and understand that BIM is solving the design issue. If they viewed this as a design issue only, they could not appreciate BIM better, thus making things difficult. Our Assistant Head, his background is architecture but he has a Master in IT. When we talk about people with IT background, what I noticed was he is so savvy about the process. So he will try his best to satisfy the process requirement to put BIM in order and therefore be able to lead the implementation successfully [...] Interviewee CC2

The management awareness about BIM is therefore identified as another readiness criterion within Company C.

As discussed in Section 4.5.3.1.1, Process Change Strategy, all of the BIM modellers that were appointed by the company were awarded scholarships as part of the company's commitment to motivate them. Viewing from risk management strategy, Interviewee CC1 explained that the scholarship awards are also carrying a purpose to dissuade the staff from moving to other companies. During the implementation process, the same group of people in the BIM team must be retained for at least 3 years to complete the BIM competency cycle which includes on-the-job training, practice and mentoring new protégés. The management competency to deal with the risk that is associated with the loss of people is therefore identified as BIM readiness criteria within Company C.

Both of the interviewees agreed that management's consistent commitment and support plays a significant factor in determining the success of BIM implementation and thus features as another readiness criterion. Both of them mentioned the evidence of the management commitment by stating that the interview that was conducted with their Managing Director by the local newspaper. The Managing Director has clearly discussed the company's commitment to take BIM as part of the company's business strategy. The public announcement made by the company has also made the BIM team aware of the important roles that they are all playing and motivates them indirectly. Although the team received very good support and commitment from the management, Interviewee

CC2 admits that as a return, the BIM team must prove that BIM is worth investing. Another important part of management commitment is consistent use of BIM, as explained by CC1:

[...] Management must keep on continuing the use of BIM within the process flow no matter how hard the challenge is. They have spent a lot of money and effort on Revit technology and training and it's really frustrating when we cause a bit of delay, and the management requests us to go back to CAD. The inconsistency in the implementation will affect the staff motivation and thus pull the team back [...]
Interviewee CC1

4.5.3.2.3 Leadership

Meanwhile, the top down approach is also evidenced in the Chronology of BIM implementation which is identified as another BIM readiness criterion within Company C. The management top down approach is evidence of the effort to:

- a) Get involved in aligning BIM implementation with business objectives
- b) Direct the development of BIM implementation plan, standard and roadmap
- c) Set up the BIM team which consists of BIM manager and modeller
- d) Identify and prepare BIM hardware and software
- e) Keep monitoring and tracking the BIM implementation progress

4.5.3.3 People

Table 4.19: Readiness criteria for people element that was identified in Company C

PEOPLE ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
ROLES AND RESPONSIBILITIES	BIM Administrator/Manager BIM Designer/Modeller Head of Change
SKILL & ATTITUDE	BIM Administrator/Manager BIM Designer/Modeller
TRAINING & EDUCATION	Formal Training On-the-job Training Continuous Education
WORK ENVIRONMENT	Knowledge capturing Knowledge sharing

Table 4.19 summarises the readiness criteria within the people element that was identified in Company C. Ten readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.5.3.3.1 Roles and Responsibility

The BIM team within Company C consists of three newly formed roles and responsibilities, namely BIM Manager, BIM Technologist and BIM Modeller. In general, the BIM managers are the head of the BIM team and are responsible to direct the BIM process in projects and assist the modeller in developing their competency. Some of the roles and responsibilities of the BIM manager, listed by Interviewee CC1, are as following:

- a) Direct BIM implementation by the BIM team
- b) Liaison with operational and top management regarding BIM needs
- c) Develop, implement and enforce BIM Implementation plan and standard
- d) Assist and enforce BIM-related deliverables such as the 3D models and drawing extraction
- e) Reporting the status of BIM implementation
- f) Assist the on-the-job training.

Meanwhile, according to Interviewee CC2, the modeller scope of work is only associated with the production of BIM 3D models and associated deliverables. Apart from the BIM Manager and Modeller roles, the BIM Technologist is responsible for looking after the technical aspect of the BIM software such as the following:

- a) Troubleshooting software technical problems
- b) Checking the accuracy of drawings and the 3D model prepared by the modeller
- c) Creating the 3D object families
- d) Assisting with on-the-job training

Both of the interviewees agreed that the company has clearly defined roles and responsibilities for the BIM Manager, Technologist and Modeller. The definitions of roles have set the job scope and expectation that each one must carry which contribute to optimise the manpower and therefore features as another readiness criterion within Company C.

Another feature of roles and responsibilities within Company C is the existence of the Head of Change roles which are carried by the Head of R&D unit of the company. Although the researcher

was not able to interview the person, the alignment and direction of BIM implementation is set by the Head of R&D unit, as according to Interviewee CC1. Interviewee CC1 is also responsible for updating and reporting the progress to the Head of R&D unit as part of the management effort to ensure the success of the implementation.

4.5.3.3.2 Skills and Attitude

According to Interviewee CC1, in addition to mastering BIM-related modelling software, the BIM Manager must also know the project development sequence and all of the associated software technology that is involved such as Microsoft Project for planning and scheduling, and Esteem for structural design. The manager is not expected to master the technical details of the other software but he should be able to understand each of their uses and most importantly to know each of the deliverables that are produced, to enable the manager to assimilate the data and information for authoring the 3D model. Apart from that, the skills and attitude that the BIM manager must have are also related to the job scope. Good communication skills, mentoring and teaching skills and sound technical knowledge regarding design process know-how and contract administration are mentioned as being important by Interviewee CC1.

Meanwhile, Interviewee CC2 explained that the BIM Technologist must be somebody who understands the full extent of BIM technology and is not limited by certain disciplines, since all of the modellers will be referring to the Technologist to deliver the modelling job. The BIM Technologist must therefore acquire a strong technical knowledge which covers software proficiency in CAD and Revit. Apart from that, the nature of the BIM Technologist's work also requires the technologist to have excellent communication skills, organisational skills and coaching skills. Meanwhile, in selecting the right people to become Modellers, Interviewee CC2 has given the following comment:

[...] For the modeller, we must select the people who are equipped with the right qualifications, attitude and skill. Take for instance, the guy who was selected to become Revit Structural Modeller. Before this, he was the main reference for the staff when dealing with computer associated problems. Throw to him any computer associated problems and he can always figure the solution out. From the management side of view, they saw that the guy is computer savvy and uses his initiative. That kind of attitude is important to ease the training process when we want to develop his BIM competency [...] Interviewee CC2

A set of skills and attitude is therefore identified as another readiness criterion within the company.

4.5.3.3.2 Training and Education

As discussed in the Chronology of BIM Implementation, Company C has engaged two types of training to develop staff competency. The formal in-class training that was provided by the software vendor was targeted at developing the basic and intermediate level of modelling proficiency which also focuses on the technical and process-related activities. Meanwhile, the on-the-job training which was conducted on the pilot project will improve their skill, knowledge and confidence level to deliver the job. The on-the-job training was assisted by the BIM Manager and Technologist.

Meanwhile, according to Interviewee CC1, the training and education of BIM must be carried out continuously toward all of the staff involved. The training and education must be made in a continuous step-by-step pattern to tackle the needs for each individual stage of knowledge, as evidenced in the following statement:

[...] We must keep on continuously educating and training the staff and ourselves. Many efforts need to be given to send them for seminars and training. First we must cater to their needs to make them understand and accept BIM by exposing them to the benefits and the true potential. After that we need to draft a program for them to appreciate BIM. When they start to appreciate BIM, the technical competency development is easy to be carried out. Along with that, since the BIM technology keeps on advancing, it is also important for us to keep our knowledge informed and updated by attending the seminar and product demo [...] Interviewee CC1

The formal in-class training, on-the-job training and continuous education is therefore identified as readiness criteria within Company C.

4.5.3.3.3 Work Environment

According to Interviewee CC2, as part of the company mission to create an environment for the people to realise their full potential, all of the staff are also encouraged to get professional certifications for BIM where the cost of the certification will be covered by the company. The certified qualification is important judging by the need of the staff to mentor the other staff once they have achieved a certain level of BIM competency, especially in modelling skills. By having the certification, the other members of staff will be more confident with the trainer. The mentoring concept implemented within the company has created a very good environment to support knowledge sharing and therefore is identified as readiness criteria.

Within the pilot project, the company made it compulsory for each member of the BIM team to prepare the lesson learnt document. The lesson learnt document will specify the benefits, process or procedure that works or may not work and the recommendation. Apart from BIM standard and

implementation plan, the lesson learnt document captures the BIM know-how and makes it possible to be shared by other members of the company. The means of capturing knowledge is therefore identified as another readiness criterion.

4.5.3.4 Technology

Table 4.20: Readiness criteria for technology element that was identified in Company C

TECHNOLOGY ELEMENT	
READINESS CATEGORY	READINESS CRITERIA
HARDWARE	ICT Infrastructure
TECHNICAL SUPPORT	Vendor Evaluation Strategy Technical Support
SOFTWARE	Software Evaluation Strategy

Table 4.20 summarises the readiness criteria within the technology element that was identified in Company C. Five readiness criteria were sorted according to the readiness category and the following subchapter discusses in further detail the evidence of qualitative data that was found.

4.5.3.4.1 Hardware

According to Interviewee CC2, the company has a group-wide standard IT policy. Each of the staff is provided with a workstation, and the specification of the workstation depends on the designation and the position. For instance, some jobs can only be equipped with windows XP workstation. As for BIM implementation, to ensure smooth running of the software, the interviewee further identified that the standard IT needs to be flexible to satisfy the need of BIM. BIM requires the latest and fastest breed of workstation. For the BIM hardware, as part of the management commitment, the management has made the policy flexible to allow for the budget so the people in the BIM team can have workstations beyond their pay grade. Meanwhile, both Interviewees CC1 and CC2 agree that BIM implementation must be equipped with adequate ICT infrastructure. The smooth interplay between software and hardware, latest operating system, fastest processor, graphic card and RAM and bigger capacity of hard disk are among the hardware requirements for the workstation while the Local Area Network and server are among the ICT infrastructure that were mentioned. Therefore an adequate ICT infrastructure and a well-defined ICT policy for BIM is identified as readiness criterion within Company C.

4.5.3.4.2 Technical Support

As discussed earlier in the Company C section, the company hired externally competent BIM personnel to drive the BIM implementation. Interviewees CC1 and CC2, who carry the role of BIM Manager and Technologist respectively, are BIM personnel and part of their job scope is to provide technical support with regards to technical needs of BIM. According to Interviewee CC1, technical support must be acquired not only from the software vendor but also from external BIM specialists to satisfy the BIM needs. To expect the software vendor to provide all the needs will risk the BIM implementation, and their capability is also limited, especially in dealing with practical implementation and BIM process flow. Meanwhile, in demanding BIM technical support services, the company must also have a proper way to evaluate the service provider as according to Interviewee CC2. The company must be able to differentiate between the sales person and the technical person, and as he further explained, the seller is very good at explaining and convincing things but never good at solving the technical problems that the company faces. The existence of a good technical person within the service provider must be clearly identified. Within the technical support, it is identified that there exist two readiness criteria important for BIM implementation; an adequate technical support internally and externally to facilitate BIM implementation, and an evaluation method to evaluate the capability of BIM service provider to deliver technical support.

4.5.3.4.3 Software

According to Interviewees CC1 and CC2, the acquisition of BIM software has been made before they joined the company. Although not getting involved in the process, they agree that the BIM software acquisition must come with a proper strategy that addresses the business needs and user requirements. The variety of BIM software in the market justifies the need for conducting the selection properly. The software evaluation strategy is therefore identified as another readiness criterion.

4.5 SUMMARY

The identification of the readiness criteria which is based on the organisational requirement for BIM implementation is important for the development of the readiness framework. By conducting a case study, much information was captured regarding the BIM implementation requirements. In this chapter, the data and information that were gathered were in a qualitative form. They lead to better understanding of logic and rationale behind each of the readiness criteria that was identified, pertaining to the people, process, management and technology issues. Each of the criterion that was identified, however, was discussed in isolation according to the company that the criteria belonged to.

In the next chapter, each readiness criterion is further discussed by cross-analysing the findings among the four companies in a matrix form and validated theoretically. The theoretical framework, which was developed early in chapter 2 as can be referred to on page 50, is used in chapter 5 by populating the data and findings from chapter 4 before a cross case analysis could be conducted. The matrix of findings, as part of the findings summary, can be referred in chapter 5, Table 5.1 on page 163. In the same chapter also, the theoretical framework was developed further, becoming the conceptual framework of the research.

CHAPTER 5: DISCUSSION AND FRAMEWORK DEVELOPMENT

5.1 INTRODUCTION

In chapter 4, an individual report has been prepared for each of the organisation involved in this research. The report discusses the current context of BIM implementation within the business process and identification of readiness criteria for each organisation. The latter are the main findings that are used to develop a framework of BIM readiness by conducting a cross case analysis and cross reference with the literature source.

This chapter discusses the findings of the research in response to answer the following objectives of the research, and therefore the arrangement of this chapter is made according to the objectives:

- a) To explore the current level of BIM implementation within the business process by each of the organisations.
- b) To develop a conceptual framework of BIM readiness by utilising the emerging findings in the case study and cross reference the findings attributes with the literature sources.

The importance of this chapter with respect to the framework development is it cross analyses each readiness criteria (that was identified according to individual cases as can be seen in chapter 4), as compared to the other cases. In addition, the second stage of the literature review was also used to make sense of the readiness criteria and justified their importance so that they can be populated into the theoretical framework to produce the conceptual framework.

5.2 DISCUSSION OF FINDINGS FOR THE OBJECTIVE: TO EXPLORE THE CURRENT LEVEL OF BIM IMPLEMENTATION WITHIN THE BUSINESS PROCESS BY EACH OF THE ORGANISATIONS

Among all of the cases that have been investigated, it is fair to say that Company A has a comprehensive context of BIM implementation within their business process, evidenced by the standard operating procedure which incorporates BIM, the presence of BIM-associated roles and responsibility (BIM administrators which have more than 10 years of experience and the BIM Designer), and a higher level of detail for the 3D models. The latter has enabled the company to:

- a) Extract the drawings,
- b) Conduct material taking off material,
- c) Determine the centre of gravity for each structural component,

- d) Determine the weight and surface area of the structure,
- e) Deliver automated clash check,
- f) Conduct walkthrough review to analyse escape route.

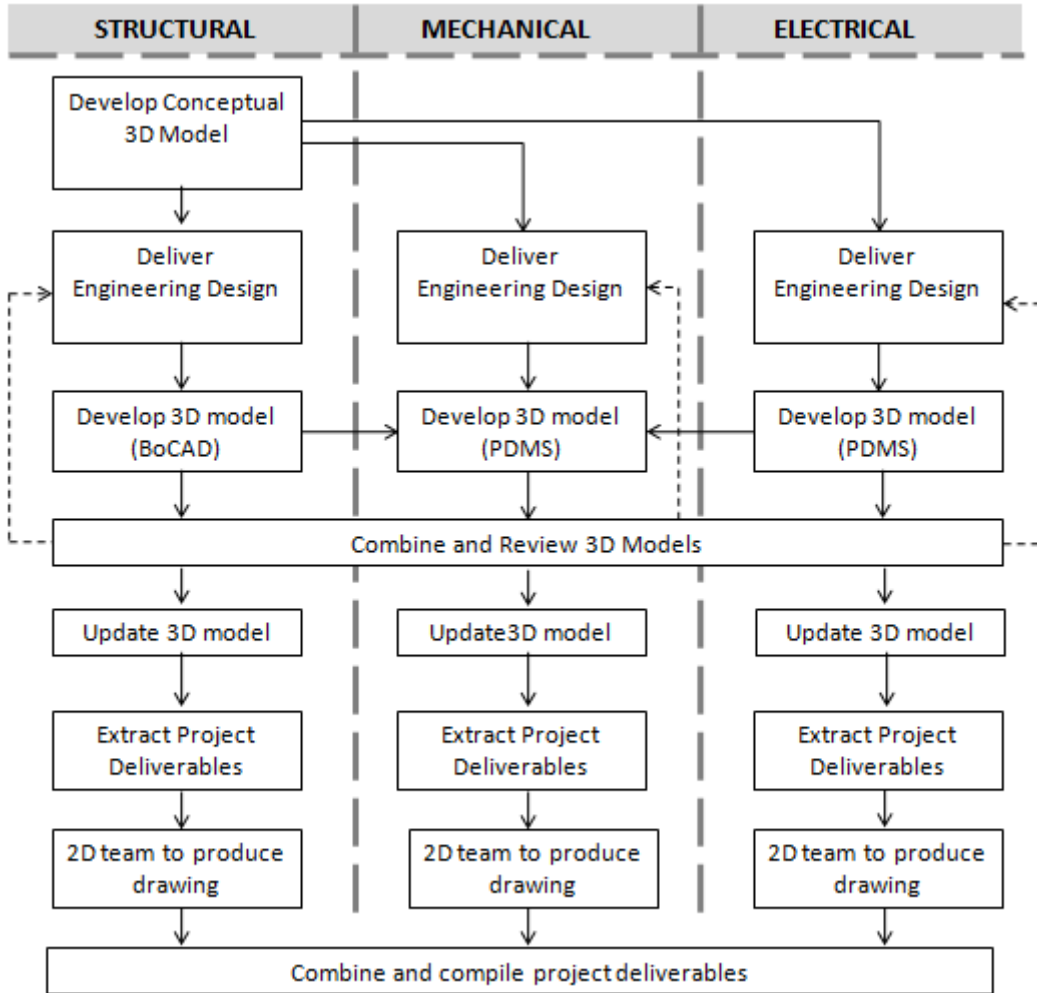


Figure 5.1: The process flow of producing design deliverables for conceptual and detail design package by Company A.

The implementation of BIM which started in 1994 makes it also reasonable to say that Company A has a higher level of BIM implementation as compared to the other companies. As can be seen in Figure 5.1, The process flow of producing design deliverables for conceptual and detail design, all activities are centred on the 3D model involving authoring the 3D models, design review and design deliverables extraction. The 3D model is therefore the main design deliverable whereas CAD drawings have becoming secondary.

As for the other companies, P, B, and C, it is probably fair to say that they are all sharing a similar level of BIM implementation where each of the companies have just finished conducting the pilot case of BIM implementation. As for the comprehensive use of the model, it is currently limited at satisfying the visualisation and surface model clash check only, leaving the model with a low level of details. As a result, the drawings and material taking off could not be generated automatically out of the model and requires CAD drafting and manual material taking off to be conducted.

Although there are different levels of BIM implementation between Company A and Companies P, B and C, all of the companies nonetheless implemented BIM within their practice which fits the purpose of conducting the case study. In addition, the investigation on the level of BIM implementation provides a reflection of the research regarding the context of BIM implementation for each individual company. The reflection is essential to assist the researcher in understanding the rationale and logic for each readiness criteria that is explored and identified in each company.

5.3 DISCUSSION OF FINDINGS FOR THE OBJECTIVE: TO DEVELOP A FRAMEWORK OF ORGANISATIONAL READINESS FOR BIM IMPLEMENTATION

As discussed earlier in this chapter, the development of the BIM readiness framework is based on utilising the emerging findings in the case studies. In chapter 4 the main findings, which are the readiness criteria and the context of their suitability for each individual case, were analysed and presented in individual reports without conducting cross case analyses to preserve the originality of the data. The data were presented in a narrative format and any personal interpretation was avoided. However, the researcher did customise the flow of the narration to make the findings presentable and easy to read. The data informed the development of the framework by identifying the readiness criteria and their context of suitability. The generalisation of the readiness criteria, however are limited since they were discussed in isolation according to each individual case study. In this section, the findings from all of the cases were cross analysed and synthesised to develop more generic readiness criteria. In addition, the second stage of the literature review was also conducted to support the researcher's interpretation and justification of each readiness criteria covering the importance. In selecting the readiness criteria to populate the theoretical framework, a minimum of two frequencies of occurrence were considered as this reflects the generality of the criteria. By referring to Table 5.1, all of the readiness criteria have a minimum of two frequencies of occurrence found in the case studies. Therefore, the researcher simply populated the framework with all the readiness criteria. The detailed justification and the synthesis of each readiness criterion are further discussed in the following section.

At this point of the framework development, it is important to mention that the researcher could not also be sure which one of the readiness criterion was generic and which one was unique to an isolated case. The process to properly reduce or generalise the readiness criteria therefore relied on the focus group workshop validation. The workshop, which was attended by fifteen participants, determined the importance of each readiness criteria within their context of practice and thus justified the need to either remain or be removed from the framework. The validation process is discussed in further detail in chapter 6.

Table 5.1: Matrix of case study findings for BIM readiness criteria

READINESS CRITERIA			COMPANY			
			P	A	B	C
PROCESS	PROCESS CHANGE STRATEGY	P01: Process Flow Redesign	x	x	x	x
		P02: Small and Incremental Approach	x	x	x	x
		P03: Incentive and Reward		x		x
		P04: Communication	x	x		
	IMPLEMENTATION MANAGEMENT	P05: Implementation Plan	x	x	x	x
		P06: Monitoring and Controlling	x	x		x
		P07: Adequate Resources		x	x	x
		P08: BIM CAD Coordination		x	x	x
		P09: Pilot Project	x		x	x
	POLICY	P10: Design and Build	x		x	
		P11: Contract Amendment	x	x	x	
MANAGEMENT	BUSINESS STRATEGY	M01: BIM Objectives Alignment	x	x	x	x
		M02: BIM Negotiation	x	x		
		M03: BIM Market Demand		x	x	
	MANAGEMENT COMPETENCY	M04: Knowledge and Awareness	x	x		x
		M05: Risk Management		x	x	x
		M06: Commitment and support	x	x	x	x
	LEADERSHIP	M07: Vision and Mission		x		x
		M08: Motivation		x	x	
		M09: Top Down Approach	x	x	x	x
PEOPLE	ROLES AND RESPONSIBILITIES	H01: BIM Administrator/Manager	x	x	x	x
		H02: BIM Designer/Modeller	x	x	x	x
		H03: Head of Change	x	x	x	x
		H04: Empowerment		x	x	
	SKILL & ATTITUDE	H05: BIM Administrator/Manager	x	x	x	x
		H06: BIM Designer/Modeller	x	x	x	x
	TRAINING & EDUCATION	H07: Formal Training	x	x	x	x
		H08: On-the-job Training	x	x	x	x
		H09: Continuous Education		x		x
	WORK ENVIRONMENT	H10: Knowledge Capturing		x	x	x
		H11: Knowledge Sharing	x	x	x	x
TECHNOLOGY	HARDWARE	T01: BIM ICT Policy		x		x
		T02: ICT Infrastructure	x	x	x	x
	TECHNICAL SUPPORT	T03: Vendor Evaluation Strategy	x		x	x
		T04: Technical Support	x	x	x	x
	SOFTWARE	T05: Software Evaluation Strategy	x		x	x
		T06: Compatibility and Interoperability	x		x	
		T07: ICT System Review		x	x	

5.3.1 PROCESS

By cross-analysing the findings from four case studies, as can be seen in Table 5.1, within the process element, eleven readiness criteria were identified and sorted according to the three categories, namely Process Change Strategy, Implementation Management, and Policy. The justification of selecting each of the readiness criteria was further discussed in the following subsection.

5.3.1.1 Process Change Strategy

According to Peppard & Ward (2004), the business value derived from IT investments only emerges through business changes and innovations, whether in a form of product or service innovation, new business models or process change, and organizations must be able to assimilate this change if they are to realize the value. The focus is on a combination of redesigning, re-organizing, rationalizing and integrating internal processes using new software suites and increasing connectivity with the user to reduce the cost of business transactions, and to improve, develop and create relationships via IS/IT which also agree with Alshawi (2007) and Bakis et al. (2006). As Soh & Marcus (1995) further suggest in their IT implementation model, the changes to internal process and practices demanded a thoughtful review of the process change strategy. In the implementation of BIM, some case studies recorded the importance of changing the delivery process, justifying the need to incorporate the activity to produce/author 3D BIM model and 3D model-oriented process flows as evidenced in Eastman et al. (2011), Smith & Tardiff (2009), Olatunji (2011), Kaner et al. (2008) and Gu & London (2010).

In the study conducted by Autodesk in 2004 (Khemlani, 2004), 82% of the respondents noted that BIM was changing the design process which forced them to re-evaluate their existing ways of working. As a result, Autodesk's consulting team often begin a BIM implementation with a process assessment. As part of BIM process change strategy, Smith & Tardif (2009) recommended process flow redesign by developing two process flow models, the as-is model, which models the current process flow of the organisation, and the to-be model which describes how the organisation might function in the future when BIM is incorporated. The importance of modelling the as-is and the to-be process flows lie in the need to identify changes and as a guide to manage the process and flow of information. They further suggested two process flow modelling techniques to ease the process, namely Integrated Definition Modelling (IDEF) and Business Process Notation Modelling (BPNM). Findings from the case study have also confirmed the need to redesign the process flow. Although only Company A has recorded full implementation of BIM within the process flow, evidenced through the Standard Operating Procedure (SOP) documents, all of the companies nonetheless

recognised the need for redesigning the process flow. Similarly with the literature review, the 3D BIM as the main deliverable and 3D model oriented process flow were mentioned as the main need to redesign the process flow by all companies. Within Company A, the SOP prior to BIM implementation was used as-is process flow to identify changes, and the externally hired BIM Administrator and software vendor representatives were consulted to model the to-be process flow. The following readiness criterion is therefore proposed for the readiness framework:

PO1: Process redesign by analysing current business process and identifying change required to incorporate BIM model oriented process

Meanwhile, a small and incremental approach is also discussed by Deutsch (2011), Jernigan (2007), Succar (2008), Eastman et al. (2011), Smith & Tardif (2009) and Laitinen (2007) as part of process change strategy to implement BIM. As the AEC (UK) BIM (2012) standard has specified twelve purposes of BIM model, a radical approach to include all the purposes is not advisable as the implementation comes with unanticipated risks, extra tasks to learn and experimenting with the new process and tools, and incurs drastic financial investment (Smith & Tardif, 2009). Meanwhile, Eastman et al. (2008) justify that each phase of BIM implementation involves its own planning and development of workflows and methods, so a small and incremental approach will allow the process change, training and adoption of advanced services without undue risks which will lead to radically new capabilities within the overall design firm. Findings from the case studies show that all of the companies are engaging a small and incremental approach in implementing BIM, agreeing with the literature review. The implementation sequences, however, differ slightly when comparing Company A with other companies. Within Company A, the BIM implementation took place in isolation, focusing first on satisfying the need of individual departments, mechanical and structural to produce drawings. Most of the effort was therefore directed on enriching/populating information to the 3D models to enable the drawings extraction before focusing on clash checking. On the contrary, other companies, Company P, B and C focused more on 3D visualisations and surface modelling clash checking, although they are all using 3D parametric modelling tools. The modelling effort is directed at satisfying the aforementioned focus leaving the model with low level of detail for the first stage of implementation. Consequently, the drawings are still drafted and refined in CAD. The justification, as found in Companies P and B, lies in promoting and getting user's buy-in for 3D visualization and semi-automated clash checking. Once the user appreciates the applications and achieves a certain level of competency, the implementation will then populate a higher level of details to the models to enable drawings extraction and materials taking off. Although approaching a different sequence, all of the companies nonetheless engage in a small and incremental approach by subdividing the

implementation into a series of small and manageable technology applications, which in this context serves as the target. Therefore, the following readiness criterion is proposed:

P02: Small and incremental approach by subdividing BIM implementation into small and manageable targets.

Alshawi (2007) also recognises that one of the factors relating to the process change strategy involves human and social-related changes, while cultural adjustment techniques are the most important factors that are needed by the management to facilitate the successful implementation of new IS/IT systems. Besides discussing the need to effectively communicate change, which is discussed further in the succeeding paragraph, the revision of rewards systems is also identified as important, justifying the need to directly motivate the staff to accept and implement change. The use of rewards is also identified important as evidenced in the study made by Olatunji (2011a) on organisations' adjustment to BIM adoption, for the people to get motivated to suit the process change and encourage innovations in teamwork and management of collaborative knowledge. Findings from the case study demonstrate that except for Company P, other companies were providing incentives and rewards to the people as part of the process change strategy. The collective justification lies on stress relieving and motivation as the people need to develop and experiment with new processes, develop personal competency and deliver daily jobs at the same time. Company A and Company C were using monetary incentives, evidenced by training incentives and scholarship awards respectively, besides promising a new wage scheme for a new job title and chances for getting promoted. Company B, although imposing similar promises to the staff as incentives, did not provide any immediate dedicated monetary incentives as for their staff; the chances to learn and master BIM itself are considered as a reward. Although engaging different means of incentives, Companies A, B and C nonetheless recognised the importance of providing incentives and rewards which also agreed with the literature. The following readiness criterion is therefore proposed:

P03: Incentives and rewards to motivate staff to change.

Meanwhile, according to Alshawi (2007) and Ruikar et al., (2004) the communication of change is another essential tool which is perceived as very important in facilitating the process and IT implementation. Communication must take place throughout the change process at all levels and for all individuals and should occur regularly between those in charge of the change initiatives and those affected by them. As part of BIM implementation, a report made by BIM Industry Working Group (2011) entitled "Strategy Paper for the Government Construction Client Group UK" also recognised communication as a key to successfully deliver the change of programme and the communication of change must be accompanied by adequate support and approaches. Within the case study findings,

the BIM communication was only stressed important and discussed by Company P and Company A. Company P, as part of their job responsibility in consulting BIM implementation to their clients (design companies), were consulting their clients to use a formal approach of communication which led to a half day meeting to explain the company's commitment for BIM implementation, demonstrating BIM advantages and discussing the staff concerns. On the contrary, Company A engaged in an informal approach to communication for BIM process change. The management of Company A believed that by using direct personal contact, talking face-to-face to the targeted people at their workstation, would be more effective than holding dedicated events such as a formal meeting. The effectiveness looked at the perspective of conveying the company's commitment and getting the user feedback. Although the means of communication differs between Companies A and P, both companies share a similar purpose, especially in getting user buy-in, informing of the company's commitment, change that was taking place and getting the user's feedback and concerns. The following readiness criterion is therefore proposed for the readiness framework:

P04: Effective means of communication to explain BIM at all levels and to all individuals within the company.

5.3.1.2 BIM Implementation Management

According to Alshawi (2007) and Peppard & Ward (2004), effective management of IT implementation is considered as a critical factor to succeed in implementing IT. Peppard & Ward (2004) further justify that the importance lies in ensuring the new processes and way of working are designed and implemented effectively in conjunction with new technology as IT cannot confer sustainable competitive advantages on its own. The implementation management in IT generally consists of several elements such as the development of action plan, monitoring technique, adequate resources and piloting the implementation (Ashawi, 2007; Stewart et al. 2002; Peppard & Ward, 2004; Bakis et al. 2006). As for BIM implementation, the importance of the implementation plan is discussed in many BIM-related literature sources and was strengthened in the case studies conducted by Kaner et al. (2008), Eastman et al. (2011), Gu & London (2010) and Arayici et al. (2011). Hardin (2009) further suggests that the implementation plan must be documented and consists of the following components:

- a) Synopsis that describes the company's stance on BIM
- b) Goals and Schedules which specify the implementation purposes and objectives, people's responsibility, and technology acquisition plan
- c) Operational information which describes the new process flow and expected deliverables
- d) Future growth plan which outlines the future goals of BIM at the company

- e) Supporting articles such as journal articles, best practices and guidelines that make the case for BIM implementation and identify potential opportunities.

The aforementioned components of an implementation plan were also found in the case studies, evidenced in Companies A and B, with an additional component for software evaluation strategy as mentioned by Company B. Although other companies did not provide the details of their BIM implementation plan, all of the companies nonetheless agreed on the importance of having a dedicated implementation plan. The plan as justified by Company P and Company C assists in identifying the important requirements of BIM and the needs of the company enabling alignment to be made prior to the implementation, and also serves as a baseline for monitoring and controlling of BIM implementation progress. In addition, Company P also justifies that the implementation plan assists in identifying and organising resources to support the BIM implementation. In developing the plan, the absence of local guides and standards was stressed as one of the biggest drawbacks by all companies except Company B, and the use of international guides and standards was strongly suggested by Companies P, A and C. Some examples were provided by Company P with regards to international guidelines such as BIM Project Execution Plan, AEC (UK) BIM Standard and CoBIM. Meanwhile, as found in Company A, the company's practice and policy to document any procedure in the process flow which complies with the ISO requirement has brought benefits to the company in developing, storing, referring and refining the plan in a structured approach. To wrap up the findings, the following readiness criterion is therefore proposed for the readiness framework:

P05: Documented plan to assist implementation process by adapting international guidelines and standards.

Another important element in the BIM implementation management is monitoring and controlling the progress to ensure success. According to Hardin (2009), by monitoring the BIM implementation progress, the staff and the leadership team of the company can gather information and analyse the effectiveness of the planning, identify any room for improvement and determine corrective action. However, according to Smith &Tardif (2009) there is always an element of the unknown in the deployment of new technology, thus imposing difficulty in establishing metrics for monitoring benchmarks as BIM involves business relationship, enterprise workflow, project delivery methods, staff skill and training and design process. Although not all goals and metrics can be expressed in dollars and cents, they must be quantified in a certain way to enable BIM progress to be measured and controlled. Smith &Tardif (2009) and Succar (2008) then further suggested that the Capability and Maturity Model of the National Building Information Modelling Standard (NBIMS) and Building Information Modelling Maturity Index as the source of references to guide the development

of BIM implementation benchmarks. The monitoring and controlling of BIM implementation was also discussed as important by Companies P, A and C. None of the companies, however, engaged specific models to monitor their BIM implementation, like NBIMS Capability and Maturity Model. As found in Company A, the implementation of BIM came with unforeseen risks and challenges and thus required some adjustment and alignment to keep the implementation progress on track. By monitoring the implementation, the problems and corrective action can be identified earlier which is also supported by Company P. Company P further identified that the most important aspect of the monitoring is whether or not BIM achieves the implementation objectives which are tied to the business needs in terms of speed of design delivery and the quality of design deliverables. Meanwhile, at the operational level, as found in Companies A and C, the following aspects are important to be monitored and controlled:

- a) Competency of people
- b) BIM documentation such as manual and standard
- c) Monetary and expenditure

The following readiness criterion is therefore suggested:

P06: BIM monitoring and controlling technique to ensure the implementation success

As found in many literature sources, BIM requires adequate resources of humans, money and time to drive the implementation. Companies A, B and C also discussed the importance of providing adequate resources to implement BIM as a variety of activities are involved to realise success. Some of the activities that were captured by the companies are peoples' competency program which includes training and education, business process change, hiring BIM-competent people to assist the implementation and software and hardware acquisition process. As evidenced in Company A, from the technical and operational perspective, the most critical resource was the urgent need to have a highly competent BIM Administrator to assist developing the competency of the people and to deliver the project at the same time. The management nonetheless has responded to the need by hiring external staff from U.K to carry PDMS Administrator roles, and also by sending out their internal staff for one month intensive training in Germany to carry BOCAD Administrator roles. However, from the top management point of view, having adequate money to cover the overall cost of the BIM implementation is rather important. The different perspective of answers is expected judging by the different focus taken by the operational and management level. Since the management is responsible for managing the expenditure and profit of the company, many of the

justifications are made based on a monetary basis. To conclude, the following readiness criterion is therefore proposed:

P07: Adequate resources to facilitate and support BIM implementation

According to Autodesk (2007), as part of BIM implementation management, the company also needs to address how the BIM solution will initially coexist with existing 2D drafting or 3D modelling applications. Wholesale abandonment of these legacy design applications is impractical and often ill-advised, but as the implementation expands, the strategy may also include plans for the phased retirement of legacy systems if applicable. In addition, according to Kiviniemi & Fischer (2009), by implementing BIM, drawings would not be obsolete, but their role would change from the main representation of design intent into storage and a view of the information, where the BIM model will store the information and necessary drawings are generated from it. As Smith & Tardif (2007), Eastman et al. (2011) and Crotty (2011) suggest, the 2D CAD process and technology will take a long time before it is replaced totally by BIM, and therefore strengthens the need to address the issue of co-existence. Kiviniemi et al. (2008) further recommended that, for the short term necessity, standard process must be established for the use of both CAD and BIM, in the same ways as AEC has developed standards procedures for document-based processes. A similar finding is also discovered in the case study. As discussed by Company B, the Malaysian construction industry might require at least 20 years to totally replace the role of CAD, and the use of CAD as a basis for tender and contract documents was identified as the biggest challenge for total change. The findings from Company A also support the existence of CAD. Although the oil and gas industry in Malaysia has been enforcing BIM since 1995, and is becoming the industrial standard, the CAD approach and drawings are still used to date and require the proper coordination of BIM and CAD process flow. By referring to Figure 5.1 in subchapter 5.2, within Company A, two processes and teams subsisted to produce the design deliverables after engineering analysis was conducted. The first one is 3D model authoring and extraction of design deliverables by the PDMS and BOCAD team which focuses on BIM process flow. The second one is 2D drawings refinement which was conducted after the 3D model was authored and coordinated, conducted by the CAD team focusing on CAD process flow. Similarly in Case B, the contract requirement which stated the need to submit 2D drawings was identified as the main factor hindering total change. In addition, the following factors are also identified in Company A which require CAD approach to be maintained:

- a) The limitation of PDMS and BOCAD tools require some components to be drafted in CAD
- b) Contract requirement that stated the need to submit 2D CAD based drawings.
- c) People issue that causes internal resistance if the CAD team is diminished.

- d) Site people are still using 2D CAD based drawings to fabricate the structure.

As suggested by both Companies A and B, the co-existence of BIM and CAD approach requires proper coordination and a clear job scope as both are engaging different process flows and deliverables. Therefore, the following readiness criterion is proposed:

P08: Coordination between BIM and CAD process flow.

Meanwhile, Arayici et al. (2011), Eastman et al. (2011) and Smith &Tardif (2009) suggest that BIM implementation should undertake a few pilot projects to find out how the organisation can benefit most from BIM besides exploring and testing the BIM action plan. In the case study that was conducted by Arayici et al. (2011) on three pilot projects, they could not stress enough on the importance of selecting pilot projects that were representing the typical projects which are normally undertaken by the company. The justification lies in minimising the risk and reflecting the normal business process of the company. As they further identified, by piloting the BIM implementation the company has gained benefits through a gradual increase of training and skill proficiency, an observation of how much efficiency can be achieved through BIM and development of an understanding of what was needed for BIM modelling, which subsequently led to improvements in how to sequence the steps in efficient BIM modelling. At the same time, their pilot implementation has also become an eye opening and convincing exercise for all stakeholders involved in the projects to mitigate the inefficiencies in their practice via BIM. Piloting BIM implementation on a few projects that are common to the company is also evidenced in Companies P, B and C. Sharing a similar purpose has been identified in the literature, and the purpose of the pilot project is exploring and testing the BIM methodology, delivering on-the-job training and documenting the best method, challenges, drawbacks, adjustments and deviation for future improvement by using the real environment of the project. The real environment focuses on the use of project data, process flow, deliverables and datelines which were mentioned in Company C. This is needed to suit the need of the project. The following readiness criterion is therefore proposed:

P09: Piloting BIM implementation on a few projects common to the company

5.3.1.3 Policy

According to Eastman et al. (2011), Deutsch (2011) and Forbes & Ahmed (2011), a number of project delivery methods are suitable for BIM implementation but the use of Design and Build is seen as important to exploit BIM benefits to the fullest. The flexibility of the Design and Build approach offers a changing process flow and enables the integration of construction information earlier in the design process. Eastman et al. (2011) further supported the argument by explaining that the Design

and Build delivery process creates a potentially smoother flow of information between project participants. However, some effort must be focused at the beginning to define the work process, which should build and maintain BIM model, and outlining specific uses of BIM including scope and responsibility of each company. Forbes & Ahmed (2011) further added that the use of BIM in Design and Build will also support collaboration which overcomes the fragmentation that is rooted in the traditional design-bid-build approach. The use of Design and Build as a project delivery method is also strengthened by the findings in the case studies that were conducted at Companies P and B. Sharing a similar point on the flexibility with the literature, the ability of choosing the team members and single entity to deliver design and construction has strengthened the advantage of smoother flow of information found in Company P. As for Company B, as an integrated company capable of delivering the design and construction individually, it is therefore leaning on Design and Build as the preferable project delivery method. The authority to select the team is also stressed as an advantage where the company is able to select an architect with BIM capability to streamline the whole delivery process by using BIM. It is important to note that although Company B is an integrated company, it does not provide any architectural design services and the type of Design and Build that was discussed is based on contractors' Design and Build which is normally used within the Malaysian construction industry. The evidence captured within the case study coupled with the literature validation has therefore directed the proposed readiness criterion:

P10: The use of Design and Build type of project delivery to implement BIM

Meanwhile, a multiple case study research conducted by Aranda-Mena et al. (2009) on five architecture and engineering companies suggest that the adoption of BIM is hindered by the legal framework and thus recommended a further research on the area. Oluwole (2011), in response to the legal frameworks needs, has drafted the legal issues of BIM into five categories in which each category has a set of issues to address. The categories are the Obligation, Tools, Cyber Security, Jurisdiction, Consideration and Duty of Care. Meanwhile, data security, Intellectual Property and Contractual arrangement have also been discussed as part of the research findings that were conducted by Gu et al., (2008) and McAdam (2010). Similarly to Olatunji (2011), McAdam (2010) further clusters the legal framework for BIM implementation into several categories before suggesting that several addenda are required on current contract forms to allow BIM to be implemented. The categories are Process, Ownership and protection of data, Use of the Model, Status of the Model, Cost of BIM process, Design liability, Design delegation, and Interoperability. In the process category, Hurtado & O'connor (2008) highlight the need to identify responsibility of the actors to produce and amend BIM model and the contractual structures to allow BIM process to be implemented. Despite many issues raised by different researchers on BIM implementation, The Legal

and Contract working group for UK BIM Industry Working Group which has prepared a Strategy Paper for Government Construction Client Group (UK BIM Industry Working Group, 2011), has concluded that only a little change is required in the fundamental building blocks of copyright law, contracts or insurance to facilitate BIM implementation for collaborative use of BIM. For the legal context of BIM implementation, among many legal issues that were raised in the literature, only two were identified. The first one is contract amendment to allow BIM process flow and deliverables to be performed, which are found within Company P, A and B. The justification lies in the different process flows and deliverables of BIM as compared to CAD. Secondly, the intellectual property issue which figured in Company P. As found in Company A, similar to the recommendation made by the UK BIM Industry Working Group, only a minor addendum is needed to allow BIM to be delivered especially on native electronic copies of the model and drawings, which is to be submitted as part of the contract requirement to allow successful implementation of BIM within the oil and gas industry in Malaysia. Meanwhile, found in Company P, the absence of an addendum to submit native electronic copies of the models and drawings has hindered the electronic exchange of the design deliverables and resulted in 2D CAD paper-based drawings to be traded as information exchange, although the project participants are using BIM within their practice. Consequently, manual re-entry of data is required which creates room for error. The problem probably lies in the intellectual property issue and trust among parties as addressed by Olatunji (2011b) and McAdam (2010) in the literature. Therefore, the following readiness criterion is proposed as part of the readiness framework:

P11: Contract amendment to allow BIM process flow and deliverables to be performed.

5.3.2 MANAGEMENT

Meanwhile, as can be seen in Table 5.1, within the management element, nine readiness criteria were identified and sorted accordingly to three categories, namely Business Strategy, Management Competency and Leadership. The justification of selecting each of the readiness criteria was further discussed in the following subsection.

5.3.2.1 Business Strategy

Lots of research has been conducted to support the benefits that can be gained by the implementation of BIM. Some common benefits are improved quality of the design deliverables, streamlining the design process, increasing the understanding of what to be built via visualisation, better coordination and planning, enable ‘what if’ simulation analysis and accelerating the cost estimation process (Atkin, 1999; Khanzode & Fisher, 2000; Staub-French & Khanzode, 2007 and Azhar et al., 2008). These benefits, as proven by many publications and case studies, nonetheless are not enough to accelerate the BIM implementation by industry players, partly because the majority of players are

unable to perceive how to practically realise the benefits from the utilisation of new technology (Steward et al., 2002 and Mui et al., 2002). As Smith & Tardif (2009) and Eastman et al. (2011) argue, the situation happened because the majority of organisations apply the new technology blindly without doing proper feasibility studies and planning and strategies. As they identified that, the implementation of BIM was more of a business decision than a technical one, thus requiring an alignment of both business needs and BIM implementation strategically which is also agreed by Succar (2010). Without such an alignment, an organization will only benefit from a small subset of what BIM has to offer and consequently, hinder the continuity of BIM implementation due to unworthy investment.

According to Smith & Tardiff (2009), at the strategic level, the implementation of BIM must address the basic objectives of the organisation which is to enhance revenue-generating and for design organisation, means, and enhancing the ability to deliver design. Since BIM implementation affects internal and external business processes, the management must first be able to recognise the tangible benefits clearly to enable rapid change and overcome institutional or legal obstacles, hence possessing a need to be able to align BIM implementation with a clear business goal. According to Aranda-Mena et al. (2009), to make the business case reliable, the BIM implementation must be developed to achieve specific objectives by taking into consideration the particular needs and characteristics of the organisation. The clearer the objectives are defined and the specific circumstances of the company analysed, the better the business case will be. A common objective that was identified by Kiviniemi & Fischer (2009) is to resolve the problems inherited in traditional 2D approach to design. According to them, the 2D approach were labour and time intensive as it involved the production of a numerous non-integrated drawings and specification, manual clash and consistency check and translation of the physical 3D building into 2D drawings. A case study of BIM implementation on an architectural company which was conducted by Arayici et al. (2011) also supported the need to align the BIM implementation with a clear business goal. As they recognised from the case study, the implementation of BIM is tailored to overcome inefficiencies that were rooted in 2D CAD practices such as duplication, lengthy lead times, lack of continuity in the supply chain, over processing, reworking, overproduction, distractive parallel tasks, lack of reliability of data and plan predictability, lack of rigorous design process, lack of effective design management, and communication. A set of similar findings were also captured in the case study conducted by Kaner et al. (2007) on two Structural Design companies. In their findings, the implementation of BIM for both cases was aligned to support the improvement of productivity and quality of design deliverables. Findings from the case studies also reveal that all of the companies that were investigated implemented BIM on the basis of supporting the business goals and aligning the objectives of BIM

implementation on that basis. At the strategic level, it is found in Companies P and C that the BIM implementation is driven to achieve the basic business objectives to increase profit, sharing a similar recommendation made by Smith & Tardif (2009), while for Company A, the BIM enforcement made by their main clients has created new business objectives that must be satisfied to ensure business survival and remaining competitive. In addition, Company B in the agreement of supporting business objectives, discussed the company's need to cater for more jobs at one time and expanding business capacity to the international market within ten years, justifying the BIM investment. Although the business objectives differ from one company to another, the findings nonetheless strengthen the need for having clear business objectives to implement BIM. Meanwhile, length of time, intensive labour and problems inherited in CAD approach were identified as the major drawbacks within the design delivery as identified in Companies A and B. The intelligent and integrated drawings production, 3D visualisation, automated clash check, and automated material taking off are among the BIM features identified in the case study which enable the companies to overcome problems caused by the CAD approach. Consequently, the productivity and quality of design delivery is improved and thus it supports the business needs. To wrap up, the following readiness criterion is proposed as part of the readiness framework:

M01: Alignment of BIM objectives with clear business goals.

According to Tardiff (2009), the full benefits of BIM will be realised only after most of the industry has made the transition from current technology and business practices because the design, construction, operation and on-going maintenance of every building is accomplished by a broad network of people and organisations who need to work together to exchange information in a coordinated fashion. However, the current situation of the industry has made companies implement BIM individually without the same effort by other organisations within the same project. Even worse, the project partners do not have any idea what BIM is all about. In addition, according to Yeomans, Bouchlaghem, & Hamalawi (2006), based on their survey, the difficulties of persuading partners to work in BIM was one of the factors inhibited the full implementation of BIM on a project. Therefore, a negotiation plays a critical part for the company to communicate effectively their internal BIM implementation program, to let their partners be aware of the company's situation, promote the BIM use and at the same time communicate clearly and convincingly new competency so that significant business opportunities are not missed. Smith & Tardiff (2009) then further suggested holding a dialogue with project partners prior to the start of the project whenever BIM is delivered, which is especially important during the pilot project as the company is still at the exploratory stage. The need to negotiate BIM implementation with business partners is also evidenced in Companies P and A. Both companies discussed that different levels of BIM understanding and readiness has caused

challenges to implement BIM effectively. As mentioned in Case P, the nature of the construction involves many partners and the negotiation is needed to gain support and assistance from the partners as the implementation of BIM creates a lot of pressure and challenges. Without proper negotiation, Company P has experienced difficulty in delivering 3D model and process flows while Company A has experienced difficulty in design coordination and communication and disputes caused by unfamiliarity of real and unreal clash. Therefore, the following readiness criterion is identified as important to be included as part of the readiness framework:

M02: Negotiation of BIM implementation with business partners.

According to Aranda-Mena et al. (2009) and Yeomans, Bouchlaghem, & Hamalawi (2006), the demand made by the clients has accelerated and assists in justifying BIM implementation at the organisational level. The demand, noticeably by the government agencies as can be seen in Singapore, Scandinavia and U.S.A, has created a push to the design companies to implement BIM. A similar effort has also been made by the U.K government through the Cabinet Office (Cabinet Office, 2011) to coordinate the government's drive to mandate fully collaborative 3D BIM by 2016. The push is important to create a sustainable BIM demand and from the business strategy point of view, justifies the BIM implementation to the management as it is related to market survival and competitiveness of one organisation. In fact, the lack of client demand was identified as the biggest barrier to the wider take up of BIM in the U.K, which scores 74% of frequency for the answer 'Very Important' and 'Important', based on a survey conducted by Building Cost Information System for Royal Institution of Chartered Surveyor (RICS, 2011). Meanwhile, the importance of sustainable BIM demands lie on justifying the BIM investment as Smith & Tardif (2009) and Eastman et al. (2011) recognized. The investment of BIM requires a series of projects implementation to develop people competency and acquire a return of investment. However, within the context of Malaysia, demand by the client was not yet realized and thus requires the company to create a sustainable market demand. As evidenced in Company A, for the oil and gas industry, the demand made by the client has created the biggest push to justify the BIM investment, influencing the whole level of the company, from operational to the management with no other choice than to accept, commit and implement BIM. Although the company was aware of the BIM benefits and potential prior to the client's enforcement, it nonetheless did not instigate the management to implement BIM. Interviewees from Company A also agree that the client demand is the biggest factor that drives the BIM implementation. Meanwhile, as for the construction industry, although all cases agree that client demand is important, only Company B further discussed the importance of the need to create sustainable BIM demand initiative. The justification, as found in Company B, lies on the continuous demand to strengthen the business needs of BIM and assist in getting management buy-in and

commitment, ensuring continuous use for developing the competency and justifying BIM return of investment, as was identified in the case study, and requires a series of projects. Within Company B, the management has started communicating and promoting BIM by the using the findings from the pilot study to convince the client about the BIM benefits which are targeted at creating BIM market demand. Therefore, the following readiness criterion is proposed:

M03: Creation of sustainable market demand for BIM

5.3.2.2 Management Competency

Generally in the implementation of IT, Peppard & Ward (2004) and Alshawi (2007) recommend that management should acquire a certain level of competency to direct and manage the implementation effectively. As they further identified, management competency is important as it is associated with good management practice which consists of understanding the IT and the organisational requirement to implement the system, championship, effective management of risks and management support and commitment. According to Smith & Tardif (2007), although the management are not expected to master the technical details of BIM technology, some awareness and knowledge are important to be acquired to effectively manage the BIM implementation. They further recommend several knowledge areas as following:

- a) Understanding of BIM implementation requirement
- b) Strategic use and direction of BIM implementation
- c) Management of BIM Expectation
- d) Management of BIM Innovation

Meanwhile, to acquire BIM knowledge, Gu & London (2010) suggest in their matrix for BIM scoping activity, the purpose and phase to conduct adoption workshops for selected senior executives to raise awareness of BIM. As evidenced in Company A, the management buy-in is the first step to develop management competency and is achieved through the awareness of rewards that BIM could offer to the company. Besides aiding to justify the investment by comparing the effort and fiscal aspect of BIM implementation with potential rewards, management awareness needs to be developed further to the knowledge of BIM, covering the technical and non-technical issues which are also supported with the findings from Companies P and C. It also makes sense for the management to acquire a certain level of BIM knowledge as the BIM implementation will be managed and directed by the management team. The management, as found in case studies P, A and C, are not expected to understand the technical details of BIM implementation such as authoring the model, but rather understand the BIM requirements such as BIM process change, human needs and problems that might be faced, similar to what is proposed by Smith & Tardif (2009). In Company A it is found that

the importance of BIM knowledge lies in providing adequate support and encouragement to the people. In Company C, attending a series of seminars and workshops, conducting software demonstrations and communication and discussion with business partners were found to be the methods used to develop BIM associated knowledge. Thus, the following readiness criterion is proposed based on the findings captured in the case study and literature:

M04: Management to have an appropriate level of BIM awareness and knowledge

According to Eastman et al. (2011), the implementation of BIM by transitioning CAD environment with BIM systems involves not only acquiring software, hardware and training but more importantly requires changes to almost every aspect of business and comes with new risks that most of the company are not familiar with. Smith & Tardiff (2009) also recognise the importance of managing the BIM implementation risk, which is also supported by Gu & London (2010), Olatunji (2011c) and Aranda-Mena (2009). Aranda-Mena (2009) further identified that in analysing BIM prior to implementation, it is important for the top management to be able to identify critical risks facing the implementation program, and suggests that any major risks associated with BIM implementation must be early quantified and prepared for a mitigation action. Findings from case studies A, B and C also support the need of the management to have an effective risk management skill to deal with the risk associated with BIM implementation. One of the critical risks is the loss of BIM competent people during the BIM implementation, as was raised by Companies A, B and C. As people with BIM competency are limited within the Malaysian market, some companies tend to snatch people from other companies by offering better benefits such as higher pay and new positions. To respond to the issues, Company B therefore has included the risk mitigation strategy within their implementation plan by providing training to as many people as the company could to become BIM competent, justified by the selection of seven personnel. Within that context, the company would have backup personnel if any of the seven personnel moved to another company, and the interruption of BIM implementation could be minimised. Meanwhile, Company C awarded scholarships to their people, not only to motivate the staff but also to bond the staff legally to avoid the loss of people. In addition to loss of people, interruption of process flow, staff resistance and budget overflow are the other risks which were found in Company A, and similar to Aranda-Mena (2009), the company suggested that the risk and potential solution must be identified early before BIM implementation takes place. The need for an effective risk management has led to the development of the following readiness criterion:

M05: Effective risk management skill to deal with risks associated with BIM implementation

The importance of having management support and commitment to implement BIM was discussed thoroughly in the literature and can be found, to name a few, in Smith & Tardif (2009), Deutsch (2011), Jernigan (2008), Hardin (2009), and Kaner et al. (2008). To this extent, Deutsch (2011) and Smith & Tardif (2009) concluded that the BIM implementation must first establish full commitment and support from the management, especially the principal of the company to ensure success. The importance lies in the financial commitment, changes in workflow and job designation, overcoming technical and non-technical challenges, and developing competency of people, as can be seen in the research conducted by Olatunji (2011), Aranda-Mena (2008), Gu & London (2010) and Kaner et al. (2008). A failure to provide appropriate commitment and support, caused implementation to be unsuccessful as can be found in the case study that was conducted by Whyte & Bouchlaghem (2002). Meanwhile, the support and commitment as was mentioned by Kaner et al. (2008) and Smith & Tardif (2009) must be continuous as the BIM implementation involves a long-term investment to achieve an appropriate level of capability. As Kaner et al. (2008) found in their case study research, the organisation that they investigated took some time to build up BIM modelling skills through several stages, namely basic 3D modelling, automation of drawings production, preparation and use of sophisticated parametric components and use of integrated structural analysis function. At the same time, Smith and Tardif (2007) also stressed that the evolving state of BIM technology requires a continuous support and commitment from the business leader to realise the full benefits of BIM implementation, and recommends the leader to align the implementation strategy with technology trends. The same issue of management to provide continuous support and commitment was found in all of the companies involved in the case studies. Continuous support and commitment is regarded as very important as it determines the success of BIM implementation and therefore must be communicated and translated into visible actions, which is especially important to let the people become aware and understand. In providing visible actions, all of the companies communicate to their staff to take BIM as the standard operating procedure while Company C goes further by publishing the company's commitment via a local newspaper which also serves as a business strategy to communicate the added value of the company. Meanwhile, Company A has demonstrated a high level of support and commitment evidenced with hiring technical competent people from U.K, sending out the staff to Germany to attend an intensive training, and monetary expenditure and incentives. Probably, the ad-hoc nature of the client demand has forced the company to provide support and commitment to the fullest. The justification of having continuous support and commitment lies in the long-term BIM investment which requires a continuous effort, energy and expenditure to develop the competency in the area of people, process and technology. In addition, management support is needed to deal with the pressure, technical difficulties and hiccups during

BIM implementation. Therefore, the following readiness criterion is proposed for the readiness framework:

M06: Continuous commitment and support from the management

5.3.2.3 Leadership

According to Smith & Tardif (2009), the BIM business process reform needs to achieve better productivity and efficiency in the building industry which can only occur through visionary leadership. As they further recommended, this leadership must come from the senior management justifying the management to have full understanding of the business vision and be able to dictate the direction of the company, similar to what Deutsch (2011) has identified in his BIM implementation framework. Meanwhile, the importance of the leadership role lies in directing change effort towards achieving strategic goals and to enable that, the management leadership must provide a clear vision and mission of the future and be able to articulate them especially on how they are going to change the current business and how those changes will improve the business. The need to have a visionary leadership was also identified as a strength in a SWOT analysis for a case study of BIM implementation for midsize structural engineering firms, as can be seen in Kaner et al. (2008). A visionary leadership is also evidenced in Companies A, B and C where the managements have a clear vision and mission of what BIM could provide for the betterment of the organisation. Company A mentioned the need to have integrated BIM and Company B mentioned the need to enter the international market, while Company C shares the vision to strive for excellent operations and high performance standards which reflects the management visions. Company A nonetheless justifies that the importance of the vision and mission lies in directing the BIM implementation in accordance with business strategy. Therefore, the following readiness criterion is proposed:

M07: Management to have a clear vision and mission for BIM implementation

In a study, Kaner et al. (2008) also identified that the management leadership must deal with human resource issues and frustration that may be felt, and the ability of the management to motivate rather than directing orders is crucial to assist the issue, which share a similar recommendation that was made by Alshawi (2007). As evidenced in Company A which went for a full implementation of BIM in 1995, the implementation of BIM has caused stress and pressure on the staff especially to the BIM Administrator and BIM Designer. The stress is rooted from the number of activities that need to be delivered simultaneously. Unfamiliar process flow, the need to learn and practice new software, the number of projects-in-hand and unchanged project datelines were mentioned as the activities which caused a stressful environment. Meanwhile, Company B also recognised the stress and pressure faced

by the staff when implementing BIM into the company. Looking from the human or soft issue, the management therefore must be able to ease the staff emotion, and the ability of the management to motivate the staff was mentioned as important. The management in Company A were using public relations by explaining the added value of having BIM skills by personally walking and talking with the staff at the workstation on a regular basis and continually motivating them and listening to the people's needs and problems. The latter is also used by Company B. In addition, Company B brings the staff together for decision making as part of the motivation, evidenced in their software evaluation strategy. The management of the company believes that by bringing the staff together in decision making, it creates a sense of belonging with the decision that was made and as a result, the staff feel responsible to deliver their decision. To wrap up, the following readiness criterion is therefore proposed under the management leadership category:

M08: The ability to motivate people

Meanwhile, a top down approach to drive the implementation was also discussed as important for BIM implementation to succeed (Deutsch 2011; Succar 2008; Smith & Tardif, 2009). The justification to engage a top down approach, as Smith & Tardif (2009) and Deutsch (2011) further identified, lies in the need to strategically align the BIM implementation with business strategy which is not possible if the bottom up approach is used. In addition, Whyte & Bouchlagem (2002) suggested that the top down approach should be strategic and addressing the needs of the management and operational level. It could be brought about by a forum between the technical managers and top management to discuss the strategic issues. A similar justification was also found in all of the companies that were investigated in the case studies. In addition, Companies P and A mentioned the authority to direct, authority to make decisions and the authority and ability to provide adequate resources, had demanded the implementation to be driven in a top down approach. The latter was also found in Company B. Meanwhile, the evidence that supported the top down approach and management involvement, which is captured during the case studies, is as following:

- a) Management decision on aligning BIM implementation with business objectives
- b) Directing the BIM implementation by appointing senior manager to lead the change
- c) Setting up the BIM team
- d) Monitoring and tracking the BIM implementation progress.

Therefore, another feature of BIM readiness is proposed within the leadership category as following:

M09: Top down approach to drive BIM implementation

5.3.3 PEOPLE

The people element, as can be referred to in Table 5.1 on page 160, consists of eleven readiness criteria which were identified and sorted through a cross case analysis. Each of the criteria was populated accordingly into four readiness categories and they are Roles and Responsibilities, Skill and Attitude, Training and Education, and Work Environment. The justification of selecting each of the readiness criteria was further discussed in the following subsection.

5.3.3.1 Roles and Responsibilities

According to Kiviniemi & Wilkins (2008), the implementation of BIM requires a definition of team roles and responsibilities. The definition depends on overall team relationships, the level of BIM implementation and the types of BIM tools that are used. The organisation must therefore align the definition to meet the expectation of both; the organisations and the project. According to Gu et al. (2010) and Sacks & Barak (2010), one of the major barriers to BIM adoption by the design firm is caused by lack of clarity on BIM associated roles and responsibilities. In the CAD approach, the focus was given more on drafting the drawings, but in BIM, much of the activities are focused on modelling which involves not only authoring the 3D model but also extracting and managing design deliverables which has changed the distribution of previous roles and responsibilities. According to Sebastian (2011), BIM goes further than an application to generate digital drawings since BIM produces an integrated model in which all processes and product information is combined, stored, elaborated, and interactively distributed. According to Smith & Tardif (2009), although it is still unclear of what the BIM roles are at the industrial level, a customised set of clearly defined roles and responsibilities is important to be developed and aligned with the company's strategy and business needs. The defined roles and responsibilities will specify the job scope that the BIM-associated roles need to deliver, provide the management expectation to be fulfilled, and inform the skills and competency set that is required. In addition, according to Deutsch (2011), the introduction of specific job titles also reflects the recognition of the company on the importance of and commitment to BIM implementation. In defining the roles and responsibilities, Deutsch (2011) suggested four BIM-related roles and responsibilities namely BIM Modeller, BIM Operator, BIM Coordinator and BIM Manager. Among four BIM-related roles and responsibilities, the BIM Modeller and BIM Manager were highlighted as particularly important and share similar roles and responsibilities as those described by Eastman et al. (2011) and Barison & Santos (2011), and are simplified in Table 5.2 as following:

Table 5.2: Roles and responsibilities for BIM Manager and BIM Modeller

BIM Modeller	BIM Manager
Perform hand-on production work	Assist in the coordination between disciplines.
Address infrastructure requirements.	Develop a BIM Execution Plan.
Identify the level of detail	Create a staffing plan for the execution of the plan
Coordinate disciplines and trade models.	Coordinate BIM software and hardware requirements.
Facilitate the coordination meetings	Develop office BIM standards: templates, libraries, and best practices in BIM workflows
Coordinate clash resolutions.	Set up a BIM department and create BIM standards and manual
Facilitate analysis done on BIM models.	Provide software support services

Findings from the case study also suggest the need to establish or acquire two new roles for BIM implementation. The title of the roles however, slightly differ where Companies A and B share the same job title, The BIM Administrator, while Companies P and C share the same job title, similar to the findings in the literature but differing with Company A, The BIM Manager and BIM Modeller. Although posing different job titles, the roles and responsibilities of the job titles share a similar characteristic where BIM Modeller or BIM Designer are responsible to operate the BIM tools such as authoring the 3D model, and extracting and preparing the design deliverables. Meanwhile, the most critical and highly demanded roles and responsibilities lie on the BIM Administrator or Manager. The BIM Administrator or Managers are responsible to manage, administrate and facilitate all the technical aspects of BIM which includes preparing the software to be used by the Modeller or Designer, troubleshooting software technical problems, monitoring and checking the accuracy of the drawings and 3D models, and preparing the 3D object libraries. At the same time, as far as BIM implementation is concerned, the Administrator/Manager is also responsible to provide internal formal training as evidenced in Cases A and B, deliver on-the-job training which is found in all companies, and in addition, it is found in Company C that the BIM Manager is also responsible to direct the BIM implementation, liaison between operational and top management regarding the BIM needs, and develop and implement BIM implementation plan, standard and assist. The different roles and responsibilities of the BIM Administrator or Manager among the companies are probably caused by the different nature of the organisation itself where each organisation has a different scope of work, organisational structure and culture. Therefore, the establishment of new job roles and responsibilities relies on the definition that was made by the company to suit the organisation's needs. As for the job titles, the researcher agrees with the title BIM Administrator and Modeller. For the BIM Administrator, since the BIM implementation for this research concentrates more on internal modelling phase, the roles and responsibilities are therefore heavy on administrating the software

tools. While for the BIM Modeller justification, the job scope really concentrates on modelling activity to create 3D models. In addition, the modeller term is also used to avoid confusion with current job titles such as Structural Designer and Architectural Designer which are found in Companies B and C respectively. Therefore, the following readiness criteria are proposed under the roles and responsibilities category:

H01: Clearly defined roles and responsibilities for BIM Administrator

H02: Clearly defined roles and responsibilities for BIM Modeller.

Another important role, as was suggested by Smith & Tardif (2009) is the Head of Change which should be carried by the senior management of the company to manage the BIM implementation. Similarly to Alshawi (2007), the Head of Change is needed to manage the associated resources to achieve optimum BIM implementation which includes providing new IS/IT tools and putting in place teams of people who can redesign roles, jobs and workflow and manage the expectation of top management and operational people. Meanwhile, the importance of appointing the senior management, as Smith & Tardif (2009) further justify, lies in the ability to align BIM implementation with strategic business needs, the authority and respect to direct the implementation, and good understanding of the current business environment. As evidenced in Cases A, B and C, the Head of Change plays a critical role for BIM implementation. The Head of Change represents the management teams to enable the top down approach to be delivered and therefore the Senior Manager was selected. As evidenced in Companies A, B and C, the Senior Design Coordinator, the Head of Structural Department and Head of R&D unit were appointed respectively to carry the Head of Change roles. In contrast with the BIM Administrator or Manager who is responsible to take care of the technical aspects of BIM, the Head of Change shares similar roles to the recommendation made by Alshawi (2007). The following roles and responsibilities are found and gathered from all of the case studies:

- i) Alignment with business needs and set the direction of BIM implementation
- j) Directing and controlling the BIM implementation
- k) Acquiring and managing the resources for BIM implementation
- l) Identifying and specifying the requirements for changing the process flow
- m) Redesigning the new roles
- n) Identifying new wage scheme for BIM newly created roles
- o) Liaison with the staff and top management to align and fulfil their needs and expectations
- p) Reporting the progress of BIM implementation
- q) Prepare and execute the BIM implementation plan

- r) Keep informed, trained and educated for BIM by attending seminars and conferences and is responsible to disseminate the information to the teams

Therefore, the following readiness criterion is proposed under the roles and responsibilities category:

H03: Clearly defined roles and responsibilities for the Head of Change

Meanwhile, according to Alshawi (2009), empowerment of the employee is identified as another factor leading to the success of IT implementation. The justification lies on self-management and collaborative teamwork. By empowering the employee, they become more involved in deciding how work should be approached, which technology to use and providing the chance to participate in the implementation process. The need of empowerment is also supported by Companies A and B. The empowerment was tailored to suit certain levels of responsibility as found in the companies. Empowerment is evidenced within Company B through a collaborative involvement of the people to decide on the software to purchase. Meanwhile, the senior management position that was appointed as the Head of Change has also justified the need for empowerment to drive the implementation as evidenced in both cases, A and B. The authority and empowerment which is inherited by the Senior Manager probably shares the same justification of other companies to appoint the Senior Manager as the Head of Change. The following readiness criterion is therefore proposed:

H04: Empowerment to all new roles.

5.3.3.2 Skills and Attitude

According to Eastman et al. (2011), the human resource considerations are the leading concern not only because the costs of training and setup of software to suit local practices far exceed the costs of hardware and software, but most importantly because the success of any BIM implementation will depend on the skill and attitude of the people tasked with using the technology. As they further justify, BIM is a revolutionary shift away from drawing production, thus imposing a different set of skills. Whereas drafting demands familiarity with the language and symbols of architectural, structural and construction drawings, BIM demands a very good focused understanding of the way buildings are built. Drafting is the laborious act of expressing ideas in two-dimensional media; modelling is virtually building the building. Meanwhile, the purpose of implementing BIM differs from one organisation to another (Smith & Tardif, 2009). The roles and responsibilities for BIM-associated roles also differ, which consequently demands different skill sets of the people. Tied with the roles and responsibilities that are defined by the company, a clear definition of skill sets and attitude of the management is also important. In defining the skill and attitude set, Barison & Santos (2011) conducted a comparative study on BIM job ads and technical literature and found that the

competency set of BIM managers consists of BIM hard skills and soft skills which are measured on the aptitude, education background, experience, skills and abilities, knowledge and attitudes. As part of the BIM soft skill, teamwork, leadership, communication, critical and analytical thinking, coaching, being self-driven, highly motivated and BIM savvy were highlighted as important. For the BIM hard skills, candidates were required to possess the ability to handle multiple BIM software especially the tools that will be used on a daily basis, troubleshooting, coordinating and developing BIM models, familiarity with BIM standard and Workflow and strong technical know-how of BIM and the design process. As for the case study findings, similar to the roles and responsibilities, the skills set that is required for the BIM Administrator and Modeller is slightly different from one company to another, depending on the definition of roles and responsibilities that was set by each company, which is similar to what is found in Smith & Tardif (2007). The common skill set and attitude that both the BIM Administrator and Modeller share for each of the companies is simplified as following:

- a) Interest
- b) IT literate and computer savvy
- c) Helpfulness and willingness to share and contribute knowledge
- d) Ability to respond to change quickly
- e) Technical competency

Meanwhile, the BIM Administrator requires additional skills and attitude which differentiate him/her from the BIM Modeller, as following:

- a) Coaching skills
- b) Troubleshooting skills
- c) Communication and liaison skills
- d) Strong technical and multidisciplinary knowledge
- e) Experience

In addition to the aforementioned skills and attitude for the BIM Administrator, it was found in Company C that the BIM Administrator must also know the project development sequence and all of the associated software technology involved such as Microsoft Project for planning and scheduling, and Esteem for structural design. The administrator was not expected to master the technical detail of the other software but be able to understand each of their uses and most importantly, to know each of the deliverables that were produced, and to enable the manager to assimilate the data and information for authoring the 3D model. To wrap up, the following readiness criteria are therefore proposed:

H05: BIM Administrator has required set of skills and attitude necessary to carry the roles and responsibilities that are defined by the company

H06: BIM Modeller has required set of skills and attitude necessary to carry the roles and responsibilities that are defined by the company

5.3.3.3 Training and Education

According to Kiviniemi & Fischer (2009), in BIM, designer are not just drawings a bunch of lines, but they are required to understand and familiar with every building object that they are authoring since each object engage geometric definition and associated data and rules. The job scope is therefore becoming complex, and required a sound technical know-how. The training thus is needed to satisfy the technical know-how need. The importance of training to deliver a successful implementation of BIM has been highlighted by many researchers, as can be seen in Deutsch (2011), Aranda-Mena et al. (2009), Oluwule (2011), Kaner et al. (2008), Arayici et al. (2011), Eastman et al. (2011), Smith & Tardiff (2009), and Kiviniemi et al. (2008). Kiviniemi et al. (2008) further identified in their survey that BIM investment and cost for training were steep and becoming one of the major obstacle for BIM implementation. Therefore, appropriate means of training and education program must be well planned and executed to avoid dissatisfaction and expenditure loss. The appropriate means were also strengthen by the evidence of a multiple case studies conducted by Kaner et al. (2009). In their study on two mid-size structural engineering organisation, the productivity for producing the design deliverables has jump to more than 600%, as a result from formal, ghosting and on-the-job training. Meanwhile, according to Yeomans, Bouchlaghem, & Hamalawi (2006) and Barison & Santos (2011), higher education institutions are also currently unable to meet the demand for BIM-competent personnel in the short-term which requires the organisation to develop BIM skills internally among their employees through training. In addition, Smith & Tardif (2009) and Arayici et al. (2011) recommend that the training activity must be grounded on the business strategy and tied with the definition of newly introduced BIM roles and responsibilities to make full use of competency development.

According to Eastman et al. (2011), BIM has introduced a new IT environment and therefore requires training to develop technical competency of BIM modelling, understand the process change requirement and bridge the gap between BIM theory and practical implementation. The training should be developed incrementally, side-by-side with existing production methods, so that the learning activity and problems will not jeopardise the completion of the current project. An incremental training was also supported by Kaner et. al (2009), evidenced by four stages of training program. The first stage targets basic 3D modelling, followed by the automation of drawing production and utilisation of sophisticated parametric components sequentially before integrating the

structural analysis function. In addition, Arayici et al. (2011) also confirm the understanding of a company's modelling standard and methodology and how to work with an external party as part of the training content. In delivering the training, as identified in Deutsch (2011), Eastman et al. (2011), Kaner et al. (2009) and Arayici et al. (2011), BIM training can be divided into two types, formal training and informal training. The formal training consists of two levels, beginner, which is normally provided by the software vendor, and advanced level, which requires the company to seek for a professional training provider and is conducted in a formal class setting. The informal training consists of ghosting training while on-the-job training is less formal and is conducted at the staff workstation and assisted by competent people within the company. The ghosting training, according to Kaner et al. (2009) is a modelling practice which uses previous project information and data as a training module whereas the on-the-job training is referred to as a modelling practice by using current project data and information. The informal training is targeted at acclimatising the people with a new set of skills and process flows and bridging the gap between BIM theory learnt in the formal class with the practical work situation. Findings from the case studies reveal that only two types of training are delivered by the companies involved in the case studies, formal in-class training and less formal on-the-job training. For Companies P, A and C, the complimentary training is acquired from the software vendor as part of the software acquisition agreement targeted at developing the basic and intermediate level of modelling proficiency, which also focuses on the technical and process related activity. In addition for BOCAD software, Company A sent their staff to attend a one month intensive course in Germany in 1994 to develop the basic, intermediate and advanced level of technical competency due to the limited capability of the trainers. As for Company B, the formal training was conducted as part of the software evaluation strategy prior to software acquisition. The company has conducted three internal trainings in a series of time laps to ease knowledge assimilation for the software Revit Structure, SECAD and Tekla. The training was targeted at the basic and intermediate level of modelling proficiency. After the acquisition was made on the Revit software, the complimentary training was then tailored to satisfy the needs of advanced skill set. The evidence from the case study and literature supports the need of formal training as part of BIM readiness and therefore the following is proposed:

H07: Formal training to develop skill and knowledge for BIM process and tools

Meanwhile, the less formal on-the-job training was also engaged in all of the case studies after the formal training was conducted. The on-the-job training was stressed as important in all of the companies and is aimed at improving the skills, developing practical competency and also increasing the confidence level of the staff. It is conducted in a step-by-step approach as evidenced in

Companies A and C with a low risk project. The on-the-job training is therefore identified as another readiness criterion and the following is proposed:

H08: Continuous on-the-job training to improve skill and confidence level.

According to Smith &Tardif (2009), in BIM implementation, the larger and often hidden investment is education as opposed to mere training that will enable the entire organisation to change the business culture, and in the resulting reform of core business processes to achieve greater productivity than can be achieved by simply automating existing processes. By taking an example of a floating iceberg, they further regard the cost of software and training as the top floating part of the iceberg whereas the education and culture change is compared to the big hidden part of the iceberg underneath the water, to justify the need of education. The need of a dedicated education program is also highlighted by Arayici et al. (2011) by stating that training teaches people how to do things while education moves beyond that and teaches people how to think. At the same time, the evolving nature of BIM technology also requires a continuous education and training not only to build up competency but also to keep up with the technology trends and identify the latest updates or BIM tools that could offer better solutions for the company. The need for continuous BIM education is also found in Companies A and C. As identified in Company A, continuous education must be attended not only by the BIM Administrators but also by the management to align the BIM implementation with technology advancement so that the company can remain competitive. As for the BIM Administrator, continuous education which is associated with technical knowledge such as software updates and new versions were mentioned, while for the management, education on strategic BIM knowledge was mentioned. The importance of BIM education points to the establishment of the following readiness criterion:

H09: Continuous BIM education and awareness

5.3.3.4 Work Environment

According to Alshawi (2007), the success of IT implementation is highly related to the ability of the organisation to absorb and integrate the proposed systems into the current practice. The system can only achieve their intended business objectives if they are fully integrated into the organisation's current work practice and are accepted and supported by both employees and management. One of the critical elements that influence the level of IT system integration into an organisation's work practice is the ability of the employees to accept and adapt to the new system. This ability is determined by the level of awareness among management and employees of the benefits that the IT system will bring to the organisation and the experience and the technical know-how to use IT to realise the benefits. Alshawi (2007) then further suggested that these two issues are underpinned by

the presence of a work environment that supports learning and is critical to ensure success. The work environment must also serve to motivate and empower employees to innovate and seek improvement changes in line with the business objectives. By combining findings from Eastman et. al (2011), Deutsch (2011) and Kaner et al. (2008) with Alshawi (2007), the work environment that supports learning consists of an appropriate means of capturing knowledge regarding BIM know-how and lesson learnt and represents an appropriate environment for sharing the knowledge among the staff. Alshawi (2007), in respect to knowledge capturing, further explains that the knowledge normally is developed through the experience acquired during the carrying through of the work and is proposed to document every procedure as the documented procedure provides a set of logical ordered activities to accomplish certain tasks. The documented procedure which is also suggested by Smith & Tardif (2009) and Eastman et al. (2011) provides guidance, suggestions and reference materials to facilitate better performance. Meanwhile, lesson learned is another form of capturing and articulating knowledge. The documentation allows professionals to record lesson-learned from the work experience, share it, and make it available for future use which covers the full and detailed description of the identification and solutions of a clearly explained problem. Lesson-learned, which is also found in Kaner et al. (2008), Arayici (2011) and Eastman et al. (2011), is presented in the form of a research journal, not only beneficial to the organisation but also industrial-wide as a source of reference to inform of the challenges that need to be addressed, the achievements and disappointments, and the changes in workflow and personnel that the organisations have experienced. Within the context of BIM implementation activity, the types of knowledge that need to be captured are as following:

- a) Knowledge and insights about procedure, relationships and dependencies of activities to complete certain tasks such as component library development and BIM modelling process flow to include types of data, information and deliverables. (Kaner et al., 2008 and Eastman et al., 2011)
- b) Amendments to existing procedure as a result of an experience gain from performing certain tasks (Smith & Tardif, 2009 and Eastman et al., 2011)
- c) Solutions to problems encountered while performing a particular procedure and best practice such as troubleshooting BIM technical problems (Kaner et al. 2008)

An appropriate means to capture knowledge regarding BIM know-how and lesson learnt are evidenced in Companies A, B and C. In Company A, the researcher was shown the documented BIM process flow and the internal training module, which are updated from time to time. As part of the company practice which also aligns with the ISO requirement, the staffs are responsible to document any change occurring in the process and technology, the resulting knowledge to be captured and

stored. The documented knowledge in the form of a written manual, procedure or module has helped the junior staff in developing their competency by creating a reference and a learning point and speeding up the learning process. Whereas for Company C, the company has made it compulsory for each member of the BIM team to prepare the lesson learnt document. The lesson learnt document specifies the benefits, process or procedure that works or may not work, and the recommendation. Apart from the BIM standard and implementation plan, the lesson learnt document captures the BIM know-how and makes it possible to be shared by other members of the company. The practice for capturing knowledge as evidenced in the case study and supported by the literature, has directed to the establishment of the following readiness criterion:

H10: Appropriate means to capture knowledge regarding BIM know-how and lesson learned.

In addition, according to Alshawi (2007), the knowledge needs to be made available and shared throughout the organisation and requires an appropriate environment that supports knowledge sharing among the staff. The appropriate environment needs the right infrastructure, creation of the right organisational culture and structures as well as fostering employees' willingness to share knowledge, and depends on the method used for sharing knowledge. Examples of the methods used are training and coaching among the staff, formal and informal socialisation which takes place in the forms of sharing experiences, spending time with each other, apprenticeship, mentorship, meetings, communities of practice, brainstorming sessions and group work technologies. A work environment that supports learning and knowledge sharing among the staff is also evidenced in all of the companies. Beside training roles that must be played by the BIM Administrator as evidenced in all of the companies, the mentoring program has given Companies A and B an extra advantage as they have the right environment to support the competency development of the staff. For the record, the mentoring program is a norm within the practice of Companies A and B and has been practiced long before BIM was introduced. As for supporting the learning culture, Company C has directed further discussion whereas part of Company C's mission is to create an environment for the people to realise their full potential where each of the staff are also encouraged to get professional certification for BIM where the cost of the certification will be covered by the company. The certified qualification is important judging by the need of the staff to teach. By having the certification, the other members of staff would be more confident with the trainer. In addition, noticeably during the case study visits at Companies A and C, each of the BIM Administrators for both companies had a bigger working area simply to satisfy the need for delivering and sharing knowledge with the junior staff. Additionally, a dedicated area for discussion was also noticed. The importance of having the right environment has directed to the following readiness criterion to be proposed:

H11: Work environment that supports learning and knowledge sharing among the staff.

5.3.4 TECHNOLOGY

As for the final element of the framework, which is the technology element, seven readiness criteria were identified and populated accordingly into the categories of Hardware, Technical Support and Software. The following discussion was prepared to justify the importance of each readiness criterion.

5.3.4.1 Hardware

According to Olatunji (2011c), the BIM implementation requires specific hardware requirements which comply with the selected BIM software to ensure a good interplay of both for smooth running of the BIM tool. The hardware requirements differ from product to product and the cost varies from one manufacturer to another. According to McGraw Hill Construction (2007), this variance depends majorly on the selected software, the needs of the organisation, market forces and contract arrangements such as maintenance, update and structured technical support. As evidenced in the case studies conducted by Kaner et al. (2009), Arayici (2011) and Eastman et al. (2011), BIM demands powerful workstation hardware, server setup, plotting and printing configurations, network access, and other company specific hardware and IT infrastructure issues. In addition, Deutsch (2011) has labelled BIM as a disruptive technology since BIM imposes physical implications beyond culture. While CAD may have been disruptive in its time by removing the large drafting tables and bringing computers and servers into offices, BIM disrupts organisational physical surroundings in a way that CAD, relegated to the back room, never did by penetrating the front conference rooms, taking over the kitchen when team meetings grow too large, rearranging seating, opening up cubicle-like workstations and requiring a larger monitor.

As BIM technology disrupts the physical, and most importantly, the workstation for delivering the BIM-associated job, a dedicated policy probably needs to be present to allow the disruption to take place. As evidenced in Company C, the company has a standard, group-wide IT policy. Each of the staff is provided with a workstation, specified according to the designation and the position. As for BIM implementation, to ensure smooth running of the software, it is further identified that the standard IT policy needs to be flexible to satisfy the needs of BIM which requires a power workstation (Eastman et al., 2011). For the BIM hardware, as part of the management commitment, the management has made the policy flexible to allow people in the BIM team to have a workstation beyond their pay grade. The following criterion is therefore proposed:

T01: Well-defined ICT policy for BIM

According to Olatunji (2011c), some organisations may require the procurement of new hardware while some organisations just require minor or major upgrading on their existing installations. The need for either procuring new hardware or upgrading the existing hardware or infrastructure is based on current specifications of the hardware, the level of BIM implementation and the organisation's plan for BIM utilisation in the future. For instance, according to Eastman et al. (2011), if the organisation targets the implementation of BIM to support collaboration among staff, they require a system that allows multiple users to create and edit parts of the same model directly from a single project file and manage user access to these various information parts. Such systems thus require at least a disk-based platform with certain capacity. Meanwhile, Olatunji (2011c) concluded that based on a survey that was conducted on 24 industry practitioners in Australia, BIM systems required a higher hard drive capacity up to 320GB, RAM capacity up to 20GB and 64-bit operating systems. Findings from the case studies also support the literature review for the need of having an adequate ICT infrastructure. Companies A and C opted to go for procuring new workstations while Company B opted for only upgrading their workstation since the existing workstation simply needed a graphic card and RAM upgrade to 1GB and 8GB respectively to satisfy the current BIM implementation needs. The option for procuring new hardware will be considered along with the growing of BIM applications across time. The existing hardware in Company A however, was not enough to satisfy the minimum BIM system requirements and no option was left for upgrading. Therefore, the company decided to procure new workstations. By referring to the literature and supported by the findings from the case studies, an adequate ICT infrastructure is identified as important and therefore the following readiness criterion is proposed:

T02: Adequate ICT Infrastructure to support BIM implementation

5.3.4.2 Technical Support

Kaner et al. (2009) has found that the implementation of BIM has introduced several technical difficulties that the organisation had never encountered before. The technical difficulties that they have identified are mainly caused by software bug and incorrect modelling procedures resulting in difficulty recognising the right use of software objects, inappropriate aggregation relationship, incomplete drawings extraction, dysfunctional piece numbering, unwanted part lists, difficulty to setup template, and customizing component library. These technical difficulties demand an adequate technical support as a solution and is also supported by Olatunji (2011a) and Gu & London (2010). In addition, technical support is also needed for research purposes and consulting the BIM program (Olatunji, 2011b). As identified in Deutsch (2011), Kaner et al. (2008) and Eastman et al. (2011), the

technical support can be obtained internally by the BIM manager or BIM-technical competent people, software vendor/provider as part of the software acquisition agreement, or an external or embedded BIM consultant. All of the companies that were investigated agree on the importance of having an adequate technical support. In Companies A and C, the technical support is provided internally by their BIM Administrator and Manager respectively, who were hired externally. At the same time, the technical support that is provided by the software vendor as part of the acquisition agreement was also used to provide the technical support for both companies. As for Company B, it did not hire any external personnel to become a BIM Administrator, but rather trained their internal staff for the roles. Since the newly appointed BIM Administrator has limited competency in providing the technical support, the company is highly reliant on the software vendors to provide the technical support. Therefore, the capability of the software vendors has become crucial to the company and leads them to properly evaluate the capability of software vendors in providing the services. The situation faced by Company B in the need of selecting internal people to become BIM Administrators, probably became the preferred choice by other companies in the industry, justified by the understanding of the company's internal business process and the high cost of hiring an externally competent BIM Administrator. The limited number of BIM-competent administrators within the Malaysian market probably has caused higher wage demands if the company would want to hire one. Back to the discussion for Company B, it is important to mention again that the company has engaged trainings prior to software acquisition upon three items of BIM software. The training, besides serving the purpose of developing the staff competency and evaluating the software, which the latter is also discussed in the next subchapter, serves at evaluating the vendor's capability at delivering the technical support. To wrap up, the following readiness criteria are therefore identified important and proposed:

T03: Appropriate means to evaluate the capability of the software vendor in providing services

T04: Adequate technical support for BIM implementation

5.3.4.3 Software

In the literature chapter, examples of BIM software were discussed and within the design phase alone, a variety of software packages are available in the market today, especially the authoring tools which are developed from different companies. The ease of use, the capability in generating drawings, the sophistication to predefine base objects, the ease to define new object libraries, the method of updating objects, the types of surfaces that can be used, the ability to handle a large number of objects, and the interfaces with other software and the extensibility differ from one product to another (Eastman et al., 2011), causing a complex situation in which the organisation has

to acquire an appropriate software. The selection of the most appropriate software is discussed as very important, as found in Hardin (2009), Crotty (2011), Eastman et al., (2011), Deutsch (2011), Underwood & Isikdag (2010) and Smith & Tardif (2009), and supported by a survey and case study that was conducted by Aranda-Mena (2009), Kaner et al. (2009), Gu & London (2010), Olatunji (2010) and Arayici et al. (2011). Smith & Tardif (2009) further recommend as a basis that the selection of the software must support the strategic business needs and should be based on the justification of enhancing the revenue-generating potential of the organisation. The software therefore must be able to increase the productivity, streamlining workflow, increase the quality of goods and services produced, reduce operating costs, and consequently increase the profits generated. In addition to the current software capability, the development path enhancements and support systems have also affected the evaluation of the software. The importance of the right software, and the existence of many variables in selecting the software, has directed the need to have a dedicated software evaluation strategy. Arayici et al. (2011) for instance, in their case study on BIM adoption and implementation for architectural design organisation, have conducted a comparative evaluation of the potential BIM software in a quantitative manner to sufficiently determine which among three short listed software (that the organisation has pre-identified) is best suited for the organisation. In the evaluation, a list of 40 criteria was produced via brainstorming sessions, to be used as the matrix analysis, and each criterion is then rated 1 to 5 by the staff during the testing and experiment.

Companies P, B and C carried an evaluation strategy before purchasing the BIM software. Company B however, has demonstrated a more dedicated and thorough strategy in evaluating the software. The company has engaged trainings as part of software evaluation strategy as they recognised the need to align the business and operational needs. The trainings were conducted on three shortlisted items of BIM software and by using a matrix of software selection criteria. Each member of staff was then responsible to fill in the forms, process the data and finally report to the management about their final software recommendation. The software evaluation strategy, as discussed in the literature review and supported by the case study findings in Company B, is identified important and therefore the following readiness criterion is proposed:

T05: Software evaluation strategy that incorporates business needs and user requirements

Another concern of BIM software is regarding the compatibility of BIM software with legacy systems, and the interoperability of BIM software with business partner's software, as was addressed by Kiviniemi et al. (2008), Smith & Tardif (2009) and Eastman et al. (2011). It was found in the survey conducted by Yeomans, Bouchlaghem, & Hamalawi (2006) that the interoperability issues, which created by separate, non-integrated software packages, demotivate the implementation of BIM

within the industry. The interoperability issues diminished the effort for collaborative working since the companies and even separate disciplines have to find ways for enable the software to interact with each other. This usually incorporates talking to the vendor or hiring a programmer to develop a middleware to bridge between the packages, both of which need time and money. In addition, Gu & London (2010) raise the concern about the compatibility issue when the software vendor develops a new version of the application which sometimes brings significant differences from the previous version, consequently introducing incompatibility issues with the software. According Forbes & Ahmed (2011), prior to BIM implementation, several IT tools are being used by the organisation to deliver business, which refers to the legacy system. The legacy system software includes a general purpose business system such as Microsoft Word and Excel, design and construction application software such as STAAD-Pro for Structural Analysis, Primavera for Project Planning and Scheduling and Planswift for estimating, and Information Management software such as SAP and OpenText. Therefore, the existence of legacy systems requires the organisation to address the compatibility needs accordingly to avoid unnecessary problems, as evidenced in Alshwawi (2007). Based on the case study that the researcher conducted on an organisation which is involved in design and construction of new homes in the U.K, a decision was made by the structural department to buy an analysis and design software package to assist structural engineers in performing their design task. After implementing the software package for a few months, the company discovered that the output of the design software could not be communicated with existing estimating software packages used by the estimating department where the schedules of materials produced by the design package could not be read due to the incompatibility of the files produced. Consequently, the structural department was forced to abandon the design software and perform the task manually to ensure accurate information. Meanwhile, the interoperability issues have been a major concern for many practitioners and researchers with regards to BIM, despite the fact that 100% interoperability of the software would take many years to realise (Kiviniemi et al., 2008; Eastman et al., 2011; Underwood and Isikdag, 2010; Smith & Tardif, 2009; UK BIM Working Party, 2011). Kiviniemi et al. (2008) further comment that the knowledge of the degree of interoperability between different tools is also important, especially in selecting BIM software to align with the software used by the client and business partner. The same findings are also found in Companies P, A and B. In Company A, the implementation of BOCAD and PDMS caused interoperability problems for their company in 1994 where they initially failed to conduct automated clash check due to incompatibility of the file systems. As both pieces of software were regulated by their clients in the contract, the only option left for the company was to develop a special protocol to resolve the issue, making them the first design consultancy in Malaysia during that time to be able to integrate both pieces of software for automated clash checking via PDMS software. The commitment to develop the protocol lies on the

productivity objective which is tied with their business objectives for streamlining the process flow. Meanwhile, the interoperability issue between structural analysis software used by Company A, SACS and BOCAD is still not resolved technically. As discussed previously, BOCAD is the demand regulated by the clients whereas SACS, as they identified, was the best software solution to suit the company. However, the abandonment of any of the software is unlikely in contrast with the case discussed by Alshawi (2007). Interoperability issues in Company A were resolved through manual data transfer/entry. In addition, as evidenced in Company A, the enforcement of specific software by the client has resolved the interoperability issues among different parties within the same project. As it further supports the agreement, if the clients did not make the software specific, the clients themselves must therefore need to have various software packages. From the monetary point of view, it is not cost-effective to both acquire the software and prepare the people who will be using the software. A similar concern was also found in Companies P and B which led them to also survey the market about what software is being used the most, especially by the client. To wrap up, the following readiness criterion is therefore proposed:

T06: Compatibility and Interoperability of BIM software with legacy and business partners' IT system

As discussed in the subchapter 5.3.1.1: Process Change Strategy on page 163, BIM needs to be implemented in a small and incremental approach, as according to Eastman et al. (2011), each phase of BIM implementation involves its own planning and development of workflows and methods. A small and incremental approach will allow the process change, training and adoption of advanced services without undue risks which will lead to radically new capabilities within the overall design firm. In addition, as discussed in the literature, the implementation of BIM to achieve the integrated stage (Succar, 2008; Bew & Underwood, 2010) is evolutionary, subdivided into a few stages which demand different sets of BIM software and competency of people and processes. As a consequence, the small and incremental approach and evolutionary nature of BIM will impose changes in the purpose of BIM implementation over time, resulting in the changes of BIM system requirements. Therefore, to keep abreast with the changing nature of BIM, a regular review and upgrade of the ICT system is required. Similar findings were also found in Companies A and B. In Company B, implementation of BIM is projected in a series of timeframes to optimise the investment by spreading the expenditure into small chunks. Therefore, the BIM hardware and software requirements will change over time in line with the sophistication and advancement of the BIM implementation and thus require the company to regularly review their ICT system. The following readiness criterion is therefore proposed:

T07: Regular review and upgrade of ICT systems to meet changing BIM and Business needs.

5.4 CONCEPTUAL FRAMEWORK AND ITS USAGE

All of the readiness criteria, found in the case study research for each individual company, were gathered, cross analysed, discussed and theoretically validated, which was conducted in the previous subchapter. As a result, by referring to Figure 5.2, a conceptual framework is then proposed. The framework indicates the readiness criteria in general where the details of each criterion can be further referred to in Appendix 3.0: Questionnaire form for focus group validation workshop.

The framework describes the readiness of the organisation to implement BIM at the organisational level. The framework outlines four elements (people, process, technology and management) in which consist of 17 categories and 38 readiness criteria. Each of the criteria describes the BIM implementation requirement that the organisation needs to develop their capability in order to implement BIM. The framework is generic in nature which allows the users to determine the capability of their organisation by comparing each of the readiness criteria with their current state of BIM implementation. If the organisation satisfies the readiness criteria, the status could be said to match the readiness for that particular criteria. The methods used to determine the organisational status are qualitative in nature allowing evaluation through the use of interviews, observations, document review, etc. Therefore, the more experienced the evaluation team is the better and more accurate the result will be. The evaluation team should also consist of people who understand the nature of BIM implementation and the business of the organisation. The former can be achieved either by engaging internal people or independent consultants who are competent in BIM implementation. While the latter, requires internal people who understand the overall functions of the business from the operational and management point of view. Therefore, it should be attended by the middle and/or top level manager. The result of the readiness assessment would outline the readiness gap between the current states of the company as compared to the BIM implementation requirement sorted accordingly to the readiness criteria. Based on the result, the assessment team can then prioritise their BIM capability development program to suit the needs of the company.

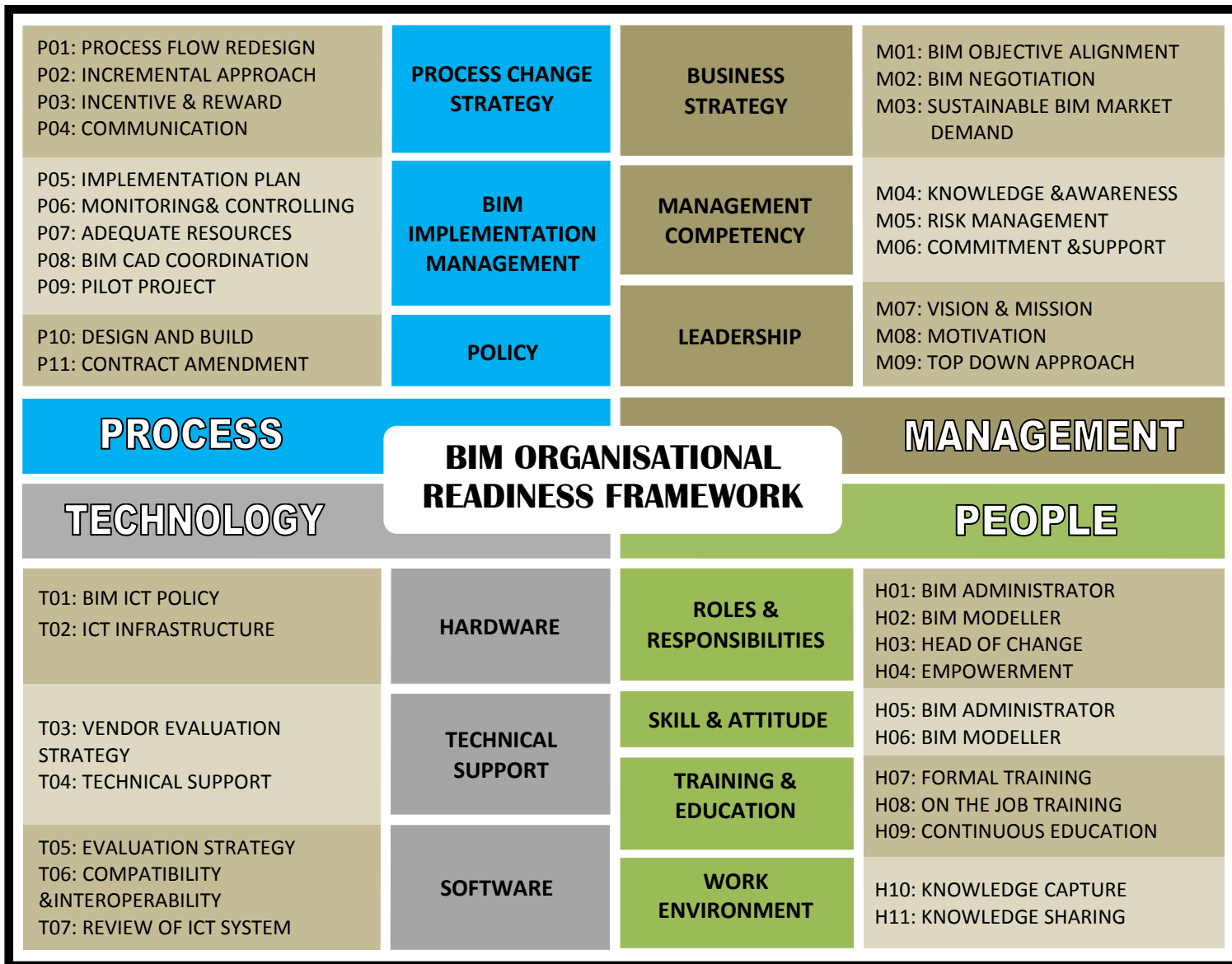


Figure 5.2: Conceptual framework for the BIM organisational readiness

5.5 SUMMARY

This chapter highlighted the discussion of findings which were related to the achievement of the following objectives:

- a) To explore the current level of BIM implementation within the business process by each of the organisations.
- b) Develop a framework of organisational readiness for BIM implementation

For objective A, it is found that Company A has the highest level of BIM implementation, evidenced in the standard operating procedure, the presence of highly experienced BIM-associated roles and responsibilities and a high level of detail for the 3D models. Other companies, which are Companies P, B and C are still at the early stage of BIM implementation where all of them had just finished conducting the pilot projects.

Meanwhile for objective B above, by gathering, cross analysing, discussing and theoretically validating each of the readiness criteria that is identified in the case studies, 38 readiness criteria were identified and populated into the theoretical framework to produce the conceptual framework. Each of the readiness criteria is sorted according to the 17 readiness categories. At this point of the research, the application of the conceptual framework is limited to the companies involved in the case studies. A more general validation is thus required which can be found in chapter 6. The chapter will discuss in further detail the validation findings and how two of the readiness criteria were removed from the framework while another two criteria were introduced.

CHAPTER 6: FRAMEWORK VALIDATION

6.1 INTRODUCTION

In chapter 2, a detailed discussion has been made regarding the development of the theoretical framework that was used to guide the research inquiry for data collection. The framework has outlined four readiness elements and seventeen readiness categories to guide the researcher in exploring the criteria for each category during the case study. The theoretical framework was then developed further into a conceptual framework by cross analysing the data collected for four case studies and connecting them with a theoretical source of reference as can be referred to in chapters 4 and 5 respectively. The drafted or conceptual framework at that point was very theoretical and was limited to four organisations that were involved in the case study judging by the source of data that was used for the development. Thus, a validation is required to obtain a broad view of perspective to generalise the framework. This chapter, therefore, focuses on the validation for each criterion resided within the conceptual readiness framework. The main purposes of the exercise are to validate the framework by measuring the importance and investigating the underlying justification of the individual criteria that make up the framework. The data and findings that were collected during the validation process were then used to refine the framework, and the final framework is presented at the end of the chapter.

6.2 WORKSHOP OVERVIEW

As discussed in Research Methodology, this research engages a workshop as a method to validate the framework. The workshop was conducted in conjunction with a roundtable event organised by The Research Institute of Malaysia, Construction Industry Development Board (CREAM, CIDB). The event, “BIM IBS: Mechanisation of Industrialised Building System (IBS) Through Building Information Modelling”, for a start serves as a kick-start meeting to gather people to sit down and discuss issues related to BIM implementation within the industry. The selection of participants was made based on the experience and professional area associated with BIM, coming from industrial players, government agencies and academia. Meanwhile, for the event, the researcher was appointed as an event coordinator and main editor for the industrial report, alongside the moderator for the validation workshop that is associated with this research.

6.2.1 APPROACH TO ANALYSIS

Within the validation process, there were two areas used to validate the individual readiness criteria: the importance of the criteria and the justification of the importance. The first one is to seek an agreement or disagreement with each individual participant about the framework criteria. Therefore, to structure and ease the participants' responses, a quantitative approach was engaged by using questionnaire forms which can be to Appendix 3.0. The questionnaire forms were distributed early before the workshop started to allow the participants to respond individually. In analysing the data collected through the questionnaire form, two types of analysis were used; The Average Index analysis where the value provides an average response of answers made by all workshop participants, and Frequency analysis to understand the frequency of answers made by the participants for the responses, made on the Likert Scale. The 5 points of the Likert scale that were used are: Highly Important, Important, Neutral, Not Important and Very Unimportant. The detail of the questionnaire can be referred to in Appendix B. It is essential to note that the use of the quantitative approach is not intended to generalise a sample of population within the context of Malaysia. Instead, it was used mainly in the workshop to demonstrate the consensus and distribution of answers that were made by the participants. Therefore, the term 'quasi statistical analysis and or findings' is used to avoid confusion. Furthermore, a limited number of participants have also disqualified the quantitative approach to be used solely. It is also essential to note that within the questionnaire form, the capability of the organisations was also measured. The capability investigation for this research basically measures the level of experience that the company has acquired for each individual criterion. The responses made by the participants would reveal the BIM experience of the organisations, which poses a stronger reliability background as compared to the knowledge that was acquired though literature or theoretical alone. Furthermore, the level of capability would also inform the research on the current capability of pioneer organisations that implement BIM, which opens up an opportunity for a future potential area of research.

The second area of investigation within the validation process was to seek for explanation regarding the justification of answers made by the workshop participants regarding the importance of each criterion. The research inquiry poses the "Why" question and it is qualitative in nature. Therefore, a qualitative approach was selected and since the researcher had an opportunity to gather participants together, a workshop was proposed. During the session, the participants were divided into three groups and within each group, the participants were then required to discuss the justification of the importance of each criterion and present their findings at the end of the session. The source of qualitative data within this exercise is therefore generated from group discussion, debate and

presentation. All the debate and discussion points during the workshops were audio recorded. Similar to the case study method of analysis, the audio source was then transcribed before content analysis was engaged to analyse the qualitative data. Supported with the quantitative data from the questionnaire form, the pattern of responses amongst the participants was then ascertained. The pattern was cross checked with the draft framework and differences or similarities were then used to refine the reliability of the final framework and conclusion. The detailed explanation regarding the development of the workshop strategy was discussed in chapter 3.

6.2.2 BACKGROUND OF PARTICIPANT AND PRELIMINARY ANALYSIS

Based on the data that was collected via the questionnaire forms, a diverse type of organisations were evidenced where the majority of the participants were coming from Integrated Consultant with a recorded number of 9 organisations, 3 participants were coming from Architect Consultant, 2 participants were coming from Structural Consultant, whereas only 1 participant was coming from Mechanical Consultant. All participants nonetheless came from Design Consultant which suits the requirement of the research which was targeted at developing a BIM readiness framework for design consultants. Meanwhile, the selection of workshop participants was made according to the following criteria:

- a) The participants must be trained in the environment of Malaysian construction industry and possess experience with BIM implementation within their organisation. This requirement is needed to match their experience with the local context which the BIM readiness framework was developed for.
- b) The work and BIM implementation experience is limited to at least 5 years and 2 years respectively. The number of years reflects the practical knowledge and familiarity of the participant with BIM-associated issues which also increases the credibility to provide comments.
- c) The designation of the participant must come from the middle or top level management since the framework is designed to be used at the strategic and management level.

Table 6.1 summarises the background of each participant which suits the aforementioned criteria. The code name was assigned based on the group that the participants are representing, to keep the confidentiality and to ease keeping track of the responses made by them. By referring to Table 6.1, a total number of 15 participants joined the workshop. Nine of the participants had working experience

of more than nine years, five of the participants had experience between 11 and 15 years, and only one participant had experience between 6 and 10 years.

Table 6.1: Background of the workshop participants.

Code	Designation	Background	Industrial Experience	BIM Experience
A1	Head of Structural Department	Engineer	>20 Years	3 years
A2	Senior Manager	Quantity Surveyor	11-15 Years	2 years
A3	Principal	Engineer	>20 Years	3 years
A4	Senior Architect	Architect	6-10 Years	2 years
A5	Principal	Planner & Scheduler	>20 Years	3 years
B1	Head of Architect	Architect	>20 Years	4 years
B2	Director	Engineer	>20 Years	4 years
B3	Senior Manager	Architect	11-15 Years	2 years
B4	Assistant Director	Engineer	11-15 Years	2 years
B5	Principal	Quantity Surveyor	>20	2 years
C1	Senior Manager	Mechanical Engineer	11-15 Years	3 years
C2	Senior Manager	Architect	11-15 Years	2 years
C3	Principal	Architect	>20 Years	4 years
C4	Assistant Director	Engineer	>20 Years	3 years
C5	Principal	Engineer	>20 Years	3 years

6.3 RESULT AND DISCUSSION

This section discusses further the analysis result for the workshop validation data. The quasi quantitative results are presented in table forms to depict the distribution of answers that were made by individual participants while readiness radar figures are used to simplify findings of Average Index (A.I) value which is applied to determine the average response for the level of importance and level of capability for each criterion. Furthermore, readiness radar would also inform the readiness gap regarding the organisation's current capability as compared to the important criteria to accomplish. The uses of A.I value, however, are only limited to represent the findings within the workshop that was attended by participants from pioneering organisations which are implementing BIM in Malaysia. The results and discussions are sorted and presented into four readiness elements - Process, Management, People, and Technology, as can be seen in the next subsection.

6.3.1 PROCESS

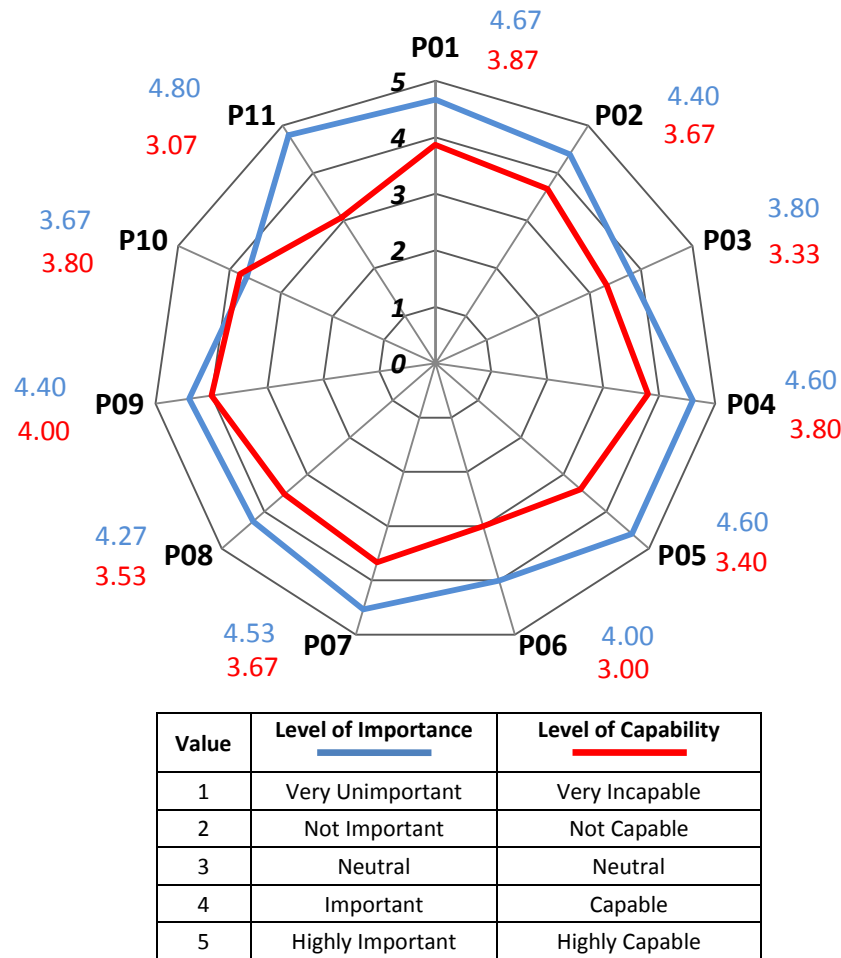


Figure 6.1: Average Index Radar Chart of Level of Importance and Level of Capability for Individual Readiness Criteria in Process Element.

Figure 6.1 summarises quasi-statistical findings of A.I analysis from the data collected through questionnaire forms. The distribution and frequency of answers can be referred to in Appendix 4.1. From the analysis that has been conducted, the results show that each criteria within the Process Element scores above 4.00 A.I value for the level of importance, with exception for 2 criteria, P10: Design and Build and P03: Incentive and Rewards. Criterion P10: Design and Build scores the lowest A.I value of 3.67 for the level of importance, followed by criterion P03: Incentive and Rewards with a score of 3.80. The highest A.I analysis is recorded by criterion P11: Contract Amendment, with the A.I value of 4.80, followed by criterion P01: Process Redesign, with the A.I value of 4.67. Although two criteria scored below 4.00 on the A.I analysis, both criteria nonetheless have recorded a value in close proximity to the value 4.00. Therefore, it can be summarised that participants of the workshop, on average, all agree that all of the criteria listed within the Process Element is important to be

included within the Readiness Framework. The detailed discussion and qualitative evidence that validate the findings are discussed in the succeeding section.

Meanwhile, for the level of capability, which indicates the level of readiness of the participants, each criterion by average, sits between the scores 3.5 and 4.00 with the exception of 4 criteria. The exceptions are recorded for the criterion P06: Monitoring and Controlling with an A.I value of 3.00, the lowest A.I value for the level of readiness; the other three criteria are P11: Contract Amendment with A.I value of 3.07, criterion P03: Incentives and Rewards with A.I value of 3.33 and criterion P05: Implementation Plan with an A.I value of 3.40. The highest A.I analysis, on the other hand, is recorded by criterion P01: Process Redesign, with a score of 3.87, followed by P02: Small and Incremental Approach in second ranking with A.I value of 3.67. In terms of participant's capability in implementing BIM, it can be summarised that most participants who attended the workshop had a mixed level of capability to validate the readiness criteria based on the variety of the capability scores. Nonetheless, no A.I value below 3.00 is recorded, which informs us that the level of capability for individual criteria sits between the answers of Neutral and Capable.

6.3.1.1 Process Change Strategy: Process Flow Redesign

Before the validation findings for the readiness criteria within the Process Element is further discussed, it is important to mention that all values for Average Index and Frequency of Answer that are mentioned in the discussion were based on the table which can referred to in Appendix 4.1. Therefore, to get a better understanding, the associated table should be viewed together with the discussion.

Criterion P01: Process Flow Redesign, by analysing current business process and identifying change required to incorporate BIM model-oriented process, scores 4.67 A.I value with the frequency of answer made up of 67% and 33% of participants agreeing on the answers 'Highly Important' and 'Important' respectively. This left the remaining answers, 'Neutral', 'Not Important' and 'Very Unimportant' with a zero value of frequency. The A.I value alone strongly validates the importance of Criteria P01 to stay within the framework. For the overall criteria, Criterion P01's A.I score sits in fifth place and is ranked second within the process element after Criterion P11: Contract Amendment. Meanwhile, under the category of Process Change Strategy, Criterion P01 scores the highest. Based on the evidence captured during the group discussion, some participants mentioned the need for 3D model development phase to be incorporated within the current process flow. The ultimate deliverable, as explained by one participant, is to produce an information-rich 3D model. Therefore, the focus is needed on developing 3D models. In BIM process flow, the drawings are still

needed. However, instead of drafting the drawings in CAD process, they are extracted from the 3D model to guarantee consistency and accuracy. The use of CAD on the other hand, is still needed in refining the detail of the drawings. However, only a few of the participants were able to deliver the 3D model-oriented process flow within their pilot project. Some of the challenges to change the process that are identified by the participants are:

- a) Low level of staff competency to deliver 3D models as part of working process.
- b) The number of currently running projects-in-hand that tighten the process change where the company needs to prioritise business delivery.
- c) Readiness and willingness of other organisations to provide related information early for developing 3D models and to enable clash check.

6.3.1.2 Process Change Strategy: Small and Incremental Approach

Criterion P02: Small and Incremental Approach, by subdividing BIM implementation into small and manageable targets, scores 4.40 for A.I analysis where the frequency of answer shows 40% of participants responded to the answer ‘Highly Important’ and the remaining 60% of participants responded to the answer ‘Important’, which also left zero frequency to the answers ‘Neutral’, ‘Not Important’ and ‘Very Unimportant’, similar to Criterion P01. According to one participant, a wide range of BIM applications, together with challenges such as training, coordination between parties and new risks, requires the organisation to implement BIM in a small and manageable approach to ease the transition process. Furthermore, each type of BIM application needs individual planning and method. The participant further backed up the argument by saying:

[...]The people, the process and the other parties working with us require some time to understand and adopt BIM. We cannot implement BIM applications in one go since we cannot bite more than we can chew. Many software companies came to us, presenting many advanced features of their product line. 4D, 5D, Cloud Modelling and all. Although the application seems to be appealing, we need to ask ourselves if we really need that application, are we ready enough to advance further, and most importantly, have we mastered enough of the BIM foundation. We do not want a one go approach that creates a big shock to the people and parties involved and leads to resistance [...]

In implementing BIM, as agreed by the case studies, some participants suggest that the prerequisite of BIM implementation is the production of the 3D BIM model. Therefore, the introduction of BIM within the company should firstly focus on building up the 3D BIM authoring capability. Once the capability is developed, then the door of opportunity is open wide to a range of applications such as structural and energy analysis, clash check, material taking off and energy simulation.

6.3.1.3 Process Change Strategy: Incentives and Rewards

Incentives and rewards to motivate staff to change, Criterion P03 scores 3.80 A.I analysis with the frequency of answers comprising only 20% of participants who responded with the answer ‘Highly Important’, 47% of participants responding ‘Important’, 27% of participants responding ‘Neutral’ and the remaining 7% of participants responded with the answer ‘Not Important’. Criterion P03, scores second lowest for A.I value as regards to the criteria within the process element and also for the overall criteria. Although the criterion scores the second lowest, the A.I value nonetheless is above 3.5 and near to the answer ‘Important’. One of the participants commented that the incentive is so important and as such, justifies the pressure that the staffs need to go through to learn new things and deliver the projects at the same time. The incentive, as he further suggested, in the form of monetary allowance, although in a small amount, could still motivate the staff to change and make them happy. The types of incentive, however, received a mixed view from the other participants. Some of them agreed with monetary incentives, but some of them did not. Incentives in the form of working leave and promotion for upper posts have also been mentioned by the participants who opposed monetary incentives. Although the type of incentive did not receive a mutual agreement, the participants agreed that the incentive is important to motivate the staff to change.

6.3.1.4 Process Change Strategy: Communication

Within the process change strategy, Criterion P04: Effective means of communication to explain BIM at all levels and to all individuals within the company scores 4.60 for A.I analysis where the frequencies of answer are made up of 73% of participants responding with the answer ‘Highly Important’, and 13% each for the participants who responded ‘Important’ and ‘Neutral’. According to one participant, the construction industry is too comfortable with the current state of process and technology. Therefore, an appropriate means of communicating change is important to rationalise the need of change and also to direct people to accept and adopt the changes that BIM will make. Communication, as the participant further added, must also be made continuously and address the concerns, ideas and questions that all the people have in mind. Another participant, although agreeing with the importance of communication as part of process change strategy, also stressed that the effective means of delivering communication is not an easy task. He supported his explanation by using his experience in changing the direction of the company from conventional into Industrialised Building System.

[...]Communication as part of BIM process change strategy is indeed important. However the approach to communicate must be made very carefully and strategically. Based on our experience in changing the company's direction towards IBS, it was a very tough job to communicate and convince people to accept and adopt. As we are all aware, IBS was introduced in a Top Down approach by the

government and to survive within the market we have to change our direction since we rely on government projects to survive. We have a strong justification and supported the business direction to convince the people to change but it was not a guarantee for people to willingly change. Therefore we need a little push to change the people but at the end we still experience resistance and two of our staff even moved away to a new company [...]

6.3.1.5 BIM Implementation Management: Implementation Plan

Criterion P05: Documented Plan to Assist Implementation Process by Adapting International Guideline and Standard scores 4.60 for A.I analysis where the frequency of answers are made up of 60% of participants who agreed to the answer 'Highly Important' and the remaining 40% all answering 'Important'. Within the Process Element, Criterion P05 shares third place with Criterion P04: Communication. According to one participant, the importance of the implementation plan lies on the grounds of guiding the process and assisting in identifying and achieving the target that is related to Criterion M01: BIM Objective. The unknown and new risks, process and role change and the technical requirements are some of the issues mentioned by other participants that justify the importance of having a dedicated implementation plan. All the issues must be identified and taken into consideration. The plan, as the participant further explained, although not necessarily focusing in too much detail on every aspect, should at least come out with a framework that addresses all of the targets that the company would want to achieve.

In addition, another participant also supported the documentation of the implementation plan and every change that took place. Taking his company implementation process as an example, each of the staff involved are responsible to document the technical procedure regarding the use of the software such as library development, training module and modelling workflow. The main justifications are:

- a) The documentation is in line with the ISO requirement and company standard operating procedure.
- b) The documented plan and changes make it easy for all people to refer, track and make adjustments for the best process or procedure.
- c) As a part of the knowledge database.

Meanwhile, another participant, during the group presentation, also elaborated further on the need of local guidelines and standards. According to her, the absence of local BIM guidelines and standards is also considered as one of the biggest challenges in developing a BIM implementation plan. Although the company can adopt the international standard as an alternative, much work is needed to customise the standard to suit the local requirements. Different context, cultural challenges and scope were also mentioned as some of the issues that inhibit direct adoption of the international

standard and guideline. Another participant further added that the Malaysian standard and guideline must be developed first to make BIM widely used within the country, and she also suggested that developing the guideline and standard is one of the jobs that the Malaysian BIM taskforce should cover.

6.3.1.6 BIM Implementation Management: Monitoring and Controlling

Criterion P06: BIM Monitoring and Controlling Technique to Ensure the Implementation Success, scores a solid 4.00 for A.I analysis. The distribution of answers were made up of 27% of participants responding ‘Highly Important’, 60% of participants responding ‘Important’, 7% responded ‘Neutral’, and 7% of participants responded ‘Very Unimportant’. In spite of some participants being aware of the existence of BIM-related readiness models such as National BIM Standard Capability Maturity Model, no discussions were captured regarding the model for the purpose of managing BIM implementation progress. Rather, the discussion of monitoring and controlling for BIM implementation was centred on human resources, time and cost required to implement BIM. The evidence that was captured is as follows:

[...] what we monitor is the speed of product delivery when we utilise BIM. For a certain value of project, we can roughly estimate the time that is normally required to deliver the drawings by using CAD. So when BIM comes into the process, we have to make sure it manages to shorten the duration or else the BIM implementation is considered unsuccessful [...]

[...]We claimed to the top management that BIM is able to shorten the duration to produce drawings. Therefore, in the first attempt to use BIM on a real project, we set the target of 10% in time reduction and we have to closely control and monitor to make sure it is delivered as promised. Despite the toughness, considering the low level of competency, we do not really have any option or the management will stop investing [...]

[...]Another aspect of BIM that is highly promoted is the reduction of manpower that is needed to produce design deliverables. Therefore, we take that as our objective and closely monitor the implementation [...]

[...]The BIM implementation requires monetary investment to cover the software package and yearly update, training, hardware upgrade and continuous education. Each of the elements is important and therefore requires prioritisation, monitoring and control [...]

6.3.1.7 BIM Implementation Management: Adequate Resources

Adequate Resources to Facilitate and Support BIM Implementation, Criterion P07, within the category of BIM Project Management scores 4.53 for A.I analysis and the distribution of answers

were made up of 53% of participants responding ‘Highly Important’ and the remaining 47% participants responded ‘Important’. Qualitatively, no data or evidence was captured related to the adequate resources either during group discussion or presentation. The quantitative data, however, validated the importance of the criterion based on A.I value in which the score was 4.53, sitting in the middle between the answer ‘Important’ and ‘Highly Important’. The frequency value also suggests the same response, justifying the pattern of answers that were made only on the answers ‘Highly Important’ and ‘Important’.

6.3.1.8 BIM Implementation Management: Coordination Between BIM and CAD

Coordination Between BIM and CAD Process Flow, Criterion P08, scores 4.27 for A.I analysis and the frequency of answers for ‘Highly Important’ is 33%, ‘Important’ is 60% and ‘Neutral’ is 7%. The A.I and frequency values suggest that the response position is close to the answer ‘Important’. One participant explained that the BIM and CAD coordination is needed since the design process and deliverables within the construction industry are comprehensively delivered using CAD. By envisioning BIM might replace the role of CAD and become mainstream in the future, he stressed that many issues need to be resolved to take BIM forward, and that the replacement will not take place in the near future. Some of the issues are also highlighted by other participants besides him, strengthening the need of CAD and BIM coordination such as:

- a) The use of CAD in contract documents
- b) The majority of industrial players are currently using CAD
- c) The requirement by the local authority and client to submit the drawings in CAD

6.3.1.9 BIM Implementation Management: BIM Pilot Project

Criterion P09: Piloting BIM Implementation on a Few Projects Common to the Company recorded 4.40 value for A.I analysis where the frequency of answers included 53% of participants answering ‘Highly Important’, 40% of participants answering ‘Important’ while the remaining 7% answered ‘Not Important’. Except for one participant, who did not agree with the need of BIM as part of the requirement to implement BIM, others however agreed with its importance. Therefore, based on the A.I and frequency values, Criterion P09 is validated although no qualitative response was captured during the workshop discussion.

6.3.1.10 Policy: Design and Build

Criterion P10: The Use of Design and Build type of project delivery to implement BIM, scores the lowest A.I analysis with the value of 3.67. The criterion’s ranking is therefore positioned in last place

as compared to the other criteria. The frequency of answers were made up of only 13% of participants responding 'Highly Important', 40% of participants responding 'Important' and the largest frequency, 47%, was directed to the answer 'Neutral'. Smith & Tardif (2009), Eastman et al. (2011) and Reddy (2012) in the literature suggest that the use of Design and Build is the most suitable project delivery method to be used in BIM implementation. The recommendation is based on the contractual characteristics of Design and Build that appoint a single organisation to carry the whole design and construction activities. The characteristic therefore creates a potentially smoother flow of information between design and construction entities and also enables a simpler process to submit drawings for construction. Contrarily, one participant did not agree regarding the use of Design and Build as part of the criteria in implementing BIM. The justification is based on two major points where the design consultant does not have power - to dictate what project delivery method to be used, and to dictate the requirements needed to allow BIM use (in the case of Design and Build being engaged within a project). The evidence that supported the disagreement, captured during the group presentation, is as following:

[...]I cannot see how we can be selective enough to favour Design and Build project to be used with BIM since the use of Design and Build is decided by the client. Even if we get awarded a Design and Build project, it is normally led by the contractor. Therefore, in both situations we do not have any power to dictate BIM or any related requirement to be used within the project. If the contractor is using BIM, then we are able to align our implementation process with them quite easily. However, if the contractor is still using CAD, which the majority of them do, there is no advantage of using Design and Build since the process still remains the same. The best that we can do is to negotiate with our partners or clients and align our BIM process with their project requirements regardless of what type of project delivery they are using. [...]

Therefore, Criterion P10 is suggested to be replaced with new criteria: Alignment Between Organisational BIM Requirements and Project Delivery Requirements. The suggested replacements are made based on the justification:

- a) The literature evidence that supports the use of Design and Build as the best project delivery method is based on the implementation of BIM within a project which is different from the purpose of the research which focuses on the organisation.
- b) The lack of power to dictate or control BIM requirement within the project.
- c) Low value of A.I and frequency which indicates that the workshop participants also hesitated about the importance of Design and Build to be used with BIM.

6.3.1.11 Policy: Contract Amendment

Contrary to Criterion P10, Criterion P11: Contract Amendment to Allow BIM Process Flow and Deliverable to be Performed, scores 4.80 for A.I value and the frequency of answers include 80% of participants responding 'Highly Important' and only 20% responding 'Important'. As compared to the other overall criteria, Criterion P11 shares the same ranking as Criterion M07; Management Vision and Mission and sits at the top based on A.I value. Meanwhile, the A.I and frequency value strongly suggest the importance of Criterion P10. However, according to the same participant who responded to Criterion P10, the contract and the type of project delivery are closely related to each other and in both of them, the design organisation has no power to dictate any BIM requirement as part of the policy. In addition, it should also be noted that the readiness criterion that is identified needs to satisfy the research scope, which is the internal use of BIM implementation by the organisation. The focus is given on transforming the internal BIM process and deliverables of the organisation rather than collaboratively delivers BIM with the clients or other shareholders. The trade of information thus, is still reduced on drawings and other traditional deliverables rather than 3D BIM models. Therefore it does not impose any contractual implications. As a result, although the A.I and frequency analysis suggest a strong numerical validation value, the lower authority power of contract and suitability issues to fit the scope of research disqualifies Criterion P11. Thus, the criteria needs to be removed and the suggested new criteria for P10, Alignment Between Organisational BIM Requirements and Project Delivery Requirement, should cover the need to be used within the framework.

6.3.1.12 Policy: Continuous Use Of BIM

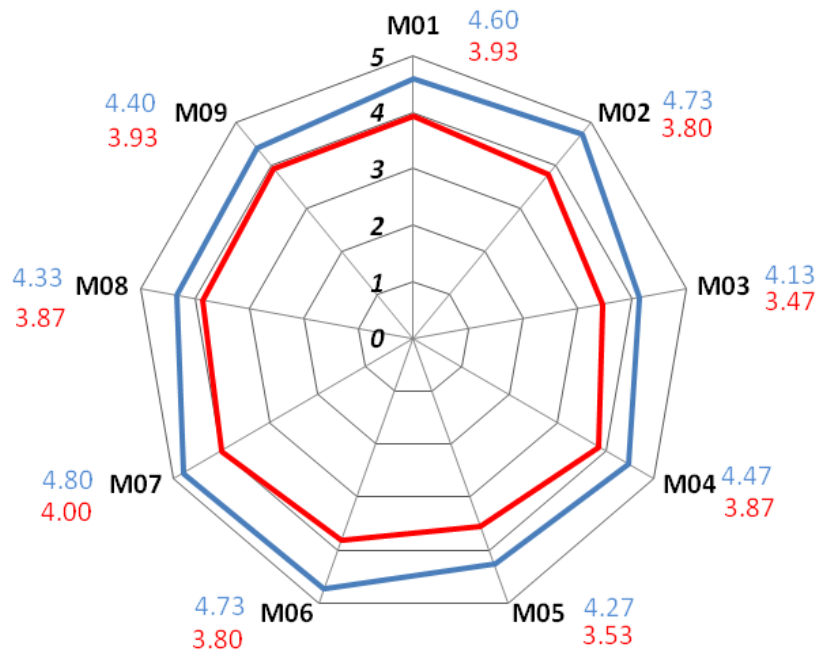
Meanwhile, many participants mentioned the importance of continuous use of BIM and some of them explained that solely tying BIM use with market demand, as can be seen in Criterion M03, is very risky in sustaining BIM use. One of them suggests that although the market demand is not present, the top management must impose internal policies that ensure a continuous use of BIM. He recognised the challenge to impose BIM on every project, but the company must ensure the continuity of BIM use for at least one project for every year. Besides the high expenditure that forces BIM to be used once invested, the other justifications which were also agreed by a few group members are:

- 1) To ensure continuous practice and on-job training to increase the staff level of competency and confidence.
- 2) To continuously test and refine the best process and procedure for BIM implementation

3) To share and support the management commitment of BIM implementation.

Therefore, another criterion is suggested to be introduced within the framework under the Policy category and it is “Criterion P11: Policy That Ensures Continuous Use of BIM Within the Company”. The criterion will also support and complement other criteria such as Criterion M06: Management Commitment and Support, and also Criterion H08: On-The-Job Training.

6.3.2 MANAGEMENT



Value	Level of Importance	Level of Capability
1	Very Unimportant	Very Incapable
2	Not Important	Not Capable
3	Neutral	Neutral
4	Important	Capable
5	Highly Important	Highly Capable

Figure 6.2: Average Index Radar Chart of Level of Importance and Level of Capability for Individual Readiness Criterion in Management Element.

Figure 6.2 shows quasi-statistical findings of Average Index derived from the analysis of data, collected through questionnaire forms that were distributed early before the validation workshop started. Meanwhile, the individual response by each participant and the distribution of answers can be referred to in Appendix 4.2. All of the readiness criteria within Management Element scored values

between 4.00 and 5.00 for level of capability which indicates that on average, participants all agreed on their importance in implementing BIM. The highest A.I value was scored by Criterion M07, Motivation, with a value of 4.80 whereas Criterion M03, Sustainable BIM Demand, scored the lowest with a 4.13 value.

Meanwhile, the level of capability which indicates the level of readiness of the participants, on average sits between the scores of 3.50 and 4.00 where Criterion M07, BIM Vision and Mission scored the highest value of 4.00 and Criterion M05, Risk Management scored the lowest value of 3.53. In terms of participant's experience in implementing BIM, it can be summarised that most participants attending the workshop had a moderate level of capability to validate the readiness criteria based on their capability scores. The next section will discuss in detail validation for each component by combining the quasi-statistical value with qualitative data captured during the workshop.

6.3.2.1 Business Strategy: BIM Objectives Alignment

Similar to Process Element, before the validation findings for the readiness criteria within the Management Element are further discussed, it is important to mention that all values for Average Index and Frequency of Answer that are mentioned in the discussion were based on the table in appendix 4.2. Therefore, to get a better understanding, the associated table should be referred to, together with the discussion.

Criterion M01, Alignment of BIM Objectives With Clear Business Goals within Business Strategy category scores 4.60 for A.I value with the frequency of 40% and 60% for the answers 'Important' and 'Very Important' respectively. Most participants agree that the BIM objectives is an important requirement and should be aligned with the current need of business objectives, which also agrees with the literature and findings gained from the case study. Some of the evidence captured during the group discussion also supports the importance of Criterion M01:

[...]For us to optimise our return of investment, we need to be able to turn around the project in a very short period of time, and the only way for us to achieve that is to optimise our design delivery. BIM is the platform that would allow us to make quicker decisions over a short period of time, with very minimal impact [...]

[...]Regardless of any type of new technology that we would want to implement, it always goes back to what actually we want to achieve at the end of the game that supports the business. At the end, we want to shorten the project duration and deliver high quality products, with minimum use of manpower [...]

Based on the group discussions made by the participants, the BIM implementation objective was stressed as compulsory to be tied with business objectives. Some of the business objectives that were mentioned are:

- a) To resolve current business problems
- b) To increase drawings quality
- c) To speed up delivery
- d) To increase productivity

One respondent also stressed that once the alignment of BIM and business objectives were clearly defined, the BIM objectives should also consider an achievable and incremental target within the subsequent project. Each target must be achieved so it can help the top management to justify and monitor their BIM investment.

[...] maybe we can only expect 10% faster when using BIM on the first project. For the second and third project however, we should expect more, maybe 20% or even 30%. From there, the management can see their BIM investment is returning something to them [...]

Meanwhile some participants suggested that BIM should also address the resolution of current problems encountered by the organisation, and based on the context of BIM implementation, one example was given by one of the participants; to resolve the drawings coordination problem between Structural, Mechanical and Architectural, which contributes to the quality of product delivery.

[...] previously we were using AutoCAD to coordinate our drawings. The process was very tedious and still resulted in system clash. By using BIM, however, we manage to deliver clash free design and the clash check process was simplified where it was done automatically by the software rather than manual [...]

6.3.2.2 Business Strategy: BIM Negotiation

Criterion M02: Negotiation of BIM Implementation with Business Partner scores 4.73 for A.I value with the frequency of 73% of participants answering 'Highly Important' and the remaining 33% of participants agreeing with the answer 'Important'. The Criteria ranked in second place based on the A.I value, sharing the same place as Criterion M06: Commitment and Support. Two participants also responded that the management must negotiate BIM implementation as it plays an important requirement and should be done on the first project which attempts to use BIM. The negotiation ideally involves all parties within the same project such as the consultant, the contractor and mainly the client, so every party is aware of what to expect and hiccups might be faced by the organisation. As one of the participants further explained, although it is difficult to get other parties to implement BIM together, the negotiation is so critical to avoid other parties putting too much pressure on the

organisation's transition process. An example of a successful negotiation was also shared by the participant where his company managed to get a new extended date for drawing submission to allow the BIM process to be performed within the project. However, it is worth mentioning that the organisation that the participant represented has a long historical relationship with the client and the negotiation was made early before the project milestone was finalised. The justification to the clients for demanding an extended date was given as follows:

[...] when implementing BIM, an additional process is required (3D model development) and it is important to negotiate with the client to assist the process. We simply justified how the client will benefit in terms of reduction of variation order and in the long-term, faster delivery of time with high quality of design.[...]

Meanwhile, an interesting argument was also captured during the group presentation. During the presentation, one participant proudly explained that his BIM pilot project was a success by measuring a zero variation order made by the contractor which indicates that his organisation has managed to deliver an error-free design. However, the client's representative who was also working on the same pilot project, (and participated in the conjunction event) stood up and argued the statement by saying:

[...] It may be a success story for you but not for us. Have you considered how long (duration) that you have delayed to deliver the design and the cost overrun to cover up the delay? [...]

It could be summarised that in implementing BIM, negotiating BIM implementation is needed since each party involved in the same project carries individual expectations to fulfill. Therefore, the negotiation should address every party's expectation first before it can be aligned with BIM implementation. Common understanding should then be developed and agreed on before the project kicks off so it can avoid any dispute later on.

6.3.2.3 Business Strategy: Sustainable BIM Market Demand

Creation of Sustainable Market Demand for BIM, Criterion M03, scores 4.13 for A.I value with 33% of participants responding 'Highly Important', 53% of participants responding 'Important', 7% of participants responding 'Neutral' and the remaining 7% responded 'Not Important'. The importance of Criterion M03 is associated with the preference of the company to engage on-the-job training and to provide a continuous practice for developing staff competency as supported by the qualitative evidence. Both the training and the practice require the organisation to use BIM constantly within the business process and can only be carried if the demand for BIM is created or present. Many participants agreed that the demand for BIM in Malaysia currently does not exist, and therefore, the management of the organisation need to be proactive to create them. A few strategies were also

suggested such as organising BIM awareness seminars to tackle clients' awareness, establishing industrial drivers like BIM Malaysian Taskforce, direct promotion to the client and conduct and document BIM case studies to convey the successful BIM implementation evidence to the client. Significantly, most of the strategies proposed by the participants demand an organisation to collaborate with other industrial players who share the same interest.

In creating BIM market demand, one participant acknowledged that BIM has created a competitive advantage to his business, as can be referred to in the qualitative evidence as follows:

[...] it is not that the client does not want to implement BIM. The main problem is they are not aware of what BIM is and how BIM could create better value for them. When we presented our BIM approach to design, especially to tackle tight schedules, most of them were appealing and they were excited to explore more about BIM with us which also led us to win the tender [...]

The statement made by the participant, also reveals that the level of BIM awareness among clients is still low. Many participants were aware that it is a big challenge for the organisation to work alone, creating market demands for BIM. The demand should be created by the government by enforcing BIM implementation through the policy as suggested and agreed upon by some of the participants. The example from the IBS experience was also used to support the argument:

[...] The government should get involved in creating the market demand for BIM. Similarly to what we have experienced in IBS, the uptake of IBS back then was very slow when no policy was in place to promote it. The use of IBS in our country was only increased drastically after the government regulated it in their project. Since we are all aware of the BIM advantages, we should drive the effort to convince the government to implement BIM like how we used to do with IBS [...]

6.3.2.4 Management Competency: Management Knowledge and Awareness

For Management to Have an Appropriate Level of BIM Awareness and Knowledge, Criterion M04 scores 4.47 for A.I value. The value was contributed by 60% of the participants responding 'Highly Important', 27% of participants responding 'Important' and 13% of participants responding 'Neutral'. During the workshop, one participant responded to justify the importance of the management awareness and knowledge as an important criterion for the BIM implementation requirement by explaining:

[...] the management are not expected to have the knowledge to the extent that they manage to author the 3D model. Most importantly, they know what are the BIM implementation requirements, the advantages and disadvantages and also the challenges to expect [...]

[...] the management should also be able to connect the business need with BIM implementation strategy and closely monitor whether BIM is making return on investment or not [...]

Obviously, there are two sets of knowledge and awareness competency that the management should acquire; general knowledge regarding BIM which aids the implementation process, and strategic BIM knowledge which aids setting up the direction and justification of BIM where it is also related to Criterion M01. The participant also recommended several methods to acquire knowledge and awareness for the management, such as:

- a) Direct presentation by the software provider
- b) In-house awareness class
- c) BIM seminar
- d) Open discussion with industrial partners

Also, another participant pointed out that management awareness and knowledge are highly essential by stating:

[...] to allow BIM implementation, the most important thing for management is their belief. They must really believe that BIM brings many advantages and the implementation is worthy of the investment. We can talk about contract amendment, policy change and everything else, but nothing is moving until they believe. Therefore, the awareness strategy must be carefully formulated so that the management believe in BIM [...]

6.3.2.5 Management Competency: Risk Management

Criterion M05: Effective Risk Management Skill to Deal with Risk Associated with BIM Implementation, scores 4.27 A.I values where the score was contributed by 13% of participants responding with the answer 'Neutral', 47% responding 'Important' and the remaining 40% responded with the answer 'Highly Important'. Qualitatively evidenced, one participant explained that the investment of any new technology comes with additional risks and it is therefore important for the management to identify the risks and prepare the risk management strategy so the implementation of BIM can run smoothly. The management must also be cautious not to cause any problems related to the project such as delay and drawing errors. Meanwhile, the risks associated with BIM implementation that were captured during the group discussion are:

- a) Loss of staff during training
- b) Design errors
- c) Design deliverable delays
- d) BIM tool troubleshooting
- e) Staff demoralization

6.3.2.6 Management Competency: Commitment and Support

Management Competency in Providing Continuous Support and Commitment, Criterion M06, scores 4.73 A.I value where 80% of the respondents agree with the answer ‘Highly important’, 13% agree with the answer ‘Important’ and only the remaining 7% of participants agree with the answer ‘Neutral’. As compared to the overall criteria, Criterion M06 sits in second place out of 38 criteria, sharing the position with Criterion M02: BIM Negotiation. The criterion also scores the highest frequency for the answer ‘Highly Important’. The importance of the continuous commitment and support lies on the fact that the Return of Investment of BIM implementation is long-term. The continuous support and commitment is also dependable on the objective of BIM implementation that supports the business case especially when BIM could create the market demand. The evidence of the aforementioned interrelated points is as follows:

[...] we are not able to develop competency of BIM within one project. A series of projects is needed in order to develop the staff competency, the process change and the quality of the deliverables. Therefore, the management needs to make a real commitment and it must be continuous [...]

[...] commitment and support come in place when the management can see how BIM supports the business case. What is meant by the business case is that how BIM could support the objectives of the company and should be the best case if it could create a market demand from the client [...]

Making a point on behalf of the staff directly involved with BIM, the support from the management to fulfil the staff need is also essential, as mentioned by one participant. As the participant further explained, the BIM implementation process was putting additional pressure on the staff where they are responsible to carry two tasks at the same time; mastering the BIM tools and delivering the project. So, strong support from the management must be translated into fulfilling the need of:

- a) Training
- b) Incentive in the form of working leave or monetary
- c) Solving BIM technical issues

6.3.2.7 Leadership: Clear Vision and Mission

Management to Have a Clear Vision and Mission for BIM Implementation, Criterion M07, proved to be the most important criteria within the framework based on the highest A.I score of 4.80 which is contributed by 80% of the participants agreeing with the answer ‘Highly Important’ while only the remaining 20% of participants answered ‘Important’. The frequency of answer ‘Highly Important’ is also the highest as compared with the other overall criteria, and shares first place with Criterion P11: Contract Amendment. Many participants agreed that the management who is responsible to lead BIM

implementation within the organisation, must firstly obtain a clear understanding of the business vision and mission. BIM implementation then must be tailored to support those visions and missions. One participant who responded to the answer ‘Highly Important’, although agreeing with the importance of having a clear vision and mission, disagreed for BIM to have its own vision. The participant stressed that a company can only have one vision and the way BIM could support the vision must be made in the form of missions. The argument was supported by giving the example of his company’s vision and how BIM could support it. The BIM mission however, is not yet defined as the company is still currently at the pilot stage of implementing BIM.

[...] One of our vision statements is to be excellent in everything we do and our mission statement among others is to provide exceptional products and services at competitive prices and deliver them ahead of schedule. Therefore, to support the mission and achieve the vision, BIM is very essential, justifying its unique features of intelligent 3D object and its ability to deliver automated clash check, which contributes to shorten the duration of our design works and increase the quality.[...]

6.3.2.8 Leadership: Motivation

The Management Ability to Motivate People, Criterion M08, within the leadership categories scores 4.33 for A.I analysis with 53% of participants contributing to the answer ‘Highly Important’, 27% contributing to the answer ‘Important’ and the remaining 20% of participants selecting the answer ‘Neutral’. During the workshop, many of the participants were aware of the challenges and burdens that the management put on the staff especially to those who are involved directly in change, such as the drafter (to become designer) and the engineer (to become administrator). In supporting the change and minimising the burden, a few participants agreed that the management should motivate and encourage their staff rather than force. One of the participants, who holds a position at top management, motivated his staff by communicating personally to the staff involved, as can be seen in the following evidence:

[...] we do not push them to move. Instead, we motivate them to start from the beginning by communicating the advantage of having BIM skill and how BIM could streamline their daily work. I personally talk to them, listen to their problems and encourage them to keep on using BIM [...]

Other comments that support the importance of motivation are as follows:

[...] Pushing the staff too hard to do something that they are not familiar with will result in resistance and productivity reduction. The management should balance it with a good style of motivation by encouraging them.

[...] We make it clear to our staff that anyone who possesses BIM skill will have an extra advantage for promotion. It is one of our strategies to motivate them in doing BIM [...]

6.3.2.9 Leadership: Top Down Approach

Top down Approach to Drive BIM Implementation, Criterion M09 within the leadership category, scores 4.40 for the A.I analysis where the value is contributed by 54% of participants responding ‘Highly Important’, 33% responding ‘Important’ and the remaining 13% who responded ‘Neutral’. Since the implementation of BIM involves a long-term commitment and an overhaul of the current business process, people and technology employment, the top down approach is necessary since the decision making begins at the top level. On the other hand, the mandate and empowerment issues were also mentioned by the participants. The evidence that validates the criteria is collected as follows:

[...] Top down approach is important since BIM must support the business need of the company. The business need can only be envisioned by the top management people and therefore it is important to be driven in top down style [...]

[...] Driven by the top management means the implementation process has enough mandate and empowerment to put everything in place [...]

[...] The implementation of BIM or any new technology requires the decision and approval from the top. Therefore, the top management must come first. Many interrelated factors such as monetary, process change, new roles and market demand requires the top management to take the lead and get involved [...]

One participant, who answered ‘Neutral’ for the criterion, disagrees that the implementation of BIM solely depends on the top management. Based on his experience, everybody must contribute, starting from the top until the operational level, with clear roles. There are two areas that were mentioned that can be used to define the roles; strategic and technical. The evidence is as following:

[...]The strategic BIM should be led by the management since they are the ones who understand the business function better and set the direction of the company. However, when it comes to the technicality of BIM such as what tools to be used and the process flow to follow, it must come from the operational level as they are the ones who will be using BIM on a daily basis [...]

Group 2 however, discussed the top down approach from the industrial perspective rather than the organisation. Participants within the group agree that Top Down approach is important, evidenced by the answer pattern where 3 participants answered ‘Highly Important’ and 2 participants answered ‘Important’. The discussion circulated around the role of government to mandate the use of BIM within the project so the market demand is created, thus resulting in an increase of BIM uptake within the industry. The participants were aware that without the market push by the government, the uptake of BIM will progress slowly and based on the IBS experience, one participant supported the argument by explaining:

[...] The promotion of IBS started before the year 2000. Although many companies were aware of the benefits, the implementation was progressing very slowly. Based on the study conducted by CIDB in 2003, before the government mandated the use of IBS, the IBS uptake was standing at around 15% only. We could witness the drastic increase only after the government mandated it within the government project in the 9th Malaysian Plan. The same approach therefore should be applied to BIM. Without the government involvement, BIM is not going to make good progress [...]

Representing the government agency, another participant explained that to mandate the use of BIM in the industry is not an easy task. Good cases of BIM advantages within the Malaysian context must first be present so the government has a strong justification to mandate BIM. The need of having the good Malaysian cases lies on the bad experience of the government where they had encountered many challenges and critics during the early stage of IBS implementation. Therefore, as a lesson learnt in engaging new approach to design and construction for the public project, the government has to be very careful and rigour in mandating new rules to avoid a similar situation. The cases must prove that BIM is able to improve basic project objectives; shorten project duration, increase quality and optimise cost. Therefore, the private agency should lead the uptake first. The bureaucracy, red tape, complexity and rigidity of procurement were also mentioned as drawbacks for the government to currently drive BIM implementation. Recommendation however, was made by Group 2 during the presentation, such as follows:

- a) Private agency to provide a good case example for BIM implementation
- b) JKR and CIDB to play their role by piloting BIM within government projects. It is worth mentioning however, that currently the JKR is already piloting BIM on one of its projects, National Cancer Institute at Putrajaya, Malaysia. The outcome of the pilot test will be used to justify whether BIM should be implemented in the 10th Malaysian Plan.
- c) Once the benefits are quantified, the government should mandate the use of BIM
- d) Incentives such as tax reduction should also be given to promote BIM

6.3.3 PEOPLE

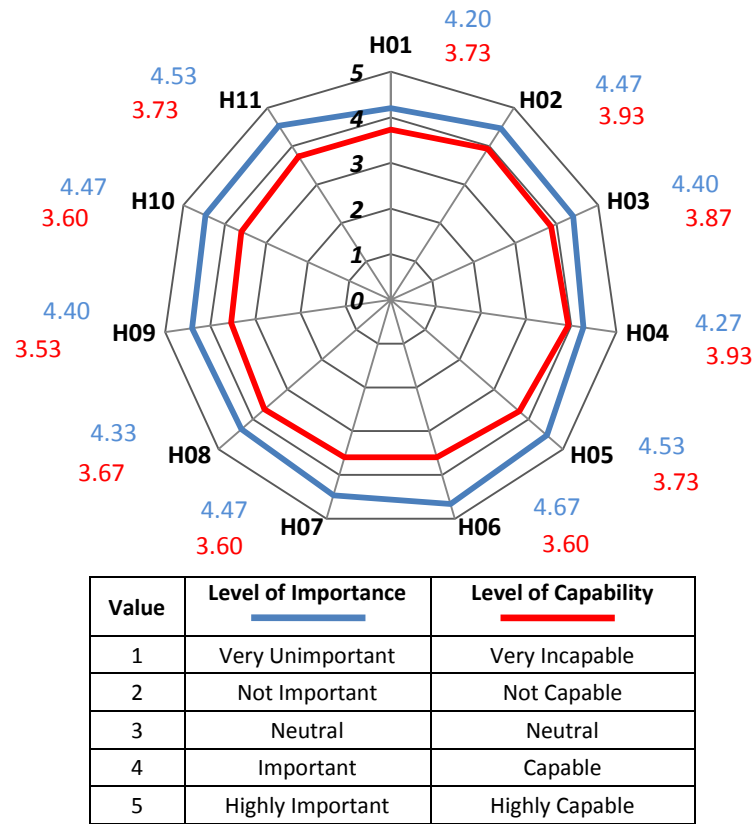


Figure 6.3: Average index radar chart for level of importance and level of capability for individual readiness criterion in people element.

Figure 6.3 summarises quasi-statistical findings of A.I analysis from the data collected through questionnaire forms. The distribution and frequency of answer can be referred to in Appendix 4.3. From the analysis that has been conducted, the results show that each criterion within the People Element scores above 4.00 A.I value for the level of importance. The highest A.I score is recorded by Criterion H06: Skill and Attitude of BIM Designer with the A.I score of 4.67, followed by Criterion H05: Skills and Attitude of BIM Administrator and H11: Working Environment That Supports Knowledge Sharing, which share the same A.I value of 4.53. Meanwhile, the lowest A.I score is recorded by Criterion H01: Roles and Responsibility of BIM Administrator with 4.20. Criterion H04: Empowerment of the New Roles comes in with the second lowest A.I score of 4.27 within the same element. The A.I values indicate that the participants of the workshop on average all agree that all the criteria listed within the People Element are important to be included within the Readiness Framework. The detailed discussion and qualitative evidence that validate the findings are discussed in the succeeding section.

Meanwhile, for the level of capability which indicates the level of readiness of the participants, the A.I value for each criterion sits between 3.50 and 4.00. The highest A.I score, 3.93 is recorded by Criterion H04: Empowerment of New Roles, followed by Criterion H03: New Roles and Responsibility for Head of Change with 3.87. On the other hand, the lowest A.I value is recorded by Criterion H09: Continuous Education with a score of 3.53. In terms of participant's capability in implementing BIM, it can be summarised that on average participants attending the workshop are capable of validating each readiness criteria within the People Element based on the capability scores of above 3.50. All of the scores evidently are in close proximity to the answer 'Capable'.

6.3.3.1 Roles and Responsibilities: BIM Administrator.

Similar to Process and Management Element, before the validation findings for the readiness criteria within the People Element are further discussed, it is important to mention that all values for Average Index and Frequency of Answer that are mentioned in the discussion were based on the table in appendix 4.3. Therefore, to get a better understanding, the associated Table should be referred to, together with the discussion.

By referring to Appendix 4.3 and Figure 6.3, Criterion H01: Clearly Defined Roles and Responsibilities for BIM Administrator, scores 4.20 for A.I analysis where the biggest frequency was contributed by 60% of the workshop participants who responded to the answer 'Important'. The remaining 33% and 7% of participants responded to the answers 'Highly Important' and 'Not Important' respectively. The A.I value and the biggest frequency positioned Criterion H01 in close proximity to the answer 'Important' which validates the criteria. In addition, qualitatively, there were some evidences suggesting that Criterion H01 was the most critical criterion where it is consistent with the pattern of 'Highly Important' answer. Three participants were in agreement that Criteria H01 plays the most important role in managing the technical aspect of BIM. A clearly defined role was further discussed as important to alert and guide the selected staff on the job scope and the necessary requirements to deliver the job. Additionally, the staff would also have some idea on the challenges to expect, as further supported by other participants. Meanwhile during the workshop, some of the participants also discussed their preference to select internal staff to take the Administrator roles over hiring external staff. Some of the considerations were the cost of hiring external personnel, the competency of internal staff regarding the company's process flow, and the current establishment of relationships with other staff. The participants also mentioned a list of roles and responsibilities that the Administrator needs to carry, such as:

- a) Deliver training to the staff
- b) Administer the BIM software including developing a component library

- c) Provide technical support to the staff
- d) Troubleshoot the technical problems

6.3.3.2 Roles and Responsibilities: BIM Modeller.

Clearly Defined Roles and Responsibility for BIM Modeller, Criterion H02, scores 4.47 for the A.I analysis where the distribution of answers are made up of 53% of participants opting for the answer ‘Highly Important’, 40% opting for the answer ‘Important’ and the remaining 7% opting for the answer ‘Neutral’. Qualitatively, a few agreements were collected from the participants about the importance of having a clear definition of roles and responsibility for the BIM Designer. However, only one role was mentioned by the participants, which was the need to author the 3D model in spite of many other roles that were collected in the literature and case studies, such as extracting drawings from BIM, coordinating the model for clash check and producing material schedule.

6.3.3.3 Roles and Responsibilities: Head of Change

H03: Clearly Defined Roles and Responsibilities for the Head of Change recorded 4.40 A.I analysis with the distribution of answers made up of 47% of participants each selecting the answers ‘Highly Important’ and ‘Important’, and only 7% selecting the answer ‘Neutral’. During the group presentation, one of the participants also shared his experience carrying the roles and responsibilities as BIM Head of Change. According to the participant, one of the crucial roles of the Head of Change is to liaise the needs and expectations of the Top Management with the operational level who implement BIM, and vice versa. To deliver the roles effectively, the Head of Change needs to look in depth into the organisation’s process flow and must possess a great understanding about the internal people, process and technology alongside the organisation’s vision and mission. Therefore, the roles need to be taken by the Senior Manager who has served the company long enough to understand the overall game plan of the company and is also savvy with BIM technology. The authority that the Senior Manager has was also mentioned as an essential factor to drive people to change successfully. As compared to the BIM Administrator who is responsible for the technical aspect of BIM, the Head of Change is responsible for the management of BIM implementation. Other roles were also suggested by the participant, which are:

- a) Monitor BIM implementation progress in terms of money and time.
- b) Identify BIM needs such as software and hardware selection, training program and implementation plan.
- c) Designing and coordinating associated BIM roles and responsibilities
- d) Communicating and motivating the staff involved directly with BIM

- e) Promoting BIM use with business partners.

6.3.3.4 Roles and Responsibilities: Empowerment

Empowerment to All New Roles, Criterion H04, scores 4.27 for A.I analysis with 40% of participants responding ‘Highly Important’, 47% responding ‘Important’ and the remaining 13% responding with the answer ‘Neutral’. The A.I and frequency value positioned Criterion H04 to the answer ‘Important’ which validates the criterion to stay within the framework. Qualitatively, some participants agreed that the new roles must come with a certain level of empowerment to drive the BIM implementation forward. The empowerment, as mentioned by one participant, should be limited based on the roles and responsibilities carried by the personnel. For instance, the decision for the type of software and training programmes used must be made by the BIM Designer and Administrator. Again, the same participant who gave a detailed explanation about the importance of Criterion H03, further supported the importance of empowerment by focusing on empowerment of the Head of Change to control expenditure of BIM implementation. Continuing the explanation about Criterion H03 during the group presentation, the participant supported the argument by saying:

[...]Although we came out with a thorough planning, we will only know what works best for us when we start running the BIM tools on a real project. During that time, we started to realise that the RAM or Graphic Card was not fast enough to deliver the job and some technical difficulties beyond the capability of the software provider required a BIM specialist to be called in. Such problems require immediate solutions but as a consequence involve monetary expenditure. In this situation, the Head of Change must have authority to approve the budget instantly or else the process will be slowed down and the motivation of staff will drop in a case where the budget must go through the meeting and approval from the top management [...]

6.3.3.5 Skills and Attitude: BIM Administrator

Criterion H05, BIM Administrator, requires a set of skills and attitudes necessary to carry the roles and responsibilities that were defined by the company score of 4.53 for A.I value where the contribution of answers were made up of 53% of participants who responded ‘Highly Important’, and the remaining 47% agreed on the answer ‘Important’. Although no qualitative evidence was collected during the group discussion, the A.I and frequency value positioned the criteria between the answer ‘Highly Important’ and ‘Important’ which strongly suggests a consensus of answer regarding the importance of the criteria to stay within the framework. Furthermore, as compared to other criteria listed within the People Element, Criterion H05 ranked at second place after criteria H06, Skills and Attitude of BIM Designer.

6.3.3.6 Skills and Attitudes: BIM Modeller

Criterion H06, BIM Modeller, requires a set of skills and attitudes necessary to carry the roles and responsibilities that were defined by the organisation score of 4.67 for A.I value where the contribution of answers were made up of 67% of participants who responded ‘Highly Important’ while the remaining 33% all agreed on the answer ‘Important’. Similar to Criteria H05, no qualitative evidence was collected during the group discussion. The A.I and frequency value however, lean Criteria H06 towards the answer ‘Highly Important’ which validates the criterion regarding its importance. Furthermore, as compared to other criteria listed within the People Element, Criterion H05 ranked at the top place, while it ranked sixth in the overall criteria within the framework.

6.3.3.7 Training and Education: Formal Training

Formal training to develop skill and knowledge for BIM process and tools, Criterion H07, scored an A.I value of 4.47 where the contribution of answers were made up of 53% of participants responding ‘Highly Important’, 40% responding ‘Important’ and the remaining 7% responding ‘Neutral’. The A.I value positioned the criterion within the answer ‘Important’. During the group discussion, many of the workshop participants agreed to the need of formal training. Since BIM is identified as a new technology introduced into the company, professional assistance is a must. The formal training as identified during the group discussion is needed to achieve several purposes such as:

- a) To develop understanding of BIM concepts in terms of the technology and process flow
- b) To develop and strengthen the technical skills to use BIM tools
- c) To identify the knowledge area that needs to be developed further
- d) To get buy-in to use BIM tools

Other points picked up during the group discussion were the importance of BIM tool basic training which focuses on getting user buy-in and also in assisting the user at the advanced level as evidenced by the two following responses, respectively:

[...]The purpose of basic training is to get user buy-in and therefore must be tailored in a way that demonstrates BIM is easy to use. It must focus on giving an exposure to the staff, how it is better than CAD in terms of its advantages, what are the practical ways to use BIM software within the current practice and most importantly, to guide them with the easiest method to use the software.[...]

[...]In the basic training the user must be trained to get familiar with the software interface, the function of each button and technical terminology that is used. This foundation is indeed important to assist them at the advanced level. Even in the situation where the user is having technical difficulties, the trainer can simply instruct them via phone to overcome the problem [...]

6.3.3.8 Training and Education: On-The-Job Training

Criterion H08, Continuous On-the-job Training to Improve Skill and Confidence Level, scores 4.33 for A.I analysis where the frequency of answers are made up of 40% of participants responding 'Highly Important', 53% responding 'Important' and the remaining 7% responding 'Neutral'. Based on qualitative evidence, besides improving the skill and confidence level of the user, the on-the-job training also serves the purpose of identifying and reducing the disparity between what is learnt during the formal training and what is practical to be implemented within the organisation's process flow. The word "continuous" was also agreed to be pertinent by some of the participants as they acknowledge that the desired competency can only be achieved through a series of practices within a real project and is associated with constant practice and hands-on experience. The minimum of three consecutive starts to end projects rather than a number of years involved was also mentioned imperative to achieve the desired level of competency. Therefore, an organisation needs to ensure consistent BIM use within the organisation even though the market demand for BIM is not present. The point that was made is in line with the new criterion that was suggested, as can be referred to in Section 6.2.12 Policy: Continuous Use of BIM within The Company. Another point that was also picked up during the group discussion was the nature of real projects which have a strict dateline and quality to accomplish. They also added up as a good motivator to force the user to develop their competency quickly.

6.3.3.9 Training and Education: Continuous Education

Continuous Education and Awareness Program, Criterion H09, scores 4.40 for A.I analysis where the distribution of answers are made up of 47% of participants responding 'Highly Important' sharing the same figure with the participants who responded 'Important'. Only 7% of participants responded with the answer 'Neutral'. The A.I and frequency value suggest that Criterion H09 is positioned near to the answer 'Important'. Similar to Criteria H05 and H06, no qualitative evidence was captured during the group discussion.

6.3.3.10 Work Environment: Knowledge Capturing

Appropriate Means to Capture Knowledge Regarding BIM Know-how and Lesson Learned, Criterion H10, scores 4.47 for A.I analysis where the distribution of answer are made up of 47% of participants responding 'Highly Important', and the remaining 53% responding with the answer 'Important'. The A.I and frequency value positioned the criterion between the answers 'Highly Important' and 'Important', thus validating the criterion. Qualitatively, the method used to capture the BIM knowledge as mentioned by the workshop participants was done by documenting any related BIM

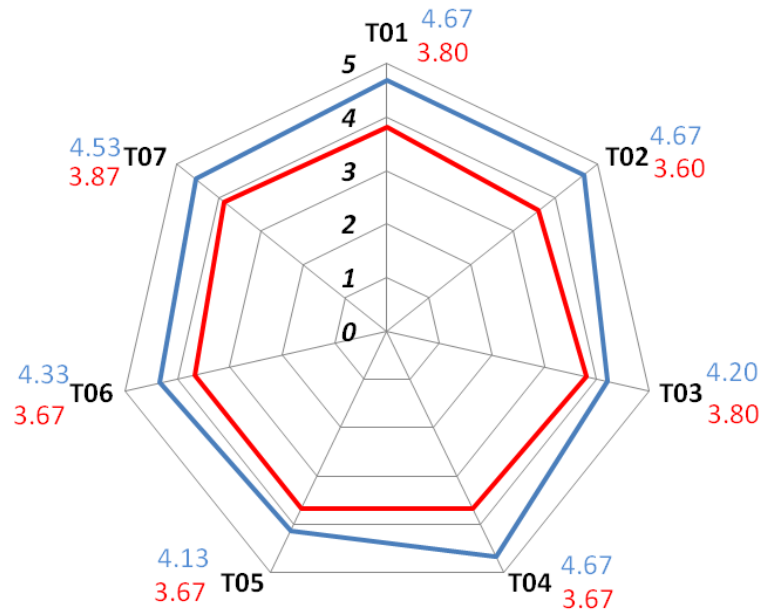
procedures or methodology in a tacit form such as technical reports or company's guidelines. A tacit form would enable knowledge-sharing among staff and can be used for implementation improvement in the future. By using IBS experience as a metaphor, the importance of criteria H10 was further supported by one of the workshop participants:

[...] capturing BIM knowledge is similar to what we did when we implemented IBS as our core business. We make it mandatory for every staff to document every detail regarding IBS, for instance, the procedure they used to design the connection. Having that, every staff can refer, share and comment on the procedure [...]

6.3.3.11 Work Environment: Knowledge Sharing

Criterion H11, Work Environment That Supports Learning and Knowledge-sharing Among the Staff, scores 4.53 A.I analysis where the contribution of answers come from 53% of participants responding with the answer 'Highly Important' and the remaining 47% of participants responding with the answer 'Important'. Similar to Criterion H10, Criterion H11 is positioned between the answers 'Highly Important' and 'Important', but the A.I and frequency value suggest the answer is 'Highly Important'. The quantitative value alone strongly validates the importance of Criterion H11 to stay within the framework. Meanwhile, as compared to other criteria within People Element, Criterion H11 ranked in third place after Criterion H05 BIM Administrator Has Required Set of Skills and Attitude Necessary to Carry Roles and Responsibility Defined by the Company. According to one of the workshop participants, every skill that the staff possesses during BIM implementation process must be shared with other related colleagues. The justification lies in the situation where competent personnel are absent, such as on emergency leave, or in the worst scenario, leaving the company to grant a better offer, the organisation will still have back-up personnel to deliver the BIM job. In this context, Criterion H11 is also supporting Criterion M05, Effective Risk Management Associated with BIM Implementation, which relates to the loss of BIM technically competent personnel. Some workshop participants recognised the importance of creating a learning and knowledge sharing environment and mentioned that the learning environment is a norm within the construction organisation.

6.3.4 TECHNOLOGY



Value	Level of Importance —————	Level of Capability —————
1	Very Unimportant	Very Incapable
2	Not Important	Not Capable
3	Neutral	Neutral
4	Important	Capable
5	Highly Important	Highly Capable

Figure 6.4: Average Index Radar Chart of Level of Importance and Level of Capability for Individual Readiness Criterion in Technology Element.

Figure 6.4 summarises quasi-statistical findings of A.I analysis from the data collected through questionnaire forms. The distribution and frequency of answers can be referred to Appendix 4.4. From the analysis that has been conducted, each criterion within the technology element scores above 4.00 with Criteria T05: Software Evaluation Strategy scoring the lowest A.I value of 4.13, whereas three criteria share the highest A.I value, 4.67, which are Criterion T01: BIM ICT Policy, T02: ICT Infrastructure, and T04: Technical Support. On average, it can be said that participants of the workshop agree that each criteria listed within the Technology Element are important in implementing BIM. The detailed discussion and qualitative evidence that validates the findings is discussed in the succeeding section. The discussions however, are captured for group three only. Due to the time constraint of keeping the event on schedule, only group three managed to discuss the Technology Element in detail and no evidence was captured from other groups.

Meanwhile, for the level of capability, which indicates the level of readiness of the participants, on average, sits between the scores of 3.50 and 4.00 with Criterion T02: ICT Infrastructure scoring the lowest A.I value of 3.60 and Criterion T07: Review of ICT System scoring the highest value of 3.87. In terms of participant's experience in implementing BIM, it can be summarised that most participants attending the workshop had a high level of capability to validate the readiness criteria based on their capability scores which were above 3.5, which agree with the answer 'Capable'.

6.3.4.1 Hardware: BIM ICT Policy

Similar to Process, Management and People Element, before the validation findings for the readiness criteria within the Technology Element are further discussed, it is important to mention that all values for Average Index and Frequency of Answer that are mentioned in the discussion were based on the table which can be referred in Appendix 4.4. Therefore, to get a better understanding, the associated Table should be referred to, together with the discussion.

Well Defined ICT Policy for BIM, Criterion T01, scores 4.67 for A.I analysis where the value is contributed from 67% of participants who agree with the answer 'Highly Important' and the remaining 33% who agreed with the answer 'Important' with no answers recorded for 'Neutral', 'Not Important' and 'Very Unimportant'. On average, it can be said that the participants achieved a consensus that BIM ICT Policy is an important readiness criterion to implement BIM within the organisation. The discussion of BIM ICT Policy in one of the groups during the discussion session however, only focused on the monetary expenditure. According to one participant, the ICT policy should not be limited to the hardware alone. It must cover the entire interrelated ICT components such as software, hardware, technical support and training. Furthermore, the uptake of BIM is planned in several stages over a certain time frame and the progression of the expense needs to be projected accordingly. A yearly time frame was also suggested as a milestone. Therefore the BIM expense policy within the company must satisfy the need. Regarding the yearly dedicated BIM allocation, some evidences were collected as following:

[...]BIM and any ICT related product requires a dedicated allocation. Every year, there are updates that need to be paid. Without the update, our tools might be obsolete and for the yearly renewed licensed, it is worsened, where we could not use it without renewing the license. Therefore, this expenditure must be included within the company's expense policy [...]

[...]Our experience in using software has proven how we need to pay for yearly updates and the same will definitely be applied to BIM tools [...]

[...]The policy maker within the company should treat BIM as operational expenditure rather than Capital Expenditure, giving the on-going cost of update [...]

6.3.4.2 Hardware: ICT Infrastructure

Adequate ICT Infrastructure to Support BIM Implementation scores 4.67 for A.I analysis where the biggest contribution of answers came from 67% of respondents who answered ‘Highly Important’ while the remaining 33% came from the answer ‘Important’. Therefore, the importance of ICT Infrastructure can be summarised as validated based on the A.I and frequency figures that were given by the participants. Qualitatively, according to one participant, the current ICT infrastructure must be able to support BIM application to avoid disruption of the software utilisation. The supporting infrastructure however, depends on the BIM tools that are selected and the advancement of BIM that the company would want to pursue. Within his experience, since the focus of BIM implementation is currently on the modelling activities, the company therefore needed just a minor upgrade of the current workstation which consists of the computer RAM and Graphic Card, rather than acquiring a new workstation.

6.3.4.3 Technical Support: Vendor Evaluation Strategy

Criterion T03, Appropriate Means to Evaluate the Capability of the Software Vendor in Providing Services, scores 4.20 for A.I analysis, the second lowest score after Criterion T05, Software Evaluation Strategy. The 4.20 value is contributed by 33% of participants who agreed with the answer ‘Highly Important’, 53% who agreed with the answer ‘Important’ and the remaining 13% who agreed with the answer ‘Neutral’. The importance of the Vendor Evaluation Strategy lies on the reliance of the company of the vendor to gain adequate and pre-eminent support on the after-sale services such as troubleshooting technical problems and formal training, as mentioned by one participant. Another participant then further suggested several strategies that can be used to evaluate the vendor capability by also mentioning the assessment criteria, such as the following:

[...]Similarly in bidding for a construction project, we are evaluated on our track record, financial capability and competency of our staff in delivering the service. Therefore these criteria need to be also assessed as part of the BIM vendor evaluation strategy. The most important is their technically competent staff. We started by communicating with other companies to get a shortlist of reliable vendors and then we invited them to present their product. During the presentation, we bring our problems to let them demonstrate their solution by using BIM. By having this approach, we manage to evaluate their capability straight away rather than relying on promotional written sources such as the website and pamphlet, which do not really reflect their true capability [...]

6.3.4.4 Technical Support: Technical Support

Adequate Technical Support for BIM Implementation, T04, scores 4.67 for A.I analysis, the highest value within Technology, which also shares the same A.I value and frequency of answer as

Criteria T01: BIM ICT Policy and T02: ICT Infrastructure. The frequency of answer was made up of 67% of participants who agreed with the answer 'Highly Important' and 33% who agreed with the answer 'Important'. The frequency and A.I value strongly validate Criterion T04 in implementing BIM. The importance of Technical Support was explained by the participants:

[...]The technical support is important to assist and guide the staff to develop their BIM competency after they have done the formal training. It serves as an agent to connect the formal training with the practical implementation [...]

[...]The practical problem will only be figured out when we implement BIM on the real project. Therefore, the technical support is very important to support the staff to deal with the problem, and without an adequate technical support, the motivation of the staff will decrease [...]

Three sources of technical support were also mentioned by the participants in Group 3, to facilitate BIM implementation, namely:

- a) Software Vendor that normally comes with complementary training and technical assistance which is also related to Criterion 4.3: Vendor Evaluation Strategy
- b) Independent or third party support such as BIM Consultant or any source other than Software Vendor that is engaged with the company
- c) BIM Administrator which is related to Criteria H01: Roles and Responsibility of BIM Administrator and H05: Skill and Attitude of BIM administrator, where both of them are seated within People Element

As further explained by another participant, the current trend of BIM implementation in Malaysia is relatively new and therefore hiring a highly competent BIM Administrator could come at high cost. Most companies would rather convert their internal staff to become BIM Administrators, which is also agreed by others within Group 3. Therefore, the preferable source of technical support comes from the Software Vendor and the use of independent or third party support is the last resort, only if the Software Vendor cannot assist with the problem. Some participants, however, recognised that the technical support provided by the Software Vendor is adequate without the need for seeking extra support. The importance of technical support from the Software Vendor indirectly also strengthens the validation of Criterion T03: Software Vendor Evaluation Strategy, given the important role of the vendor to assist technical support, thus the selection process must be made accordingly.

6.3.4.5 Software: Evaluation Strategy

Criterion T05, Software Evaluation Strategy That Incorporates Business Needs and User Requirements, scores the lowest A.I analysis within Technology Element with a score of 4.13. This is positioned as the second lowest A.I score for all criteria within the BIM organisational readiness framework. T05 also shares the same ranking with Criterion M03: Sustainable Market Demand within Management Element, where the frequency of answers are made up of 33% of participants responding with the answer ‘Highly Important’, 47% responding with the answer ‘Important’ and the remaining 20% responding with the answer ‘Neutral’, while no response was recorded for ‘Not Important’ and ‘Highly Not Important’. Although the A.I value is fairly low as compared to the other criteria, the number nonetheless still tipped above 4.00 with the frequency of answer for ‘Important’ and ‘Highly Important’ combined at 80%. Therefore, it is fair to conclude that the criterion is validated. One participant recognised the need of having the software evaluation strategy and the incorporation of business needs and user requirement. Although no explanation was gathered for the business needs, the participant explained that the user requirements are very important in assisting the staff with BIM. The familiarity of the staff with AutoCAD software has also demanded the same interface as part of the user requirements to select BIM software in addition to its user-friendliness.

6.3.4.6 Software: Compatibility and Interoperability

Compatibility and Interoperability of BIM Software With Legacy and Business Partners’ ICT System, Criterion T06, scores 4.33 for A.I analysis with 47% of respondents agreeing with the answer ‘Highly Important’, 40% agreeing with the answer ‘Important’ and the remaining 13% agreeing with the answer ‘Neutral’. According to one participant in Group 3, the importance is based on the need for exchanging data and information seamlessly between different parties, and since most companies within the Malaysian construction industry are using AutoCAD package, therefore the use of REVIT package was suggested as the most suitable. To understand the reason for such a suggestion, the researcher managed to further the inquiry all of the G3 members regarding the justification of the suggestion. All of the G3 members are in agreement with the participant, with the justification as following:

[...]Many of our partners are using AutoCAD package as compared to other packages. Therefore, we need BIM tools that can support drawing format provided by AutoCAD to reduce manual data entry. Since Revit and AutoCAD are coming from the same company, therefore their interoperability is not an issue [...]

6.3.4.7 Software: Regular Review Of ICT System

Criterion T07: Regular Review and Upgrade of ICT Systems to Meet Changing BIM and Business Needs, scores 4.53 for A.I analysis where the contribution of answers were made up of 53% of the workshop participants responding with the answer 'Highly Important' and the remaining 47% of participants all responding with the answer 'Important'. The frequency and A.I value strongly position the criterion between the answers of 'Highly Important' and 'Important', thus validating the criterion although no qualitative evidence was captured for the whole session of the workshop.

6.4 OVERVIEW FOR THE VALIDATION FINDINGS

The following result summary was derived from the data and analysis that was conducted during the validation processes:

1. All the criteria that were developed from the case study research and literature as the main variables in the framework were perceived 'Important' by the participants in the workshop, having an A.I value of above 3.50. Supported with the qualitative evidences that were captured during group discussion and presentation, all of the criteria are therefore quasi-statistically validated
2. Criterion P11: Contract Amendment to Allow BIM Process Flow and Deliverable to be Performed, although, received the highest A.I value of 4.80, but the nature of design consultant roles in Malaysia does not permit them to amend the contract terms (Saidin, 2000; Public Work Department, 2007). Therefore the criterion was considered unsuitable and is removed from the framework. Additionally, the criterion also did not satisfy the scope of the research which focuses on internal implementation of BIM which does not impact the contract arrangement of the project. Criterion P10: The Use of Design and Build as Favourable Project Delivery Method, which received the lowest A.I value of 3.67, has also been removed based on the limited number of Design and Build projects that the organisation has acquired, and the absence of authority to dictate the BIM requirement within the contract delivery (Public Work Department, 2007). Both criteria, P11 and P10, were under the authority of the client to amend the contract and implement the type of project delivery and therefore are not suitable for the framework for design consultant.
3. In the response of the exclusion of Criteria P11 and P10, a new criterion was introduced under the same policy category which is Criterion P10: Alignment between Organisational BIM Requirements and Project Delivery Requirement.

4. The need for continuous use of BIM within the organisation has also demanded a new criterion to be introduced, Criterion P11: Policy That Ensures Continuous Use of BIM within the Organisation. The importance of the criterion lies in providing constant BIM usage by the staff, real management support and commitment and BIM process improvement, which all require the organisation to use BIM consistently.
5. Although the workshop participants agreed that all of the criteria are important to the organisation, moderate A.I values were recorded for the organisational capability with most of the criteria scores falling within the range of 3.00 to 4.00. The figure indicates that the current capability to implement BIM is still low and requires further improvement. It is important to note that the participants who joined the workshop came from organisations that are pioneering BIM implementation in Malaysia. Meanwhile, on the bright side, the industry in Malaysia is very keen to push BIM forward as evidenced by the participants' commitment to establish a BIM taskforce.
6. Although the validation process is not tailored to prioritise the criteria, qualitatively and quantitatively, the Management Element is perceived as important by the participants judging by the top three criteria receiving the highest A.I values and points of discussion, as compared to other criteria. Those criteria are M07: LEADERSHIP: VISION AND MISSION, followed by M02: BUSINESS STRATEGY: BIM NEGOTIATION, and ranked at third is M06: MANAGEMENT COMPETENCY: COMMITMENT AND SUPPORT. The participants agreed that the implementation of BIM must be driven by the management by focusing on external and internal issues associated with BIM implementation.

6.5 PRESENTATION OF FINAL FRAMEWORK

Based on the validation analysis and overview of validation findings, the readiness framework was further refined as in Figure 6.5. It should be noticed that the only refinement that was made was on the policy category where two of the proposed criteria in the conceptual framework, P10 and P11, were removed and replaced with a new criterion, P10: Alignment between Organisational BIM Requirements and Project Delivery Requirement. In addition, a new criterion was also introduced, Criterion P11: Policy That Ensures Continuous Use of BIM within the Organisation. In addition, the use of the framework must be accompanied by the detail description of each criterion, as can be seen in page 248, to gain a better understanding. The justification of removing and introducing the readiness criteria was discussed under Sections 6.3.1.10, 6.3.1.11, 6.3.1.12 and 6.4.

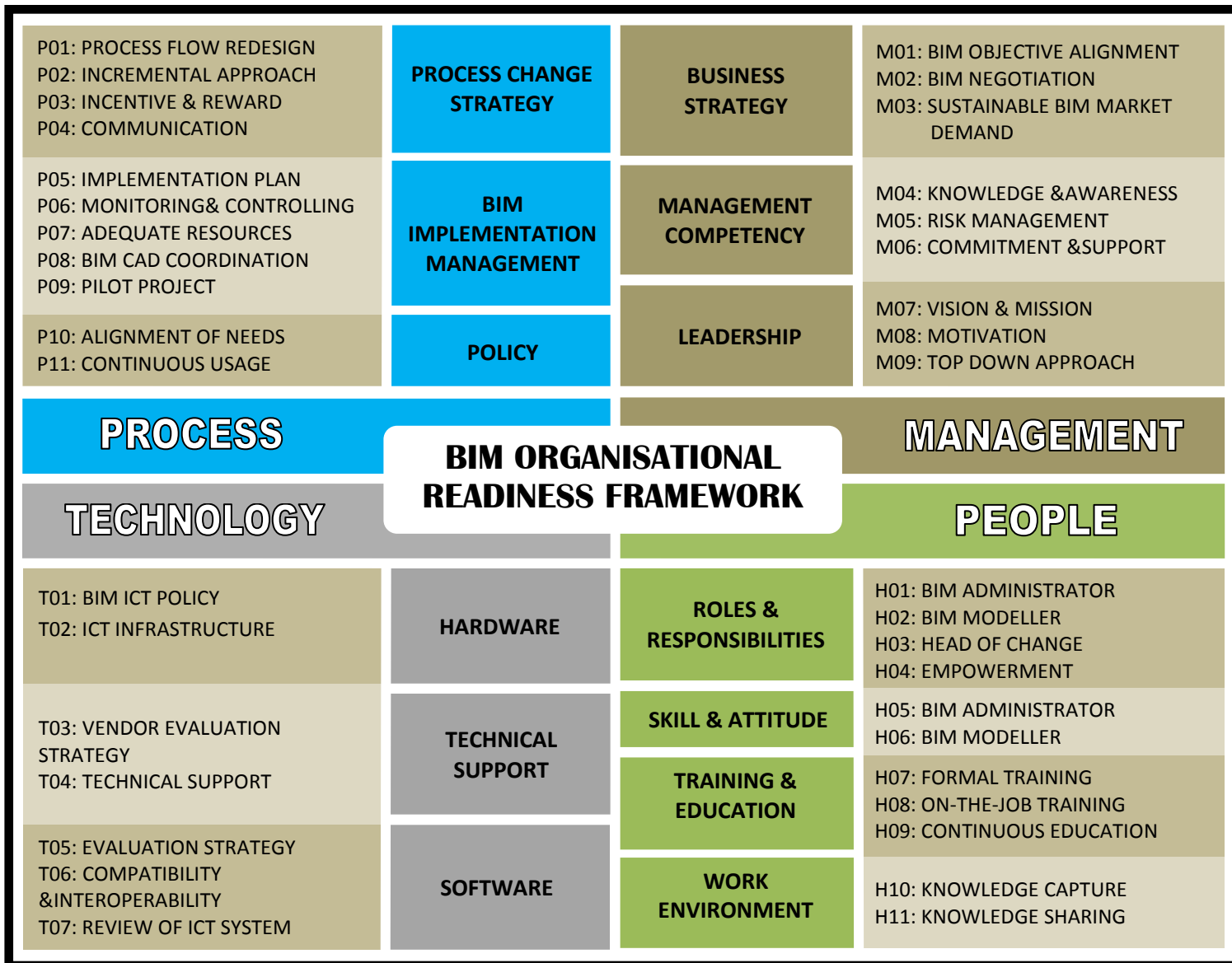


Figure 6.5: Final framework for the BIM Organisational Readiness

6.6 SUMMARY

This chapter highlighted further validation of the criteria within the conceptual framework with the industrial focus group via workshop. In the validation process, each criteria was validated and perceived as important to make up the BIM readiness framework except two criteria, P10: The use of Design and Build Type of Project Delivery to Implement BIM, and P11: Contract Amendment to Allow BIM Process Flow and Deliverable to be Performed. On the other hand, two criteria were also introduced based on the data collected during the workshop session. The first was Criterion P10: Alignment between Organisational BIM Requirements and Project Delivery Requirement, which replaces the conceptual Criteria P10 and P11. The second criterion that was identified and introduced is Criteria P11: Policy That Ensures Continuous Use of BIM within the Organisation. Taking into consideration the criteria change, the final framework was then developed and presented in this chapter. The framework consists of four elements which are Process, Management, People and Technology, with thirteen categories and 38 criteria residing within the elements. The refinement of the framework especially on its criteria, were regarded as vital for the use of the organisation to measure the BIM readiness level, thus assisting them in the implementation process. The next chapter provides the conclusions of this research and discusses them against the original aims and objectives of the study. It also outlines some recommendations for both industry and the research community based upon the research findings contained within this thesis. In addition, some ideas for future research will also be highlighted.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

This chapter aims at providing the conclusions, recommendations for the industry and research, and suggests future research as a result of the findings, encapsulated in the research that was carried out and detailed in this thesis. In order to realise these aims, the overview will be provided by revisiting the research objectives, process and main findings, and these will be discussed critically to evaluate the extent to which the research objectives were met. The evaluation will highlight the limitations and weaknesses which can be improvised by future research. In addition, the discussion of the main findings will provide some ideas about interesting aspects of research questions for the future. A few recommendations for the industry and research community will also be drawn.

7.2 REVISION OF RESEARCH AIMS AND PROCESS

This research was initiated by reviewing the literature to form knowledge of the current issues in the construction industry and subsequently identify the research problems and form the research aims and objectives. It was identified that fragmentation and drawings associated problems are among contributing factors of the inefficiency of project implementation, and the use of BIM is identified as a potential solution. A research gap however, arose on evaluating the readiness of organisations to implement BIM, where an evaluation framework that is specific for organisations to implement BIM in Malaysia, is absent. This led to the formation of research aim and interrelated objectives. The research aim is to support improvements in the design consultant practice through their implementation of BIM by developing an organisational readiness framework of BIM implementation. The following describes each research objective:

Objective 1: To explore, appraise and synthesise relevant literature related to BIM with specific focus on the concept, usage, evolution, implementation requirement and success factors.

Objective 2: To explore, appraise and synthesise relevant literature related to readiness assessment with specific focus on the concept, currently available model and its component.

Objective 3: To explore the current implementation of BIM within the business process by the organisation.

Objective 4: To identify the readiness criteria for implementing the achieved BIM status.

Objective 5: To develop a conceptual framework by utilising the emerging findings in objective 4, and to cross reference the finding with the literature review.

Objective 6: To finalise the framework by validating and refining the conceptual framework in objective 5 into organisational readiness framework for BIM implementation

Subsequently, a more detailed and specific literature review was conducted to form the fundamentals of the research and develop a theoretical framework. The literature review was first conducted on the background of the Malaysian construction industry to understand the industrial context and the position of BIM within the industry. Succeeding that, a thorough literature review was conducted to explore, appraise and synthesise relevant literature related to BIM with specific focus on the concept, usage, evolution, implementation requirement and success factors, and readiness assessment with specific focus on the concept, currently available model and its component to achieve Objectives 1 and 2. As a result, a theoretical framework was proposed. The purpose of developing the theoretical framework was to set out the area of exploration which was important to guide the researcher on the line of research inquiry to identify readiness criteria. 4 readiness elements and 17 readiness categories were identified. The framework was then furthered to be used in defining the research methodology.

In the research methodology, a literature review was again engaged to explore, identify and justify the most appropriate methodology and method to develop research design. This research method is qualitative in nature where it engages case studies as a data collection strategy. The main deliverable of the research methodology exercise was the research design and process flow, which is illustrated in Figure 3.2 as can be referred in chapter 3 on page 56. As for the case and its unit analysis, the design consultant organisations and the top and middle level management were identified respectively. A total of four companies were involved in this research, namely Companies P, A, B and C. Company P is a BIM implementation and management consultancy, Company A is an integrated engineering consultancy for oil and gas, Company B is an integrated Industrialised Building System (IBS) Specialist, while Company C is an integrated property development company.

The case study research was conducted to achieve Objectives 3 and 4. The case study was conducted in collaboration with Construction Research Institute of Malaysia (CREAM), firstly at Company P as the pilot case P to help refining data collection plans with respect to both the content of the data and the procedure to be followed, before the multiple case studies research was delivered. In conducting the case study, the current level of BIM implementation for each company was first explored and

investigated to support Objective 3 and to understand the context of BIM implementation. After that, the primary data of the research, which is the readiness criteria, was collected. The main techniques that were used to collect the data were semi-structured interviews and direct observation at the organisation. Each interview was audio recorded by using a Dictaphone. As for analysing the data, it was firstly transcribed into an interview script before content analysis was conducted. The findings from each company were then cross analysed in a table of matrix form to determine the pattern of answers. Subsequently, a literature review was also conducted to theoretically validate and make sense of the findings resulting in a conceptual framework being proposed. Similar to the theoretical framework, the conceptual framework consists of 4 readiness criteria, 17 readiness categories, but with an additional 38 readiness criteria, positioned according to the readiness categories that they belong to.

The 38 readiness criteria were then developed further into a questionnaire form, used to determine the level of importance and level of capability. The level of importance measures the importance of each readiness criteria while the level of capability measures the organisation's current level of BIM capability of the workshop participants. The questionnaire form was one of the techniques used for validating the conceptual framework. It is important to note that the validation was qualitative in nature by engaging a focus group workshop, and the use of the questionnaire form was to ease capturing the workshop participant's view. The questionnaire form was distributed early before the workshop started to give each participant some time to think, review and respond. The workshop was conducted in collaboration with CREAM in a full day roundtable event entitled "Industrialised Building System (IBS): Mechanisation through Building Information Modelling (BIM)". In the workshop, the researcher was reserved a two hour time slot to conduct the focus group workshop in the afternoon session. In the workshop, the fifteen workshop participants were divided into three groups, and within their groups they were all required to discuss their justification of importance for each readiness criteria, prepare the presentation slides and present their discussion findings at the end of the workshop session. In addition, the discussions that were running and the group presentation were all audio recorded using a Dictaphone. Similar to case studies data analysis, the qualitative data of the workshop was analysed using content analysis whereas the quantitative data was analysed using "Average Index" and "Frequency" analysis. The findings from the validation exercise refined the conceptual framework further into the final framework. The process flow of the research is described in Figure 3.2, Research process flow, as can be referred to at the end of chapter 3, Research Methodology.

7.3 CONCLUSION OF MAIN FINDINGS

The aim of this research was to support improvements in the design consultants practice through their implementation and use of BIM. Therefore, an organisational readiness framework for BIM implementation was developed for Malaysian design consultants. The aim was consists of several objectives and by attaching the discussion of the main findings with the research objectives, the evolution of the framework from the theoretical until final framework is demonstrated.

***Objective 1:** To explore, appraise and synthesise relevant literature related to BIM with specific focus on the concept, usage, evolution, implementation requirement and success factors.*

The findings for objective 1 were discussed in chapter 2, Literature Review. The infancy stage of BIM in Malaysia has created misconceptions and irresponsible market claims of BIM implementation. Therefore, as part of objective 1, Building Information Modelling requires a workable definition which is related to the research context to be set. Building Information Modelling was defined as an approach to building design and construction through modelling technology, an associated set of processes and people to produce, communicate, and analyse building information models. The Building Information Model is defined as digital representation of physical and functional characteristics of a facility where the information is contained or attached to the components of the model. Meanwhile, the use of 3D parametric authoring tools was identified as central to BIM implementation and therefore set as the modelling technology to be used in this research. Meanwhile, the design stage involved design activities where a major part of the information about a project was produced. Most of the information about a project originates with the design consultancy which consists of the architect consultant, civil and structural engineering consultant and MEP consultant as the major design consultants. It was found that an estimated 80% of the cost of a building is determined in the first 20% of the design process and by implementing BIM, the peak of design effort could be moved early. Consequently it justified the need to focus the research on the design phase. Meanwhile, it was also found that BIM investments require a long-term investment and could only justify the return on investment through a series of projects implementation, thus requiring a long-term effort by the organisation. The long-term investment covers the needs for training and education, hardware and software deployment and cultural and process flow change. This led to focus the research on the organisation rather than the project. Meanwhile, for design consultants, the use of BIM can be categorised into four points of view; Conceptual Design, Design and Analysis, Construction Level Documentation and Design and Construction Integration. The design benefits of BIM were also identified, important in understanding the organisation's motivations for BIM implementation which reflects the context and

level of implementation. The benefits were the reduction of errors inherited in CAD design, improvement in the clarity of design intent and consistent drawings production, improvement in communication and coordination and enabling an integrated approach to design and construction to be implemented. As for the evolution of BIM, it was found that BIM implementation progresses in a series of evolutionary stages starting with the transition from CAD to Modelling stage, followed by Collaborative stage and finally Integrated stage. The CAD to Modelling stage was set as research focus.

Objective 2: *To explore, appraise and synthesise relevant literature related to readiness assessment with specific focus on the concept, currently available model and its component.*

For objective 2, critics were prepared on The U.S National Building Information Standard, NBIMS Capability Maturity Model, as a currently available BIM readiness model. Among the critics' points, the NBIMS CMM was only useful in assessing building information models and the project teams, but not at the organisations level of implementation. In addition, the process focus of the NBIMS CMM was given towards the production of the building information model rather than the competency set that is needed to enable BIM to be implemented within an organisation. The critics identified the gap within the current model, and the attempts of the research could possibly fill the gap. Meanwhile, the readiness assessment refers to a managerial evaluation tool to measure the readiness gap of the organisation prior to Information System/Information Technology investment where it identifies the current capability of an organisation as compared to the targeted level that a company would want to achieve. There are two elements which are critical to readiness assessment. The first element is identifying the evaluation criteria that needs to be used (since the accuracy of the assessment is dependent on it) when Building Information Modelling is placed in the framework as the proposed system. The second element is the target of the system implementation, which refers to the implementation requirements that need to be achieved in order to implement the system. The implementation requirement is referred to as readiness criteria within this context of research. In addition, eight associated IT and construction-related models were reviewed in order to develop the theoretical framework. It is important to mention that the approach of the research was not on developing the readiness framework theoretically and validating it through the case study. Instead, the proposed categories of assessments were used to guide the line of research inquiry and the development of the readiness criteria for the framework was based on the emergence of the exploratory data that was captured in the case studies. Consequently, as an outcome of the literature review to support objective 1 and objective 2, a theoretical framework was proposed as in Figure 7.1, in the following page. The figure depicts the term readiness element, category and criteria that were used across the thesis. Note that the readiness criteria attribute was blank at the literature review point

but was filled based on the data from the case study, which was captured, conceptualised, cross analysed and theoretically validated.

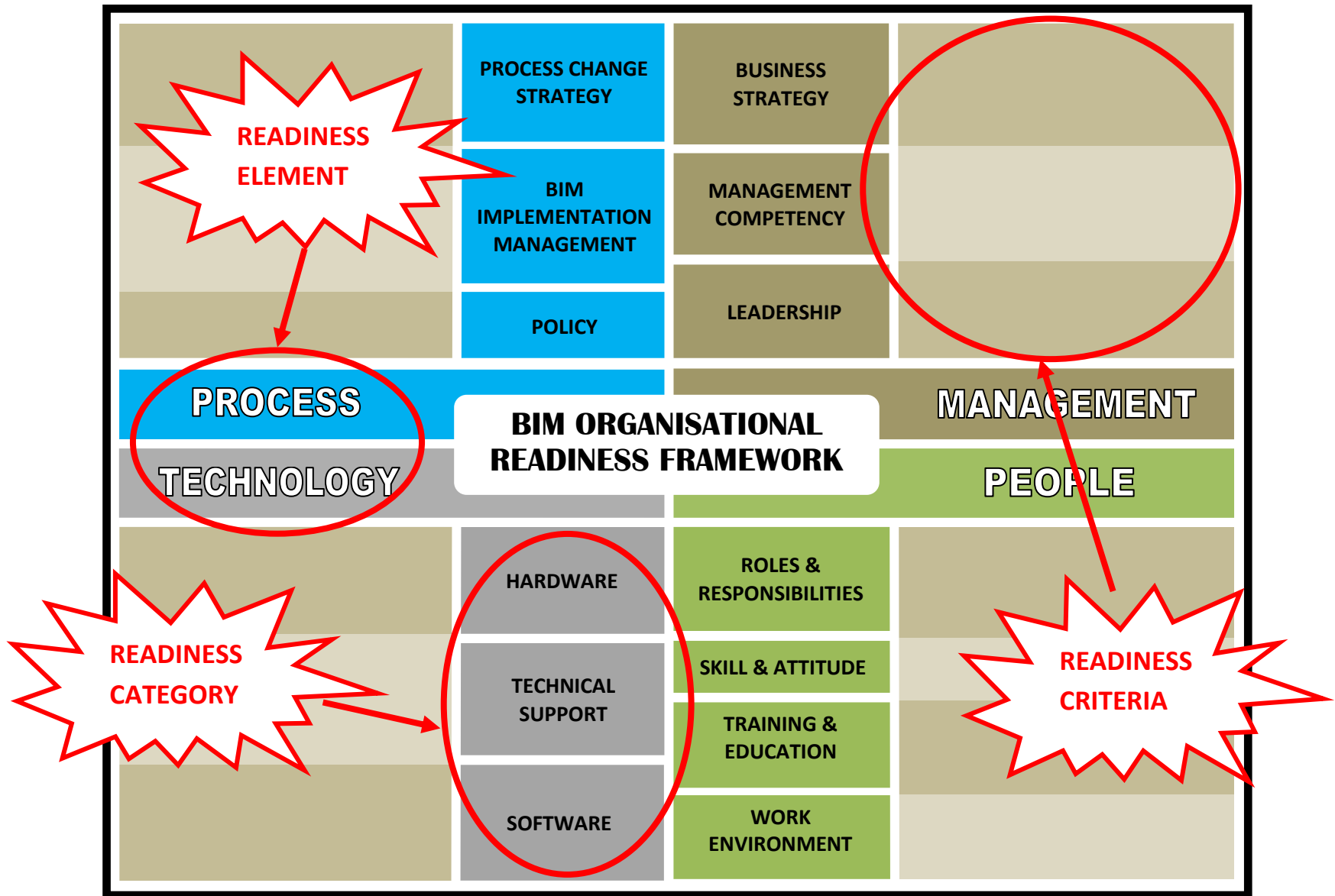


Figure 7.1: Revisited conceptual framework for the BIM Organisational Readiness

Objective 3: *To explore the current implementation of BIM within the business process by the organisation.*

Objective 3 was partly discussed in chapter 4 for the individual level of BIM implementation by each company and partly discussed as to compare and discuss the level of BIM implementation between companies. Company A had a comprehensive level of BIM implementation within their business process, evidenced by the standard operating procedure which incorporated BIM, the presence of BIM associated roles and responsibility (BIM Administrators and the BIM Designer), and a higher level of detail for the 3D models. The implementation of BIM which started 1994, made it also reasonable to say that Company A had a better experience of BIM implementation as compared to the other companies. It was probably fair to say that Companies P, B and C were all sharing a similar level of BIM implementation where each of the companies had just finished conducting the pilot case of BIM implementation. As for the comprehensiveness use of the model, the usage was currently limited at satisfying the visualisation and surface modelling clash check, only leaving the model with a low level of detail. As a result, the drawings and material taking off could not be generated automatically out of the model and required CAD drafting and manual material taking off to be conducted.

Objective 4: *To identify the readiness criteria for implementing the achieved BIM status.*

Objective 4 discussed the findings of the research to identify the readiness criteria for BIM implementation by individual company. The discussion was conducted in chapter 4. The summary of findings for each case can be referred to in Table 7.1, Summary of individual case study findings for BIM readiness criteria, on the following page.

Table 7.1: Summary of individual case study findings for BIM readiness criteria.

READINESS CRITERIA			COMPANY			
			P	A	B	C
PROCESS	PROCESS CHANGE STRATEGY	P01: Process Flow Redesign	x	x	x	x
		P02: Small and Incremental Approach	x	x	x	x
		P03: Incentive and Reward		x		x
		P04: Communication	x	x		
	BIM IMPLEMENTATION MANAGEMENT	P05: Implementation Plan	x	x	x	x
		P06: Monitoring and Controlling	x	x		x
		P07: Adequate Resources		x	x	x
		P08: BIM CAD Coordination		x	x	x
		P09: Pilot Project	x		x	x
	POLICY	P10: Design and Build	x		x	
		P11: Contract Amendment	x	x	x	
MANAGEMENT	BUSINESS STRATEGY	M01: BIM Objectives Alignment	x	x	x	x
		M02: BIM Negotiation	x	x		
		M03: BIM Market Demand		x	x	
	MANAGEMENT COMPETENCY	M04: Knowledge and Awareness	x	x		x
		M05: Risk Management		x	x	x
		M06: Commitment and support	x	x	x	x
	LEADERSHIP	M07: Vision and Mission		x		x
		M08: Motivation		x	x	
		M09: Top Down Approach	x	x	x	x
PEOPLE	ROLES AND RESPONSIBILITIES	H01: BIM Administrator/Manager	x	x	x	x
		H02: BIM Designer/Modeller	x	x	x	x
		H03: Head of Change	x	x	x	x
		H04: Empowerment		x	x	
	SKILL & ATTITUDE	H05: BIM Administrator/Manager	x	x	x	x
		H06: BIM Designer/Modeller	x	x	x	x
	TRAINING & EDUCATION	H07: Formal Training	x	x	x	x
		H08: On-the-job Training	x	x	x	x
		H09: Continuous Education		x		x
	WORK ENVIRONMENT	H10: Knowledge capturing		x	x	x
		H11: Knowledge sharing	x	x	x	x
TECHNOLOGY	HARDWARE	T01: BIM ICT Policy		x		x
		T02: ICT Infrastructure	x	x	x	x
	TECHNICAL SUPPORT	T03: Vendor Evaluation Strategy	x		x	x
		T04: Technical Support	x	x	x	x
	SOFTWARE	T05: Software Evaluation Strategy	x		x	x
		T06: Compatibility and Interoperability	x		x	
		T07: ICT System Review		x	x	

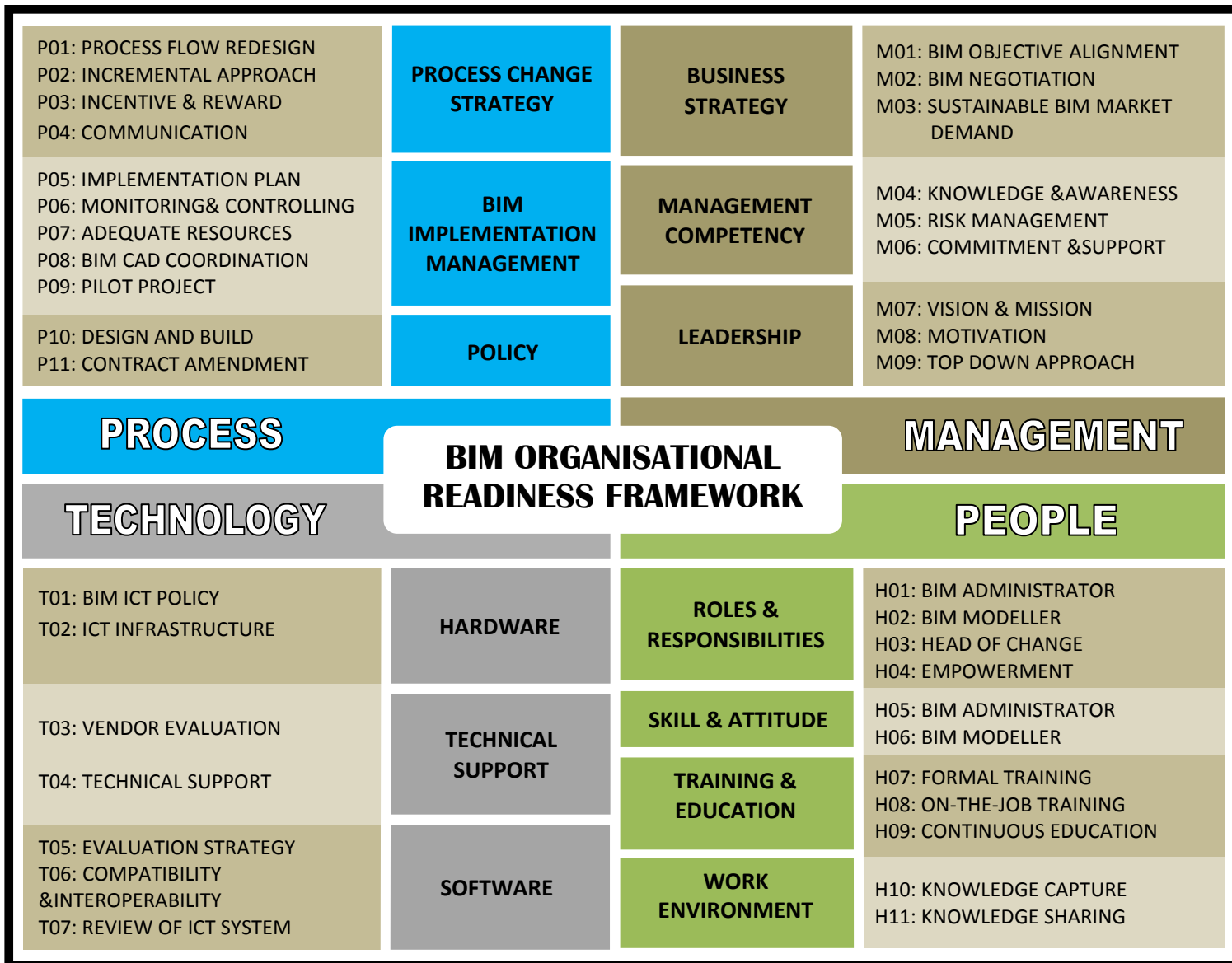


Figure 7.2: Revisited Conceptual Framework for the BIM Organisational Readiness

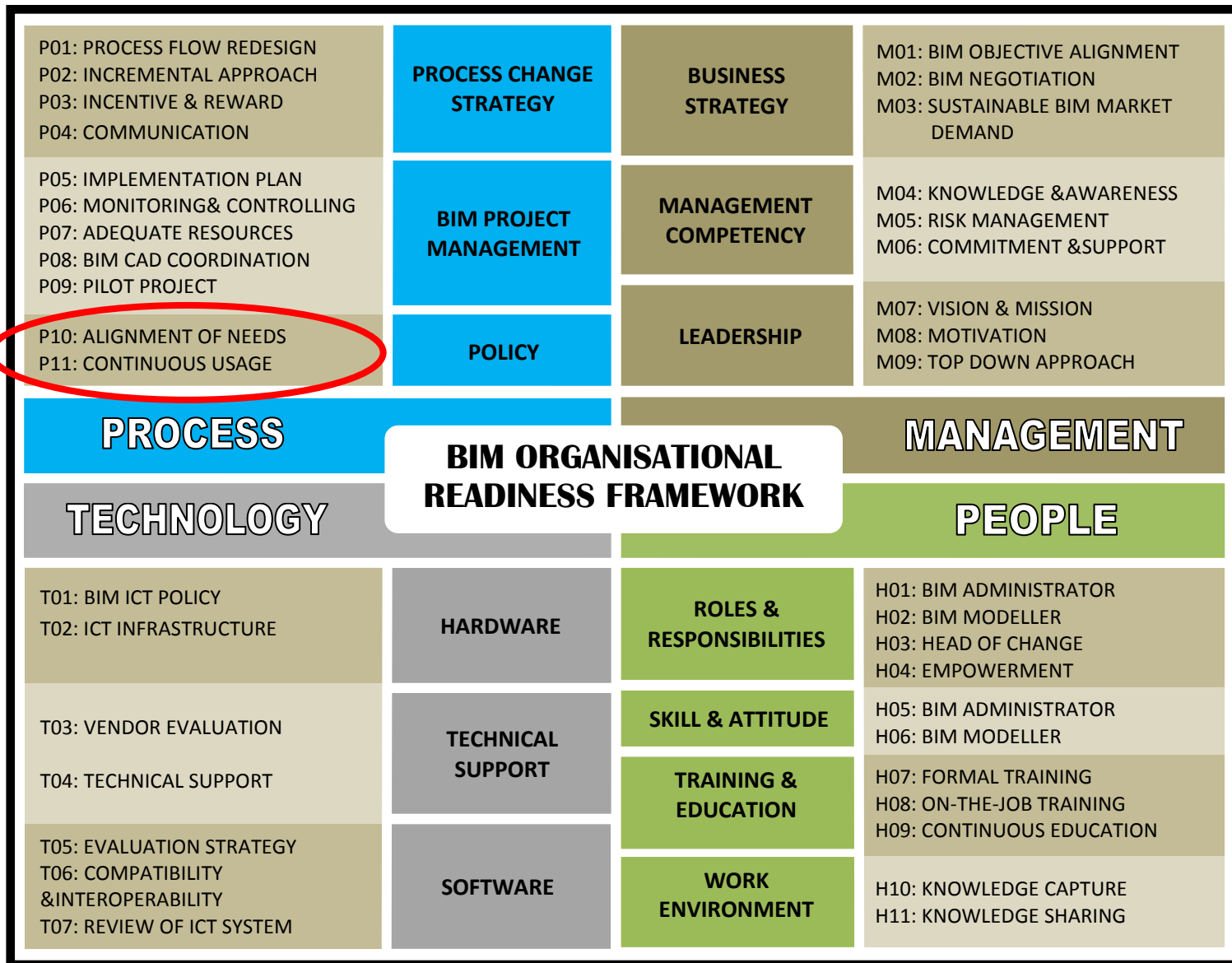


Figure 7.3: Revisited Final framework for the BIM Organisational Readiness

Objective 5: *To develop a conceptual framework by utilising the emerging findings in objective 4, and to cross reference the finding with the literature review.*

Chapter 5 discussed objective 5 compressively by cross analysing the findings from objectives 3 and 4. Each readiness criteria was discussed in further detail with the theoretical source from the literature review to make sense of the overall data. By cross analysing the findings, it was found that some criteria were evidenced in all of the companies involved in the case study. By referring to Table 7.1, the criteria are Criteria P01: Process Change Strategy, P02: Small and Incremental Approach, P05: Implementation Plan, M01: BIM Objectives Alignment, M06: Commitment and Support, M09: Top Down Approach, H01: BIM Administrator/Manager, H02: BIM Designer/Modeller, H03: Head of Change, H05: BIM Administrator/Manager, H06: BIM Designer/Modeller, H07: Formal Training, H08: On-the-job Training, H11: Knowledge Sharing, T02: ICT Infrastructure, and T04: Technical Support. Noticeably, the people element received close attention as it regularly appeared in each case. As a result, a conceptual framework, as in Figure 7.2 in page 249, was proposed from the exercise of conceptualising, cross analysing and theoretically validating the data that was captured in individual case studies. Note that as compared to the theoretical framework in Figure 7.1 on page 242, the readiness criteria was assigned to each readiness category at the end of the cross analysing. The detailed description of each readiness criteria can be referred to page 252.

Objective 6: *To finalise the framework by validating and refining the conceptual framework in objective 5 into organisational readiness framework for BIM implementation*

Chapter 6 discussed the findings of objective 6 from a focus group workshop which was attended by fifteen participants. All the criteria that was developed from the case study research and literature as the main variables in the framework were perceived as ‘Important’ by the participants in the workshop which had an A.I value of above 3.50. Supported with the qualitative evidence that was captured during group discussion and presentation, all of the criteria were therefore validated as ‘Important’ except for Criteria P11: Contract Amendment to Allow BIM Process Flow and Deliverable to Be Performed and P10: The Use of Design and Build as Favourable Project Delivery Method. In the response of the exclusion of Criteria P11 and P10, a new criterion was introduced under the same policy category which was Criteria P10: Alignment between Organisational BIM Requirements and Project Delivery Requirement. The need of continuous use of BIM within the organisation had also demanded a new criterion to be introduced, Criteria P11: Policy That Ensures Continuous Use of BIM within the Organisation. The importance of the criteria lay in providing constant BIM usage by the staff, real management support and commitment and BIM process improvements which all required the organisation to use BIM consistently. The red circle in Figure

7.3, page 250 depicts the refinement made on the conceptual framework to finalise the framework and the detail criteria of the final framework are as follows:

1) PROCESS

A. *PROCESS CHANGE STRATEGY*

P01: Process redesign by analysing current business process and identifying change required to incorporate BIM model oriented process.

P02: Small and incremental approach by subdividing BIM implementation into small and manageable targets.

P03: Incentives and rewards to motivate staff to change

P04: Effective means of communication to explain BIM at all levels and to all individuals within the company.

B. *BIM IMPLEMENTATION MANAGEMENT*

P05: Documented plan to assist implementation process by adapting international guidelines and standards.

P06: BIM monitoring and controlling technique to ensure the implementation success

P07: Adequate resources to facilitate and support BIM implementation

P08: Coordination between BIM and CAD process flow.

P09: Piloting BIM implementation on a few projects common to the company.

C. *POLICY*

P10: Alignment Between Organisational BIM Requirements and Project Delivery Requirement.

P11: Policy That Ensures Continuous Use of BIM Within the Company

2) MANAGEMENT

A. *BUSINESS STRATEGY*

M01: Alignment of BIM objectives with clear business goals.

M02: Negotiation of BIM implementation with business partners.

M03: Creation of sustainable market demand for BIM.

B. *MANAGEMENT COMPETENCY*

M04: Management to have an appropriate level of BIM awareness and knowledge.

M05: Effective risk management skill to deal with risks associated with BIM implementation.

M06: Continuous commitment and support from the management

C. *LEADERSHIP*

M07: Management to have a clear vision and mission for BIM implementation.

M08: The ability to motivate people.

M09: Top down approach to drive BIM implementation.

3) PEOPLE

A. *ROLES AND RESPONSIBILITIES*

H01: Clearly defined roles and responsibilities for BIM Administrator.

H02: Clearly defined roles and responsibilities for BIM Modeller.

H03: Clearly defined roles and responsibilities for the Head of Change.

H04: Empowerment to all new roles.

B. *SKILLS AND ATTITUDES*

- H05:** BIM Administrator has required set of skills and attitude necessary to carry the roles and responsibilities that are defined by the company.
 - H06:** BIM Modeller has required set of skills and attitude necessary to carry the roles and responsibilities that are defined by the company.
 - C. *TRAINING AND EDUCATION*
 - H07:** Formal training to develop skill and knowledge for BIM process and tools.
 - H08:** Continuous on-the-job training to improve skill and confidence level.
 - H09:** Continuous BIM education and awareness.
 - D. *WORK ENVIRONMENT*
 - H10:** Appropriate means to capture knowledge regarding BIM know-how and lesson learned.
 - H11:** Work environment that supports learning and knowledge sharing among the staff.
- 4) **TECHNOLOGY**
- A. *HARDWARE*
 - T01:** Well-defined ICT policy for BIM.
 - T02:** Adequate ICT Infrastructure to support BIM implementation.
 - B. *TECHNICAL SUPPORT*
 - T03:** Appropriate means to evaluate the capability of the software vendor in providing services.
 - T04:** Adequate technical support for BIM implementation
 - C. *SOFTWARE*
 - T05:** Software evaluation strategy that incorporates business needs and user requirements.
 - T06:** Compatibility and Interoperability of BIM software with legacy and business partners' IT system.
 - T07:** Regular review and upgrade of ICT systems to meet changing BIM and Business needs.

In general, the framework that was developed describes the readiness of the organisation to implement BIM at the organisational level. The framework outlines four elements (people, process, technology and management) in which consist of 17 categories and 38 readiness criteria. Each of the criteria describes the BIM implementation requirement that the organisation needs to develop the capability in order to implement BIM. The framework is generic in nature where the users can determine the capability of their organisation by comparing each of the readiness criteria with their current state of BIM implementation. If the organisation satisfies the readiness criteria, the status could be said to match the readiness for that particular criteria. The methods used in determining the organisational status are qualitative in nature allowing evaluation through the use of interviews, observations, document review, etc. The result of the readiness assessment would outline the readiness gap between the current state of the company as compared to the BIM implementation requirement sorted accordingly to the readiness criteria. Although the use of the framework within the context of this research is limited to internal application by the design consultant, it could also be

expanded for a wider use. Prior to the start of the project, the client for instance can use the framework to evaluate the BIM readiness of the project team as part of the company's evaluation strategy to acquire the right company. The justification lies on selecting the team, which has an appropriate level of BIM readiness. The appropriate level of BIM readiness among the team is crucial to minimise BIM hiccups and misunderstandings when the project is executed. To enable the extended use, further modifications of the framework are required to suit the needs of the multidisciplinary nature of the project team and the requirements of the project itself.

Meanwhile, at this stage of the framework development, the framework could only be used to assess the readiness of the company by using several criteria as they suit the purpose to determine the readiness gap. However, by specifying the content of the readiness criteria in further detail, the framework could also be expanded as a BIM guideline to assist the BIM implementation program of the organisation. For instance, the readiness framework simply outlines "clearly defined roles and responsibilities for BIM Administrator" as the readiness criteria. The content of the criteria (the roles and responsibilities) could be expanded as follows to serve as a BIM guideline:

- a) The administrative role of the software (such as creation of project, setting up of users and environment, setting up database, database management functionality, database integrity checking utility).
- b) Preparing and updating catalogue components and specifications to be used by the designer.
- c) Data checking and liaison with internal and external engineers to ensure the completeness of the data and information that is received to produce the 3D models and other design deliverables.
- d) Focal point for all disciplines related to the 3D model and its deliverables

(taken partly from the case study result of Company A)

In the above example, the specification of the content of the readiness criterion will guide the personnel on the specific roles and responsibilities that he or she must deliver as part of the BIM implementation program. The content specifications of the readiness criterion are also applicable to the remaining criteria. The process however requires a very extensive research for each of the readiness criterion before a comprehensive BIM guideline could be produced.

7.4 RESEARCH LIMITATIONS

In the course of conducting this research, the following obstacles were encountered:

- a) There were problems in finding appropriate literature information relevant to the study area, as only a limited amount of work was available on organisations' BIM implementation and readiness. Positively, in adding to the small body of knowledge already available, this research has also made a contribution to the current literature context.
- b) The number of selected case studies was restricted to only four companies. However, this was inevitable since BIM is a new approach to design and not so many companies have started implementing BIM yet. Although ten companies were initially identified, a low level of willingness to share and cooperate had reduced the number to four.
- c) The shortage of BIM experts and a limited number of cases knowledgeable in BIM approach to design was a fundamental limitation since the readiness criteria that was developed was based on the experience of just a few experts and may not be seen as general to a wider population of the design consultancy organisation.
- d) The constraints of time limit and financial requirement for this research, the confidentiality issue of the case study companies, and the lack of awareness and knowledge of BIM among the top and middle level management, all posed major obstacles in the attempts to increase the sample size of this research. The obstacles, besides contributing to the generalising issue to reflect the Malaysian design practice, had also restricted the variations of identifying BIM readiness criteria.
- e) In conducting the focus group workshop, the involvement of fifteen participants divided into three groups, although beneficial at collecting a wider opinion and insights, had caused difficulties in monitoring and controlling the point of discussion. Some of the problems are listed as following:
 - a. The time dedicated to discuss the importance of each readiness criteria fluctuated.
 - b. Some participants were very active in contributing opinions and dominated the group discussion while others chose to remain silent.
 - c. There were also situations where the discussion moved to topics irrelevant to the focus group needs.
 - d. The problems caused some of the readiness criteria to receive no qualitative data and the validation could only rely on the quasi analysis of the quantitative data.
- f) The readiness concept that was used to develop the readiness elements and categories for this research was based on the capability and maturity model. However, the early stage of BIM implementation by most of the companies involved has restrained the stage of maturity to be defined inductively (as exploratory case study was used) for the readiness criteria. The readiness criteria nonetheless set the competency area for capability.

- g) Except for Company A which has achieved a collaborative stage of BIM implementation, other companies that were investigated in the case studies are positioned at the transitioning stage from 2D CAD stage to 3D modelling stage. The framework was therefore limited and suitable to be used within the transitioning stage.

7.5 RESEARCH NOVELTY AND CONTRIBUTION

The novelty of this research lies in the development of a readiness framework, specific for BIM implementation at the organisational level. At the early stage of the research, it was found that there exists a knowledge gap in the BIM readiness area where a set of assessment criteria, specific for an organisation to implement BIM, was absent. Along the process of the development, this research extended the range of existing theories surrounding BIM readiness issues by compiling a set of readiness categories and developing a set of organisational readiness criteria to implement BIM. In developing the readiness criteria, a qualitative approach via case studies for data collection and a focus group workshop for framework validation that was engaged, has provided information-rich data on industrial perspectives which are theoretically validated with the current source of literature. The exercises lead to position the outcome of the research within the current knowledge gap of BIM readiness assessment area. The context however, is limited to Malaysia with specific focus on the design consultants.

Meanwhile, the research has also contributed to the industry, simplified as following:

- a) The research will add to existing knowledge on BIM by mapping issues surrounding BIM implementation from the perspective of the design consultant. This will assist the companies and the policy makers, especially the government, in identifying the future direction of BIM and ICT implementation and policy in Malaysia.
- b) The thesis presented an exploratory study that measures the most recognised readiness criteria for BIM implementation among pioneer BIM implementers. The readiness criteria would assist an organisation to identify the BIM area of competency and evaluate their current capability for BIM implementation, important in prioritising their effort for BIM implementation.
- c) The individual case report that was prepared in this research, in which the strength lies in information-rich data, could help the industry to understand the BIM implementation issue within the context of Malaysia and provides a lesson learnt document.

- d) The outcomes of this research could also be used for appropriate education and awareness purposes. The readiness criteria could be integrated into the higher education programmes of A/E/C related disciplines. This would improve students' understanding of not only BIM implementation, but also assist in creating a case of learning from decision theories and operational management sciences. The framework developed in this research could be used as an industrial training programme. This would make a contribution in improving the decision-making for BIM implementation and thus help increase the uptake.
- e) The research has also investigated the current level of capability among BIM practitioners in Malaysia. The level of capability assists the industry in understanding the current capability, which is especially important at identifying the biggest readiness gap so BIM roadmap and strategy can be formulated.

7.6 RECOMMENDATION FOR FUTURE RESEARCH

The research has established an organisational readiness framework for design consultants in Malaysia. The framework, as discussed in the limitation of research, would not be able to be generalised in a Malaysian context due to a limited number of cases involved, confidentiality issues of the case study companies, the lack of awareness and knowledge of BIM among the top and middle level management, and a lack of BIM experts. The research however, has produced a set of readiness criteria which could be researched further to generalise and verify the findings. Probably a quantitative survey could be used to validate each criterion for a wider sample of population. In addition, the readiness framework was purposely developed to be applied by the design consultant. As the construction industries involved a variety of parties, it also identified the importance of furthering the research on other parties, especially the owner and the contractor. The readiness framework which consists of generic readiness criteria could be used as the baseline of the research.

Meanwhile, the validation workshop that was conducted has opened a door to the researcher to get involved seriously with the industrial players in Malaysia. After the workshop validation, the researcher was invited to join a few discussions with the Construction Research Institute of Malaysia (CREAM) and the Construction Industry Development Board of Malaysia (CIDB) as can be seen in the Appendix 5.0, List of publications and presentations, as part of the research. Within the discussion, among the comments received from the industrial players, was how the framework was comprehensive in covering the readiness competency of people, process, technology and management, but lacked prioritisation of which readiness criteria were more important than others.

Therefore, as part of any future research, it is suggested to conduct a research to determine the level of importance for each readiness criteria by investigating the ranking and the cause and effect of each readiness criteria on BIM implementation. In addition, the organisational readiness framework has also been suggested to be developed further as BIM implementation guidelines by expanding the attributes for each readiness criteria, leading to other chances of future research work.

As part of the research progress, the direct involvement with the industry has led the CREAM and CIDB to appoint the researcher to become a member of research and technical committee for Industrialised Building System (IBS) and a member of CIDB BIM Taskforce, respectively. As for CREAM, the researcher's scope of appointment is to be involved with research and development (R&D) of IBS with specific focus on Building Information Modelling. The R&D is targeted at publishing a BIM fundamental and readiness book, preparing trainings and awareness modules for BIM and developing approaches for BIM software selections. Although the researcher himself did not know how the scope of work truly reflected the industrial demands, it was nevertheless recognised and extracted from the organisational BIM readiness framework that was produced as part of this research's main deliverable. As for CIDB, the researcher will get involved to develop a national BIM implementation framework where the research deliverable will be used as an instrument to evaluate the organisation's capability to implement BIM. The development of the instruments however, requires a thoughtful review of many aspects of the research deliverables and requires a dedicated research to refine the current research deliverable, which is the organisational readiness framework for BIM implementation.

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APPENDIX 1.0: THE INTERVIEW QUESTIONS.

1.0 BACKGROUND OF THE COMPANY

- 1.1 What type of business is your company involved in?
- 1.2 In which sector of construction and building does your company mostly operate?
- 1.3 What is the gross annual revenue of your company?
- 1.4 What is the current number of employees in your company?

2.0 CURRENT STATUS OF BIM IMPLEMENTATION

- 2.1 What is the BIM software that the company currently uses? How many licenses are they? Could you discuss the purpose of the aforementioned software? What are the software applications that the company is currently using?
- 2.2 So far, to what stage has BIM been implemented within the company? How does the company engaging BIM approach in the current process flow of design? What types of job scope requires BIM approach to be implemented?
- 2.3 Did the company create new roles and responsibilities for BIM implementation? If yes, what are they?
- 2.4 Would it be possible to acquire/view the BIM related design deliverables?
- 2.5 What has triggered the BIM implementation by the company?
- 2.6 Could you explain the benefits of BIM?
- 2.7 What are the challenges of BIM implementation, internally and externally?

3.0 BIM READINESS CRITERIA

3.1 PROCESS

- 3.1.1 BIM approach to design has introduced many changes within the CAD based process flow. What are the important criteria/requirements to change the process flow to enable BIM to be incorporated into CAD based process flow?
 - a. Did the company change their process flow when implementing BIM? If yes, why?
 - b. How did the company change the process flow?
 - c. How long is/was the company target to achieve full BIM implementation? Why is such a duration needed?
 - d. BIM has many applications such as 3D Authoring, Clash Check, Material Take Off , Walk through Review, 3D Design Review etc. How did the company prioritise/choose which applications to use?

- e. As BIM is a new approach to design, some people find BIM transformation challenging. What were the challenges that the people of the company experienced and how did the company respond to them?
- 3.1.2 As part of managing the BIM implementation, what are the important criteria/requirements to successfully implement BIM?
- a. Did the company develop any BIM implementation plan? If yes, how did the company develop the plan? How useful was the plan to assist BIM implementation?
 - b. How did the company monitor/control the BIM implementation?
 - c. How important it is to have adequate resources to implement BIM?
 - d. What happened to CAD when BIM was implemented? Do we still need CAD or not? Why?
 - e. Has the company conducted any BIM pilot projects? If yes, why is it important to conduct pilot projects?
- 3.1.3 What are the best contract and project delivery method to be used with BIM? Why?

3.2 MANAGEMENT

- 3.2.1 Did the company consider BIM implementation to support its business strategy? If it did, what are the important criteria/requirements of BIM implementation to support the business strategy?
- a. How important is the investment/implementation of BIM supporting the business objectives/needs? Please explain in detail and provide examples where necessary.
 - b. Many of the industrial players are not yet ready for BIM implementation and thus may create many issues when implementing BIM on a project. Is the company aware of the issues and what are they? How did the company respond to them?
 - c. Did the client play an important role in order to support your BIM implementation program? Why was it important?
- 3.2.2 What are the competencies that the management should have to support BIM implementation? Why are they important?
- a. What do you think of management buy-in? Why is it important?
 - b. What do you think of management's ability to manage the risks and challenges associated with BIM? Why is it important?
 - c. Is management's commitment and support important for BIM implementation? Why?

- 3.2.3 Did the management leadership play important roles in BIM implementation? If yes, how important is the support, commitment and vision of the management and board of directors? Please explain in detail and give examples.

3.3 PEOPLE

- 3.3.1 Did the company create any new roles and responsibilities associated with BIM implementation? If yes, what are they? Why do you think the new definition of roles and responsibilities is important?
- 3.3.2 How did the company evaluate the people carrying out the new roles and responsibilities? What type of skills and attitude set must the aforementioned roles have to implement BIM? How did the company identify people with those skills and attitude sets?
- 3.3.3 What types of training and education programs did the company use to develop the BIM competency among the staff? Why was each type of training is important and how it can benefit the company? How was the training conducted?
- 3.3.4 What is the company's strategy to expedite the learning curve in BIM?
- 3.3.5 What are the important criteria of the work environment to support BIM implementation? Why?

3.4 TECHNOLOGY

- 3.4.1 Did the BIM implementation cause changes to current hardware and infrastructure? What changes has BIM introduced? How did the company identify the technical requirements for change/upgrade?
- 3.4.2 Since BIM is still new in Malaysia, we have a limited number of software vendors who are really capable of delivering BIM services. How did you select the software vendor? What criteria were used for the selection?
- 3.4.3 What are the technical difficulties when implementing BIM on a real project? How did the company respond to resolve them?
- 3.4.4 How did the company select the BIM software? What are the strategies used in selecting the right software?
- 3.4.5 Did the company address the issue of interoperability and compatibility in selecting BIM software? If yes, why is it important? Did the legacy software of the company or business partner have interoperability and compatibility issues with BIM software? If yes, how did it affect the BIM implementation program?

----END OF QUESTION----

APPENDIX 2.0: SCHEDULE FOR CASE STUDY INTERVIEW

	List of Interviewee	Date	Activities
Company P	CP2-4D Planner/BIM Strategist/Principal CP3-Project Manager/Principal	06/09/2010	Forward intention, formal briefing about the research, preliminary interview to determine the status of BIM uptake (Conducted at Golf Club in Selangor)
	CP1 -BIM Manager/Strategist/Principal CP2-4D Planner/BIM Strategist/Principal CP3-Project Manager/Principal	17/09/2010	Data collection interview (Conducted at Company P Office, Johore)
	CP1 -BIM Manager/Strategist/Principal CP2-4D Planner/BIM Strategist/Principal	02/03/2011	Validation interview for case study findings (Phone interview)
Company A	CA1-Engineering Manager/Board of Director	29/09/2010	Forward intention, formal briefing about the research, preliminary interview to determine the status of BIM uptake (Phone interview)
	CA1-Engineering Manager/Board of Director	01/10/2010	Data collection interview (HQ office, Kuala Lumpur)
	CA2- Senior Engineer/PDMS Administrator	05/10/2010	Data collection interview (HQ office, Kuala Lumpur)
	CA3-Lead Design Engineer/ Coordinator CA4-Designer/Bocad Administrator	06/10/2010	Data collection interview (HQ office, Kuala Lumpur)
	CA1-Engineering Manager/Board of Director	04/11/2010	Validation interview for case study findings (HQ office, Kuala Lumpur)
Company B	CB1- Engineering Manager/Principal	11/10/2010	Forward intention, formal briefing about the research, preliminary interview to determine the status of BIM uptake (HQ Office, Kuala Lumpur)
	CB1- Engineering Manager/Principal	22/10/2010	Data collection interview (HQ office, Kuala Lumpur)
	CB2- Senior Engineer	27/10/2010	Data collection interview (HQ office, Kuala Lumpur)
	CB1- Engineering Manager/Principal	10/03/2011	Validation interview for case study findings (Phone interview)
Company C	CC1- BIM Manager CC2- BIM Technologist	06/12/2010	Forward intention, formal briefing about the research, preliminary interview to determine the status of BIM uptake (Phone interview)
	CC1- BIM Manager	09/12/2010	Data collection interview
	CC2- BIM Technologist	14/12/2010	Data collection interview
	CC1- BIM Manager	07/03/2011	Validation interview for case study findings (Phone interview)

APPENDIX 3.0: QUESTIONNAIRE FORM FOR FOCUS GROUP VALIDATION WORKSHOP



School of Built Environment
University of Salford,
The Crescent, Salford, U.K
M5 4WT

Research Information Statement for the PhD Project

ORGANISATIONAL READINESS TO IMPLEMENT BIM: A FRAMEWORK FOR DESIGN CONSULTANT IN MALAYSIA

Dear Madam/Sir,

My name is Ahmad Tarmizi Haron, faculty member of Universiti Malaysia Pahang and currently undertaking PhD program at School of Built Environment, The University of Salford, U.K under the supervision of Dr. Amanda Jane Marshall-Ponting and co-supervision of Prof Ghassan Aouad, Pro-Vice Chancellor (Research) of the university.

As part of the ongoing PhD program, you are kindly invited to validate my research findings on the research entitled Organisational Readiness to Implement BIM: A Framework for Design Consultant in Malaysia. The research aims at developing BIM readiness framework and therefore, I am requesting for your kind cooperation in giving your time, experience and thoughts by answering the questionnaire form provided. Your cooperation is most essential as the deliverables of the case study could be beneficial to both industry and academia.

Importance Definition.

Within the context of this research, BIM is defined as a modelling technology and associated set of processes to produce, communicate and analyse building information models (Eastman et al., 2008). Modelling technology within this context of research is referred to 3D parametric authoring tool and some examples are BoCAD, Tekla Structures, Revit Architectures and Structures, Bentley Systems.

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 anonymous data collected from your verbal and written 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.

SECTION A: PERSONAL PROFILE

Company Name :
 Location :
 E-mail :
 Contact Number :

1.1 How many employees does your company have?

0-4	5-19	20-40	40-100	More than 100
-----	------	-------	--------	---------------

1.2 Which of the following discipline does your company belong to?

Architecture	Engineering	Contractor	Developer	Other (please specify)
--------------	-------------	------------	-----------	---------------------------------

1.3 How long have you been working in AEC industry?

Less than a year	1-5 years	6-10 years	11-15 years	More than 20 years
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1.5 Your current job title?

.....

1.6 Is your company currently using BIM tools as part of working process?

YES NO (please jump to section 2)

1.7 Please circle the BIM software tools used by your company.

Revit Structure	Revit Architecture	Revit MEP	Bently Structure
BOCAD	Archicad	Tekla Structure	Naviswork
PDMS	Others (Please specify)		

1.8 Please circle the BIM application used by your company.

Visualisation	Drawing Automation	Automated Clash Check	Material Taking Off
Energy Analysis	Structural Analysis	Others (Specify)	

For the level of importance, please select the most appropriate answer by ticking one of the box for each criteria based on your **view and/or experience** where, **1-Very unimportant 2-Not Important 3-Neutral 4-Important 5 Highly Important**

For the level of readiness, please select the most appropriate answer by ticking one of the box for each criteria based on your **current organisational capability** where **A-Very incapable B-Not capable C-Neutral D-Capable E-Highly Capable**

IMPLEMENTATION CRITERIA			LEVEL OF IMPORTANCE					LEVEL OF CAPABILITY						
			1	2	3	4	5	A	B	C	D	E		
MANAGEMENT	BUSINESS STRATEGY	M01: Alignment of BIM objectives with clear business goals												
		M02: Negotiation of BIM implementation with business partners.												
		M03: Creation of sustainable market demand for BIM												
	MANAGEMENT COMPETENCY	M04: Management to have an appropriate level of BIM awareness and knowledge												
		M05: Effective risk management skill to deal with risks associated with BIM implementation												
		M06: Continuous commitment and support from the management												
	LEADERSHIP	M07: Management to have a clear vision and missions for BIM implementation												
		M08: The ability to motivate people												
		M09: Top down approach to drive BIM implementation												

IMPLEMENTATION CRITERIA		LEVEL OF IMPORTANCE					LEVEL OF CAPABILITY					
		1	2	3	4	5	A	B	C	D	E	
PROCESS	PROCESS CHANGE STRATEGY	P01: Process redesign by analysing current business process and identifying change required to incorporate BIM model oriented process										
		P02: Small and incremental approach by subdividing BIM implementation into small and manageable targets.										
		P03: Incentives and rewards to motivate staff to change.										
		P04: Effective means of communication to explain BIM at all levels and to all individuals within the company.										
	BIM IMPLEMENTATION MANAGEMENT	P05: Documented plan to assist implementation process by adapting international guidelines and standards.										
		P06: BIM monitoring and controlling technique to ensure the implementation success										
		P07: Adequate resources to facilitate and support BIM implementation										
		P08: Coordination between BIM and CAD process flow.										
		P09: Piloting BIM implementation on a few projects common to the company										
	POLICY	P10: The use of Design and Build type of project delivery to implement BIM										
		P11: Contract amendment to allow BIM process flow and deliverables to be performed.										

1-Very Unimportant 2-Not Important 3-Neutral 4-Important 5 Highly Important
A-Very incapable B-Not capable C-Neutral D-Capable E-Highly Capable

IMPLEMENTATION CRITERIA		LEVEL OF IMPORTANCE					LEVEL OF CAPABILITY					
		1	2	3	4	5	A	B	C	D	E	
PEOPLE	ROLES AND RESPONSIBILITIES	H01: Clearly defined roles and responsibilities for BIM Administrator										
		H02: Clearly defined roles and responsibilities for BIM Modeller.										
		H03: Clearly defined roles and responsibility for the Head of Change										
		H04: Empowerment to all new roles										
	SKILLS AND ATTITUDE	H05: BIM Administrator has required a set of skills and attitude necessary to carry the roles and responsibilities that are defined by the company										
		H06: BIM Modeller has required a set of skills and attitude necessary to carry the roles and responsibilities that are defined by the company										
	TRAINING AND EDUCATION	H07: Formal training to develop skill and knowledge for BIM process and tools										
		H08: Continuous on-the-job training to improve skill and confident level										
		H09: Continuous BIM education and awareness										
	WORK ENVIRONMENT	H10: Appropriate means to capture knowledge regarding BIM know how and lesson learned										
		H11: Work environment that supports learning and knowledge sharing among the staff										

1-Very Unimportant 2-Not Important 3-Neutral 4-Important 5 Highly Important
A-Very incapable B-Not capable C-Neutral D-Capable E-Highly Capable

IMPLEMENTATION CRITERIA		LEVEL OF IMPORTANCE					LEVEL OF CAPABILITY					
		1	2	3	4	5	A	B	C	D	E	
TECHNOLOGY	HARDWARE	T01: Well defined ICT policy for BIM										
		T02: Adequate ICT Infrastructure to support BIM implementation										
	TECHNICAL SUPPORT	T03: Appropriate means to evaluate the capability of the software vendor in providing services.										
		T04: Adequate technical support for BIM implementation										
	SOFTWARE	T05: Software evaluation strategy that incorporates business needs and user requirements										
		T06: Compatibility and Interoperability of BIM software with legacy and business partners' ICT system										
		T07: Regular review and upgrade of ICT systems to meet changing BIM and Business needs										

**1-Very Unimportant 2-Not Important 3-Neutral 4-Important 5 Highly Important
A-Very incapable B-Not capable C-Neutral D-Capable E-Highly Capable**

Please suggest any other readiness criteria (if any) that is important to the successful implement of BIM.

--END OF QUESTION--

APPENDIX 4.1: TABLE OF FREQUENCY AND DISTRIBUTION OF ANSWER FOR LEVEL OF IMPORTANCE AND CAPABILITY FOR INDIVIDUAL READINESS CRITERIA IN PROCESS ELEMENT.

CRITERIA		AVERAGE INDEX		FREQUENCY					PARTICIPANTS' PATTERN OF ANSWER															
				1	2	3	4	5	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	
PROCESS CHANGE STRATEGY	P01: PROCESS FLOW REDESIGN	LI	4.67	0	0	0	33	67	4	5	4	5	5	4	5	5	5	4	5	5	5	5	4	
		LC	3.87	0	13	13	47	27	4	2	4	5	5	3	5	4	4	2	4	4	5	4	3	
	P02: INCREMENTAL APPROACH	LI	4.40	0	0	0	60	40	4	4	4	5	4	4	4	5	5	4	4	5	5	5	4	
		LC	3.67	0	13	13	67	7	4	2	4	4	4	4	4	3	4	2	4	4	5	4	3	
	P03: INCENTIVES & REWARDS	LI	3.80	0	7	27	47	20	4	3	4	5	2	3	4	5	4	3	4	3	4	5	4	
		LC	3.33	0	20	33	40	7	3	3	5	3	4	4	4	4	2	2	4	2	4	3	3	
	P04: COMMUNICATION	LI	4.60	0	0	13	13	73	5	5	4	5	3	4	5	5	5	3	5	5	5	5	5	
		LC	3.80	7	0	27	40	27	3	1	4	3	5	4	5	4	4	3	4	4	5	5	3	
	BIM IMPLEMENTATION MANAGEMENT	P05: IMPLEMENTATION PLAN	LI	4.60	0	0	0	40	60	4	5	4	4	5	5	4	5	5	4	5	5	5	5	4
			LC	3.40	7	7	40	33	13	2	1	3	3	4	4	5	4	3	3	4	4	5	3	3
P06: MONITORING & CONTROLLING		LI	4.00	7	0	7	60	27	4	5	3	4	1	5	4	5	4	4	4	4	4	5	4	
		LC	3.00	13	7	53	20	7	1	1	3	3	3	4	5	3	3	2	3	3	4	3	4	
P07: ADEQUATE RESOURCES		LI	4.53	0	0	0	47	53	4	5	5	4	4	5	5	5	4	4	5	5	4	5	4	
		LC	3.67	0	20	0	73	7	2	2	4	4	4	4	4	4	4	2	4	5	4	4	4	
P08: BIM & CAD COORDINATION		LI	4.27	0	0	7	60	33	4	5	4	5	3	4	5	5	4	4	5	4	4	4	4	
		LC	3.53	7	13	13	53	13	1	2	4	4	5	4	4	4	4	2	4	4	5	3	3	
P09: PILOT PROJECT		LI	4.40	0	7	0	40	53	4	5	5	5	2	4	4	5	5	4	5	5	4	5	4	
		LC	4.00	7	7	13	27	47	1	2	5	5	5	4	4	4	5	3	5	5	5	4	3	
POLICY	P10: DESIGN & BUILD	LI	3.67	0	0	47	40	13	4	3	4	4	4	3	3	3	4	4	3	5	3	5	3	
		LC	3.80	0	7	27	47	20	3	3	5	4	4	3	4	3	4	4	5	5	4	4	2	
	P11: CONTRACT AMENDMENT	LI	4.80	0	0	0	20	80	5	5	5	5	5	4	5	5	5	4	5	5	5	5	4	
		LC	3.07	13	7	47	27	7	3	1	1	3	3	4	4	2	3	4	5	4	3	3	3	

LI : Level of Important, LC : Level of Capability

Frequency value for L.I : 1= Very Unimportant, 2= Not Important, 3= Neutral, 4= Important, 5= Highly Important

Frequency value for L.C: 1= Very Incapable, 2= Not Capable, 3= Neutral, 4= Capable, 5= Highly Capable

APPENDIX 4.2: TABLE OF FREQUENCY AND DISTRIBUTION OF ANSWER FOR LEVEL OF IMPORTANCE AND CAPABILITY FOR INDIVIDUAL READINESS CRITERIA IN MANAGEMENT ELEMENT.

CRITERIA		AVERAGE INDEX		FREQUENCY (%)					PARTICIPANTS' DISTRIBUTION OF ANSWER														
				1	2	3	4	5	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
BUSINESS STRATEGY	M01: BIM OBJECTIVE	LI	4.60	0	0	0	40	60	5	4	5	5	5	4	5	4	5	4	5	4	5	5	4
		LC	3.93	7	7	13	33	40	3	1	5	4	5	4	4	4	5	2	5	5	5	3	4
	M02: BIM NEGOTIATION	LI	4.73	0	0	0	27	73	5	5	5	5	4	5	4	5	5	4	4	5	5	5	5
		LC	3.80	7	13	7	40	33	2	1	5	4	5	4	4	4	4	2	5	5	5	4	3
	M03: SUSTAINABLE BIM DEMAND	LI	4.13	0	7	7	53	33	4	4	5	5	3	4	4	5	4	4	2	5	4	5	4
		LC	3.47	13	0	33	33	20	1	1	5	4	4	4	3	4	3	3	5	5	4	3	3
MANAGEMENT COMPETENCY	M04: KNOWLEDGE & AWARENESS	LI	4.47	0	0	13	27	60	4	5	5	5	5	3	5	5	4	4	5	3	5	4	5
		LC	3.87	0	13	20	33	33	3	2	5	4	5	3	4	4	4	2	5	4	5	3	5
	M05: RISK MANAGEMENT	LI	4.27	0	0	13	47	40	4	4	5	5	4	3	5	5	4	3	5	4	4	5	4
		LC	3.53	7	13	20	40	20	2	1	5	4	5	3	4	4	3	2	4	5	4	3	4
	M06: COMMITMENT & SUPPORT	LI	4.73	0	0	7	13	80	5	5	5	5	3	4	5	5	5	4	5	5	5	5	5
		LC	3.80	7	0	20	53	20	3	1	5	4	5	4	4	4	3	3	4	5	4	4	4
LEADERSHIP	M07: VISION & MISSION	LI	4.80	0	0	0	20	80	5	5	5	5	5	4	5	5	5	4	4	5	5	5	5
		LC	4.00	0	7	13	53	27	3	2	5	4	5	4	4	4	4	3	4	5	5	4	4
	M08: MOTIVATION	LI	4.33	0	0	20	27	53	5	5	5	5	3	3	5	4	4	5	4	3	5	5	4
		LC	3.87	7	0	20	47	27	3	1	5	4	5	3	5	4	4	3	4	4	5	4	4
	M09: TOP DOWN APPROACH	LI	4.40	0	0	7	40	53	5	5	5	5	4	4	5	4	5	5	4	4	4	5	3
		LC	3.93	7	0	20	40	33	3	1	5	5	5	4	4	4	3	4	4	5	5	4	3

LI : Level of Important, LC : Level of Capability
 Frequency value for L.I : 1= Very Unimportant, 2= Not Important, 3= Neutral, 4= Important, 5= Highly Important
 Frequency value for L.C: 1= Very Incapable, 2= Not Capable, 3= Neutral, 4= Capable, 5= Highly Capable

APPENDIX 4.3: TABLE OF FREQUENCY AND DISTRIBUTION OF ANSWER FOR LEVEL OF IMPORTANCE AND CAPABILITY FOR INDIVIDUAL READINESS CRITERIA IN PEOLPE ELEMENT.

CRITERIA		AVERAGE INDEX		FREQUENCY					PARTICIPANTS' PATTERN OF ANSWER														
				1	2	3	4	5	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
ROLES & RESPONSIBILITIES	H01: BIM ADMINISTRATOR	LI	4.20	0	7	0	60	33	4	5	4	5	2	4	4	5	4	4	5	4	4	5	4
		LC	3.73	7	7	13	53	20	1	2	4	4	5	3	5	4	4	3	4	4	5	4	4
	H02: BIM MODELLER	LI	4.47	0	0	7	40	53	5	5	5	5	3	4	5	5	4	4	5	4	4	5	4
		LC	3.93	7	7	7	47	33	1	2	5	4	5	4	5	4	4	3	4	5	5	4	4
	H03: HEAD OF CHANGE	LI	4.40	0	0	7	47	47	5	4	5	5	4	3	5	5	4	4	4	4	4	5	5
		LC	3.87	0	13	20	33	33	2	2	5	3	5	3	4	4	4	3	4	5	5	4	5
H04: EMPOWERMENT	LI	4.27	0	0	13	47	40	4	4	5	5	5	3	4	4	4	3	4	4	5	5	5	
	LC	3.93	0	13	13	40	33	2	2	5	4	5	3	4	4	4	3	4	5	5	4	5	
SKILL & ATTITUDE	H05: BIM ADMINISTRATOR	LI	4.53	0	0	0	47	53	4	5	5	5	4	4	5	5	4	4	5	5	4	5	4
		LC	3.73	7	7	27	27	33	1	2	5	3	5	4	5	4	3	3	4	5	5	4	3
	H06: BIM MODELLER	LI	4.67	0	0	0	33	67	4	5	5	5	5	4	5	5	4	4	5	5	4	5	5
		LC	3.60	7	13	20	33	27	1	2	5	3	5	4	5	4	3	2	4	4	5	4	3
TRAINING & EDUCATION	H07: FORMAL TRAINING	LI	4.47	0	0	7	40	53	4	5	4	5	3	4	5	5	5	4	5	4	4	5	5
		LC	3.60	7	7	27	40	20	2	1	4	3	5	4	5	4	4	3	3	4	5	3	4
	H08: ON THE JOB TRAINING	LI	4.33	0	0	7	53	40	4	4	5	5	4	3	4	5	5	4	5	4	4	5	4
		LC	3.67	7	7	20	47	20	2	1	5	3	5	3	4	4	4	4	4	4	5	3	4
	H09: CONTINUOUS EDUCATION	LI	4.40	0	0	7	47	47	4	4	5	5	5	3	4	5	4	4	5	5	4	5	4
		LC	3.53	13	0	27	40	20	1	1	4	3	5	3	4	4	4	4	4	5	5	3	3
WORK ENVIRONMENT	H10: KNOWLEDGE CAPTURE	LI	4.47	0	0	0	53	47	4	4	4	5	4	4	5	5	4	4	5	5	4	5	5
		LC	3.60	13	0	27	33	27	1	1	4	3	5	3	4	4	4	3	4	5	5	3	5
	H11: KNOWLEDGE SHARING	LI	4.53	0	0	0	47	53	4	4	5	5	5	4	5	5	4	4	4	5	4	5	5
		LC	3.73	7	7	13	53	20	2	1	4	3	5	4	5	4	4	3	4	5	4	4	4

LI : Level of Important, LC : Level of Capability
 Frequency value for L.I : 1= Very Unimportant, 2= Not Important, 3= Neutral, 4= Important, 5= Highly Important
 Frequency value for L.C: 1= Very Incapable, 2= Not Capable, 3= Neutral, 4= Capable, 5= Highly Capable

APPENDIX 4.4: TABLE OF FREQUENCY AND DISTRIBUTION OF ANSWER FOR LEVEL OF IMPORTANCE AND CAPABILITY FOR INDIVIDUAL READINESS CRITERIA IN TECHNOLOGY ELEMENT.

CRITERIA		AVERAGE INDEX		FREQUENCY					PARTICIPANTS' PATTERN OF ANSWER														
				1	2	3	4	5	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
HARDWARE	T01: BIM ICT POLICY	LI	4.67	0	0	0	33	67	4	5	4	5	5	4	5	5	5	4	5	5	5	5	4
		LC	3.80	7	7	13	47	27	1	2	4	3	5	4	5	5	4	4	4	5	4	4	3
	T02: ICT INFRASTRUCTURE	LI	4.67	0	0	0	33	67	5	5	4	5	4	5	5	4	5	4	5	5	5	5	4
		LC	3.60	0	20	7	67	7	2	2	4	2	4	4	4	4	4	3	4	5	4	4	4
TECHNICAL SUPPORT	T03: VENDOR EVALUATION STRATEGY	LI	4.20	0	0	13	53	33	4	4	5	3	4	4	4	5	4	3	4	5	4	5	5
		LC	3.80	7	7	13	47	27	2	1	5	3	5	4	5	4	4	3	4	4	5	4	4
	T04: TECHNICAL SUPPORT	LI	4.67	0	0	0	33	67	5	5	4	5	5	4	5	5	4	4	5	5	4	5	5
		LC	3.67	13	0	13	53	20	1	1	4	4	5	4	5	4	4	3	4	5	4	4	3
SOFTWARE	T05: EVALUATION STRATEGY	LI	4.13	0	0	20	47	33	4	5	4	3	3	4	5	4	5	3	4	5	4	5	4
		LC	3.67	7	7	20	47	20	1	2	4	3	5	4	5	4	4	3	4	5	4	4	3
	T06: COMPATIBILITY INTEROPERABILITY	LI	4.33	0	0	13	40	47	4	5	5	4	5	3	5	4	3	4	4	5	4	5	5
		LC	3.67	7	0	40	27	27	1	3	5	3	5	3	5	4	3	3	4	5	4	4	3
	T07: REVIEW OF ICT SYSTEM	LI	4.53	0	0	0	47	53	5	5	4	5	4	4	5	5	4	4	5	5	4	5	4
		LC	3.87	0	13	13	47	27	3	2	4	2	5	4	4	4	4	3	5	5	5	4	4

LI : Level of Important, LC : Level of Capability
 Frequency value for L.I : 1= Very Unimportant, 2= Not Important, 3= Neutral, 4= Important, 5= Highly Important
 Frequency value for L.C: 1= Very Incapable, 2= Not Capable, 3= Neutral, 4= Capable, 5= Highly Capable

APPENDIX 5.0: LIST OF PUBLICATIONS AND PRESENTATIONS

5.1 WRITTEN PAPER

- Haron, A.T., Marshall-Ponting, A.J., & Aouad, G. (2010). Building information modelling: literature review on model to determine the level of uptake by organisation. In *Proceedings of the 18th CIB World Building Congress 2010, 10 – 13 May, School of Built Environment, The University of Salford, Salford Quays, UK*, 168-185
- Haron, A.T., Marshall-Ponting, A.J., & Aouad, G. (2010). Building information modelling in integrated practice. In *Proceedings of the 2nd Construction Industry Research Achievement International Conference (CIRIAC 2009). 3-5 November, Construction Industry Development Board Malaysia, Kuala Lumpur, Malaysia*
- Haron, A.T., Marshall-Ponting, A.J., & Zakaria Z., Kamar, K.A.M., & Hamid, Z.A. (2012). An industrial report on the malaysian building information modelling (bim) taskforce: issues and recommendations. *Journal of ITcon*. (Under review)
- Haron, A.T., & Kamar, K.A.M, (2012). *Industrialise building system (IBS): Mechanisation through building information modelling (BIM), Construction Industry Development Board (CIDB) Malaysia Industrial Workshop Resport, Kuala Lumpur: CIDB, (Editor)*
- Haron, A.T., & Marshall-Ponting, A.J., (2012). *Organisational readiness to implement BIM in Malaysia. In Industrialise building system (IBS): Mechanisation through building information modelling (BIM), Construction Industry Development Board (CIDB) Malaysia Industrial Workshop Report, Kuala Lumpur: CIDB, 17-22, (Author)*
- Nawi, M.N.M., Kamar, K.A.M, Abdullah, M.R., Haron, A.T., Lee, A. & Arif, M. (2009). Enhancement of constructability concept: an experience in offsite Malaysian construction industry. In *Proceedings of the Changing Roles; New Roles, New Challenges 2009, The TU Delf, Netherland, 5⁹ October 2009*.
- Kamar, K.A.M, Alshawi, M., Hamid, Z.A., Nawi, M.N.M., Abdullah, M.R., & Haron, A.T., (2009). Industrialised building system (IBS): Identifying critical success factors for the transformation of contractors. In *Proceedings of the 2nd Construction Industry Research Achievement International Conference (CIRIAC 2009). 3-5 November, Construction Industry Development Board Malaysia, Kuala Lumpur, Malaysia*
- Kamar, K.A.M, Alshawi, M., Hamid, Z.A., Nawi, M.N.M., Abdullah, M.R., & Haron, A.T., (2009). Industrialised building system (IBS): a review of experiences in UK and Malaysian construction industry. In *Proceedings of the 2nd Construction Industry Research Achievement International Conference (CIRIAC 2009). 3-5 November, Construction Industry Development Board Malaysia, Kuala Lumpur, Malaysia*.

5.2 PRESENTATION

- Haron, A.T. (2012). Organisational readiness to implement BIM: a framework for design consultants in Malaysia. In the *Roundtable Meeting of CIDB BIM Awareness Program, 22 September 2012*, organised by *Construction Research Institute of Malaysia (CREAM)* at CREAM office, Kuala Lumpur, Malaysia (Presenter)
- Haron, A.T. (2012). Organisational readiness to implement BIM: a framework for design consultants in Malaysia. In *Workshop of R&D Outcomes Development, 7-8 June 2012*, organised by *Construction Research Institute of Malaysia*, at Cyberview Lodge and Spa, Cyberjaya, Malaysia (Presenter)
- Haron, A.T. (2013). Organisational readiness to implement BIM: a framework for design consultants in Malaysia. In the *Seminar of BIM awareness program for Public Private Partnership Unit (3PU), Prime Minister Office, 7 February 2013*, at 3PU Office, Putrajaya